CETRA 2012

2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

Road and Rail Infrastructure II

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CETRA 2012
2nd International Conference on Road and Rail Infrastructure
7–9 May 2012, Dubrovnik, Croatia

TITLE
Road and Rail Infrastructure II, Proceedings of the Conference CETRA 2012

EDITED BY
Stjepan Lakušić

ISBN
978-953-6272-50-1

PUBLISHED BY
Department of Transportation
Faculty of Civil Engineering
University of Zagreb
Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE
minimum d.o.o.
Katarina Zlatec · Matej Korlaet

COPIES
600

A CIP catalogue record for this e–book is available from the National and University Library in Zagreb under 805372

Proceedings of the
2nd International Conference on Road and Rail Infrastructures – CETRA 2012
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A NEW METHODOLOGY FOR ASSESSING THE PERFORMANCE OF ROAD SURFACE MARKINGS

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Abstract

CIRIAF, in cooperation with the Municipality of Perugia (Italy), is participating in a research project whose aim is to define a methodology for road markings in–situ measurements.
The objective is to take into account the characteristics of the site of installation of road markings in order to improve safety, to optimize the maintenance and to give the municipality a tool to verify the quality of the application, in order to assess if the requirements given in tenders are fulfilled. The activity is performed within the framework of the EU FP7 funded project CIVITAS Plus 'RENAISSANCE'.
In particular, an innovative indicator was developed, in order to rate the global quality of municipal road markings. This indicator takes into account all the parameters characterizing the performance of road markings: luminance coefficient in daylight conditions Q_d, retroreflectivity in night conditions R_L (dry, wet), skid resistance SRT, colour, material and ageing of the pavement markings, traffic volume,, road surface characteristics and average local weather conditions.
This paper, after the first section about the methodology for the evaluation of the performance of road surface markings, reports the definition of the new indicator and the results of the experimental campaigns carried out on several roads of the Perugia municipality.

Keywords: road markings, monitoring, safety, maintenance, retroreflection

1 The CIVITAS + 'RENAISSANCE' Project

The 'RENAISSANCE' Project (full title: 'Testing Innovative Strategies for Clean Urban Transport for historic European cities') is co–funded by the European Union within the 7th Framework Programme CIVITAS Initiative (Plus edition 2008–2012) [1].
The goal of the RENAISSANCE project is to develop a valid, reliable and integrated package of access and mobility measures for historic cities. The cities involved in the project are: Perugia (Italy) – Project Leader (Fig. 1), Bath (UK), Szczecinek (Poland), Gorna Oryahovitsa (Bulgaria) and Skopje (Republic of Macedonia).

Figure 1 Logo of CIVITAS+ RENAISSANCE for the city of Perugia.

The activities are performed by five cities in cooperation with other 25 partner companies and research organizations, experts in the field of transport and mobility. Within the framework of the measure 5.2 of the project, 'Assessing the options for more efficient road pavement markings', CIRIAF, in cooperation with the Municipality of Perugia, focused research activities on the study of the performance of road surface markings. These activities aim at defining a modus operandi for in–situ measurement able to take into account the characteristics of the site of installation of road marking, in order to:

- optimize the maintenance;
- give the municipalities a tool to verify the quality of the application in order to assess if the requirements given in tenders are fulfilled.

This second aspect is particularly important for public administrations: as a matter of fact the current evaluation of the performance of road surface markings performed by the Municipality of Perugia is made purely by verifying the products used in terms of quantity, and by a visual judgment of the amount of paint used, without any experimental support.

2 Parameters for the evaluation of road markings performance

The incidence of pavement marking on traffic safety and driving comfort is considerable [2, 3]. The European Standard EN 1436 [4] specifies the performance for road users of white and yellow road markings based on luminance (colour), day–time visibility, night–time visibility and skid resistance, combined with durability. The specification also introduces the importance of wet–night visibility road markings. Furthermore, it describes the methods of measuring the various performance characteristics reported below.
Luminance 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 30m under normal conditions. Illumination is diffused light.
Retroreflection is the ability of a road marking to reflect light from the vehicle's headlights back to the driving position of a vehicle. The performance of the line is determined by the amount and quality of glass beads included in the body of the road marking. R_L measures, true to scale, the retroreflection (night visibility) of a road marking. The observation angle of 2,29° corresponds to the viewing distance of a motor car driver of 30m under normal conditions. The illumination angle is 1,24°. RL is measured in three different conditions of road markings: dry, wet and rain.
Colour is defined by the luminance factor β and chromaticity, which represents the co–ordinates falling within a defined square on the chromaticity diagram defined by EN 1436 for white (left) and yellow (right) road markings.
Skid resistance measurement on road markings is carried out using the standard British pendulum apparatus. The instrument, which is direct reading, gives a measure of the friction between a skidding tyre (a rubber slider mounted at the end of the pendulum arm) and a wet road surface. The quantity measured with the portable tester is called 'Skid–resistance' and it is correlated to the performance of a vehicle with patterned tyres braking with locked wheels on a wet road at 50 km/h.
EN 1436 defines the classes of performance requirements for white (a) and yellow (b) road markings (Table 1).

Table 1 Classes of performance of white road markings defined by EN 1436.

RL (dry conditions) [mcd/ (m²·lux)]		RL (wet conditions) [mcd/(m²·lux)]		Qd [mcd/(m²·lux)]		SRT [SRT]	
Class	Value	Class	Value	Class	Value	Class	Value
RO	NIL	RW0	NIL	Q0	NIL	SO	NIL
R2	≥ 100	RW1	≥ 25	Q2	≥ 100	S1	≥ 45
R3	≥ 150	RW2	≥ 35	Q3	≥ 130	S2	≥ 50
R4	≥ 200	RW3	≥ 50	Q4	≥ 160	S3	≥ 55
R5	≥ 300	RW4	≥ 75			S4	≥ 60
		RW5	≥ 100			S5	≥ 65
		RW6	≥ 150				

3 Definition of the methodology for monitoring the performance of road markings

The main objective of the research is to develop a methodology to verify the efficiency of road pavement markings, depending on installation conditions and available technologies. The results will allow the road marking department of the Municipality of Perugia to use new procedures to control the quality of works performed by external contractors.

3.1 Selection of test sites

28 experimental campaign sites were selected in collaboration with the road markings staff of the Municipality of Perugia.

The choice of measurement locations was guided by the necessity to guarantee upscaling throughout the road network managed by the Municipality; therefore the chosen sites are representative of several conditions which can be found throughout the roads crossing the whole territory of Perugia.

Three main parameters were considered for the selection: (i) road surface, (ii) marking material, (iii) traffic flow.

Three road surface conditions were identified: smoothness, roughness and other (for example presence of cobblestones).

All the road marking materials used in the Municipality were considered (paint, thermoplastic, two–components, preformed) in order to compare performance.

The Municipality of Perugia road network was divided into three classes, depending on the traffic flow (source of traffic data: Urban Plan of Traffic): (i) low, ‹ 600 vehicles/hour; (ii) medium, 600 – 1500 vehicles/hour; (iii) high, › 1500 vehicles/hour.

When measurements are carried out in municipalities other than Perugia the number of sites, the types of material, the ranges of traffic flows, etc. will of course differ. The selection of the test sites should be undertaken considering the characteristics of the roads managed by the Municipality.

3.2 Measurements execution

In each test site the following measurements were carried out:

- Retroreflection in dry (R_{LD}) and wet (R_{LW}) conditions and Luminance (Q_d), using a retroreflectometer Zehntner ZRM6013 RL+Q_d;
- Colour (chromaticity x,y), using a spectrophotometer Konica Minolta CM-2500c;
- Skid resistance (SRT), using a portable Skid Resistance Tester Zehntner SRT 5800;
- Other parameters: marking thickness, air temperature and humidity, road surface temperature, etc.

For each site, several measurement points were chosen, depending on the type (centre lines, sidelines, pedestrian crossings, stop lines, letters, etc) and the size of the markings. Measurements were always carried out in safety, thanks to the support of the local police.

3.3 Data processing

The goal of the developed data processing procedure is to assign a score to each site, combining all the measured parameters. Only white markings were considered in this research. A scale of scores was established for each parameter, according to the tables given by EN 1436 (Table 1). Scores (Table 2) go from 0 (worst) to 10 (best) and 6 represents the minimum requirement defined by EN 1436.

Table 2 Definition of scores for the measured parameters.

Score	R_{LW}	R_{LD}	Q_d	SRT	Colour
0	0-2	0-9	0-9	0-19	No
1	3-4	10-19	10-19	20-24	
2	5-9	20-39	20-39	25-39	
3	10-14	40-59	40-59	30-34	
4	15-19	60-79	60-79	35-39	
5	20-24	80-99	80-99	40-44	
6	25-49	100-149	100-114	45-49	
7	50-74	150-199	115-129	50-54	
8	75-99	200-249	130-144	55-59	
9	100-150	250-300	145-160	60-65	
10	>150	>300	>160	>65	Yes

For each site the results obtained for the different parameters are average, obtaining a mean value for R_{LD}, R_{LW}, Q_d, SRT and Colour (x,y).
For the j-th site, two different scores are calculated:

- score in dry conditions S_{Dj};
- score in wet conditions S_{Wj}.

These two indicators are obtained weighting all the parameters, through the following equations:

$$S_{Dj} = \left(SR_{LDj} * wR_{LD}\right)_D + \left(SQ_{dj} * wQ_d\right)_D + \left(SColour_j * wColour\right)_D \quad (1)$$

$$S_{Wj} = \left(SR_{LWj} * wR_{LW}\right)_W + \left(SQ_{dj} * wQ_d\right)_W + \left(SSRT_j * wSRT\right)_W + \left(SColour_j * wColour\right)_W \quad (2)$$

where SX_j represents the score of the X-th parameter (Table 2) in the j-th site. The values of the weights wR_{LD}, wColour and wQ_d in dry condition and wR_{LW}, wQ_d, wSRT and wColour in wet conditions were defined considering their influence on safety conditions for road users. They are reported in Table 3. The global score for the j-th site Sj is given by:

$$S_j = (D_W / 365) * S_{Wj} + (D_D / 365) * S_{Dj} \quad (3)$$

where D_w is the number of days of rain/snow per year (wet conditions) and D_D is the number of days without rain/snow per year (dry conditions) in the Municipality where the measurements are carried out (of course $D_D+D_W = 365$). D_D and D_w should be obtained from at least 10 years of weather data.

Table 3 Definition of weights for the investigated parameters.

Weights	Wet condition	Dry condition
wR_{LW}	0.55	-
wR_{LD}	-	0.75
wQd	0.2	0.2
wSRT	0.2	-
wColour	0.05	0.05

Once all the selected sites are investigated, it is possible to define a single score for the entire Municipality, CIS-Q (Civitas Indicator for Stripes – Quality).
First of all the score of the i-th marking material S_{Mi} (paint, two components resin, thermoplastics, tapes, other) has to be evaluated by means of Eq. (4):

$$S_{Mi} = \frac{\sum_{j=1}^{N} S_j}{N} \quad (4)$$

where N is the number of sites where the i-th typology of material is used. Then CIS-Q can be calculated with Eq. (5):

$$CIS - Q = \sum_{i=1}^{M} S_{Mi} \times P_i \quad (5)$$

where M is the number of materials used in the Municipality for road markings and P_i is the percentage of usage of the i-th material.
This procedure was developed in order to allow its use all over Europe (it is referred to European standards), since it can consider several types of material and their percentage of usage in the considered Municipality, road surface conditions, traffic flows and weather conditions without restrictions.

4 Measurement results

Results of the experimental campaign on the selected 28 sites were collected and processed with the developed methodology. The synthesis of the results is reported in Table 4. The last column reports the global score S_j for each site, calculated using Eq. (1), (2) and (3). The red (green) face represents a score lower (higher) than 6.0.
In Table 5 the scores S_{Mi} calculated for each material using Eq. (4) are reported, in Table 6 is the percentage of usage Pi of the materials in the road network managed by the Municipality of Perugia (data from the Municipality road marking staff). Finally, the global index CIS-Q is evaluated by means of Eq. (5): for the road markings system of the Municipality of Perugia CIS-Q is equal to 4,4.

Table 4 Results of the experimental campaign in the Municipality of Perugia.

Test Site CODE	Test Site Name	R_{Ld} (mcd/lx*m²)		R_{Lw} (mcd/lx*m²)		Qd (mcd/lx*m²)		SRT (-)		Colour	**Test Site Score S_i**	
Y-P-R-L-001/09	Via Centova	27	☹	18	☹	126	☺	50	☺	☺	**5.6**	☹
W-T-S-L-002/09	Via Centova (Borgonovo)	589	☺	55	☺	198	☺	42	☹	☺	**9.4**	☺
W-TC-S-L-003/09	Via Conti	126	☺	34	☺	179	☺	47	☺	☺	**7**	☺
W-TC-S-L-004/09	Piazza Umbria Jazz	132	☺	36	☺	136	☺	63	☺	☺	**6.7**	☺
W-P-R-L-005/10	Via Morettini	44	☹	11	☹	160	☺	39	☹	☺	**4.8**	☹
W-TH-R-M-006/10	Via Settevalli	139	☺	28	☺	123	☺	49	☺	☺	**6.4**	☺
W-TP-S-H-007/10	Via Settevalli	40	☹	29	☺	155	☺	48	☺	☺	**5.0**	☹
W-P-S-H-008/10	Via Dottori	40	☹	17	☹	113	☺	43	☹	☺	**4.2**	☹
W-P-R-M-009/10	Via Settevalli n.125 (Loc.Pila)	31	☹	16	☹	113	☺	37	☹	☺	**3.9**	☹
W-TH-R-L-010/10	Via Guerra	130	☺	37	☺	109	☺	55	☺	☺	**6.3**	☺
W-TH-O-L-011/10	Piazza Matteotti	100	☺	26	☺	97	☹	49	☺	☺	**6.0**	☺
W-P-L-M-012/10	Via dei Filosofi	25	☹	14	☹	107	☺	41	☹	☺	**3.4**	☹
W-TC-R-H-013/10	Via Palermo	98	☹	30	☺	155	☺	40	☹	☺	**6.2**	☺
W-O-R-M-014/10	Via Pallotta	77	☹	18	☹	120	☺	61	☺	☺	**5.1**	☹
W-TC-R-M-015/10	Via Lino Spagnoli	99	☹	24	☹	119	☺	52	☺	☺	**5.7**	☹
W-P-S-H-016/010	Via Cortonese	24	☹	12	☹	200	☺	31	☹	☺	**4.2**	☹
W-P-R-H-017/010	Via Cortonese	46	☹	20	☹	152	☺	51	☺	☺	**5.0**	☹
W-P-S-M-018/010	Viale dell'Ingegneria	25	☹	6	☹	98	☹	42	☹	☺	**3.1**	☹
W-P-S-L-019/010	Via Q.Sella	27	☹	7	☹	124	☺	49	☺	☺	**3.6**	☹
W-P-R-L-020/10	Stazione FF.SS.*	24	☹	15	☹	177	☺	48	☺	☺	**4.4**	☹
W-TC-R-L-021/10	Strada Ponte d'Oddi-San Marco	35	☹	12	☹	94	☹	43	☹	☺	**3.2**	☹
W-TH-S-M-022/10	Via Cortonese	84	☹	30	☺	80	☹	51	☺	☺	**5.5**	☹
W-O-S-M-023/10	Via dei Filosofi	117	☺	23	☹	89	☹	52	☺	☺	**5.9**	☹
W-TP-S-M-024/10	Via dell'Ingegneria	20	☹	2	☹	135	☺	45	☺	☺	**3.5**	☹
W-TH-S-L-025/10	Via Guerra (San Marco)	166	☺	37	☺	89	☹	48	☺	☺	**6.6**	☺
W-P-R-L-026/10	Via Piero della Francesca	67	☹	31	☺	215	☺	47	☺	☺	**5.8**	☹
W-TC-S-M-027/10	Via San Giuseppe	64	☹	9	☹	85	☹	48	☺	☺	**4.3**	☹
W-TC-R-H-028/10	Viale Orazio Antinori	70	☹	19	☹	89	☹	42	☹	☺	**4.5**	☹

Table 5 Score S_M for the different road markings materials in the Municipality of Perugia.

	Paint	**Two–Component**	**Tapes**	**Thermoplastic**	**Others**
S_M	4.2	5.4	6.2	6.0	5.5

Table 6 Percentages of use of the road markings materials in the Municipality of Perugia.

	Paint	**Two–Component**	**Tapes**	**Thermoplastic**	**Others**
P_i	90	8	1	1	≈0

5 Conclusions

The results of the measurement campaign show that the current system of road marking management in the Municipality of Perugia does not allow fulfilling the requirements of tenders in terms of road markings performance because of the lack of technical/instrumental control and the intensive use of pre–mixed paint. The measurement carried out during the project demonstrated that this material, even if freshly applied, can not reach sufficient levels of performance, especially in terms of night visibility.
The results of this campaign allowed CIRIAF to give to the Municipality road marking staff some useful indications for the new public tender, in order to verify the quality of the pavements markings:

- execution of a technical/instrumental control 1 month after the realization of the horizontal markings;
- execution of a technical/instrumental control 6 months after the realization of the horizontal markings, but before the final payment of the contractor by the Municipality.

This procedure aims at improving the quality, the performance and the safety of horizontal markings of the Municipality of Perugia, because the requirements of the public tender and the introduction of stricter controls force the contractors to use more performing materials than the ones used before this project.
The proposed methodology is reliable and can be easily transferred to different situations, since it takes into account the influence of local weather conditions on road markings efficiency.

References

[1] www.civitas.eu (website of the CIVITAS Initiative) and www.civitas-renaissance.eu (website of the RENAISSANCE project), 14.02.2012

[2] Parker, N. A. & Meja M.: Evaluation of the Performance of Permanent Pavement Markings, 84th Transportation Research Board Annual Meeting, Washington, 2003.

[3] Horberry, T., Anderson, J. & Regan, M. A.: The possible safety benefits of enhanced road markings: a driving simulator evaluation, Transportation Research Part F, 9, pp. 77-87, 2006.

[4] CEN (European Committee for Standardization), CEN/TC 226 - Road equipment: EN 1436:2007+A1:2008, Road marking materials - Road marking performance for road users, 2007-2008.