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Road and Rail Infrastructure III

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LONG TERM PERFORMANCE OF ROAD MARKINGS ON RURAL ROADS: GUIDE–LINES FOR MAINTENANCE MANAGEMENT

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Abstract

A lot of data has been collected concerning road marking properties deterioration in order to develop performance prediction models for correct infrastructure management. In Italy, two types of road markings are mainly used, paint or thermoplastic, based on several components (thermoplastic binder systems, paint, epoxy, methyl-methacrylate, polyester, polyurea, waterborne paint, modified urethane). Vehicle tyres are abrasive and remove paint and thermoplastic markings, but these have different service life, due to their different surface adhesion and skid resistance properties. In the last years, the budget for transport infrastructure has been heavily cut and this has led to a decrease in monitoring and maintenance activities. Thus, road markings have been left in place longer than scheduled.
Monitoring of the long-term performance of horizontal markings began in 2008, on behalf of some Italian road authorities, with the aim of focusing on wearing course surface deterioration, carriageway perception and road marking visibility. The project initially included a limited number of sections but has been increased over time (there are now 36 sections). Collected data demonstrated that thermoplastic markings present some advantages in comparison with paint, although they are slightly more expensive. According to the results, guidelines were developed for maintenance management.

Keywords: road markings, service life, maintenance, road management, retro-reflectivity

1 Introduction

The study of the photometric characteristics of road markings is a delicate sector of road research. This is because it involves the knowledge and expertise of different engineering sectors and produces results that often clash with economic and maintenance requirements. All the research developed so far, both in Italy and abroad, has recognized the importance of markings in lowering the accident rate and reducing fatalities [1][2]. An investment in the quality of road markings therefore produces economic benefits on safety and driving conditions both immediately and in the future [3].
On extraurban, non-motorway, roads a wide variety of applications and materials are used, with not always entirely satisfactory results. However, two predominate: liquid paints and thermoplastic materials, applied hot (180-200 °C). The paints, generally water-based, are low cost and have an average service life of between 6 and 18 months; thermoplastics have a higher overall cost (on average 3 or 4 times that of a paint) and a service life that, under the same stress conditions, varies between 2 and 4 years. The problem that has to be tackled is not that of just quality, which is now checked throughout the productive process, from production of the materials to the application on site, but rather that of performance. The visibility is a fundamental requirement on which savings cannot be made, because it must be constantly guaranteed over the entire route, 24 hours a day, every day of the year, and in

any environmental condition that does not preclude use of the road. If anything, the problem is how to translate the concept of visibility into measurable performances, whose values are linked both to the quality of the markings and quality of the result during the service life. A major step forward in this has been taken in recent years, since the transition began from prescriptive technical standards to performance technical standards. Today markings are defined by parameters, known as "performance characteristics", specified in standard EN 1436 [4], to be measured directly on the applied markings with suitable instruments, at any time during the service life. These characteristics include: the Coefficient of Luminance in conditions of diffuse light, to represent daytime conditions; the Coefficient of Retro-reflected Luminance – for the nighttime; Skid Resistance – for the adhesion between tyre and road surface; the Luminance Factor of an emitting surface.
There are various studies in the literature that aim to determine the hierarchy of the factors that dominate the deterioration of the performances of road markings, with the objective of guiding the choices of inspection and maintenance times [5][6][7]. In general, they are limited by the simplification of the stresses due to traffic, climate or ageing of the materials. In these studies, simple models are extrapolated, in which no reference is made to the real effect on the performance of the transit of the individual tyre. Curves of deterioration of a general nature are therefore constructed, which depend on variables of the type: aggregate, time since application, Annual Average Daily Traffic (AADT) [5]. Taking these considerations into account and the limitations due to the lack of transparency in the transmission of information by the road management authorities [8], the authors have developed a study that directs attention on the connection between the initial performances and those in proximity to the end of the declared service life. The main aim is to demonstrate that the most delicate moment in the failure of road markings on rural roads is not so much, or only, that linked to wear and tear, but rather that of the application and the first months of service [8].

2 Methods

The performance measured in this study is the retro-reflection (R_L). This is the light reflected by the markings in the direction of the driver, when they are illuminated by the vehicle headlights. The study refers to dry markings; although the environmental characteristics at the time of measurement cannot be controlled, the moisture level of the air, by day and night, and the temperature could be monitored. The results obtained regard 36 sites, of varying lengths (for a total of 606,650 m). Each site is indicated by a geographical identifier, a work package number (W.P.), and a lot number (1-36, Fig. 1) to distinguish stretches of the same road with different markings.

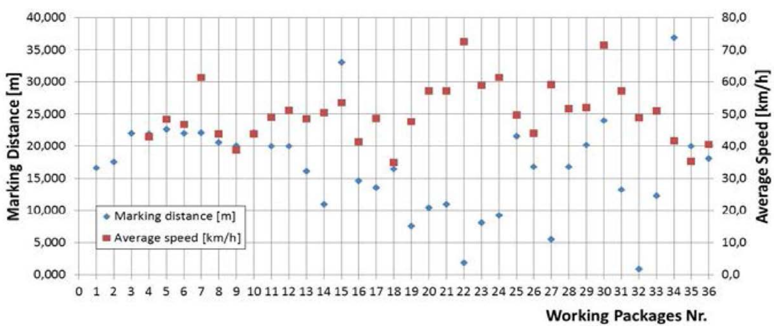

Figure 1 Work packages, speed (red) and measured markings distance (blue)

The measurements were made directly on the road with a suitably equipped and calibrated vehicle, in the presence of constant traffic in both directions; the driving speed was constrained by the conditions and therefore varied. It should be specified that most of the roads in this study are single carriageway with two lanes, one in each direction of travel (Fig. 2). The measurements of the retro-reflection of the central line were therefore interrupted when vehicles travelling in the opposite direction to that of the test were met and crossed.

Figure 2 Road layout example and survey system

The results refer to the lines along the edge of the carriageway. All measurements were made in twice: within the first 3 weeks after the application (T=0) and within the first 6 months (T=6). During the project it was possible to follow the evolution of the damage to the pavement and markings for 3 consecutive years in 12 sites [8].
The retro-reflection characteristics were acquired with a widely-used portable instrument: the Zehntner TI® ZDR 6020 Dynamic Retro-reflectometer (ZDR, Fig. 2). The device is equipped with a rigid support for installation on a vehicle, on the right or left hand side; a measuring box, equipped with sensors for measuring the photometric characteristics; an odometer connected to a wheel, which calculates the driving speed and distance travelled; moisture and temperature sensors [9]. The rotation of the odometer is continuously controlled while travelling, thus, if the vehicle is stationary or too slow, acquisition of the R_L values is interrupted. The system measures the performances on 16 sensors; unsatisfactory values are indicated and eliminated: the points in which there is no marking and those where it is worn to the point that it offers values comparable to the road pavement. The surveyed points are spaced in order to take a value of the performance every 5 metres and an average value every 50 m, for which the GPS reference, air temperature and moisture content, average speed of the vehicle are known and a photo is taken from the vehicle dashboard.

3 Materials

The choice of investigated sites was made taking into account the available finances and prompt notification of the application: all sites for which the application date is not known have been excluded. The lack of a control on the materials used should also be taken into account, because this is not included in the inspection procedures of the markings; the paints are distinguished from the thermoplastics on the basis of a simple check of the retro-reflection values. From the results obtained and the direct surveys 14 sites can be identified where a thermoplastic product was used (5-9-12-15-19-20-21-22-23-25-26-29-34-36) and 22 sites where paint was applied.

4 Results

In agreement with previous studies [5, 10], it was decided to utilize an instrument mounted on a vehicle, because this allows measurements to be taken without the need to close the road to traffic [11, 12]. The data, both punctual and the averages extracted from the elaboration, are reported on diagrams of the performances, with the varying of the distance travelled indicated by the odometer (Fig. 3, No. 34). In these diagrams it is possible to note most of the problems linked to the survey and performance. In the example reported in Fig. 3, it can be observed that the performance measured a few days after the application (site 34) is extremely variable in both directions of travel and that it is possible to find even long stretches of unsatisfactory markings, as occurs on the right hand line between kilometres 7+450 and 9+300. This variability, which was found on the majority of investigated sites, justifies the decision to represent the performance with the statistics calculated on a 50 metres basis.

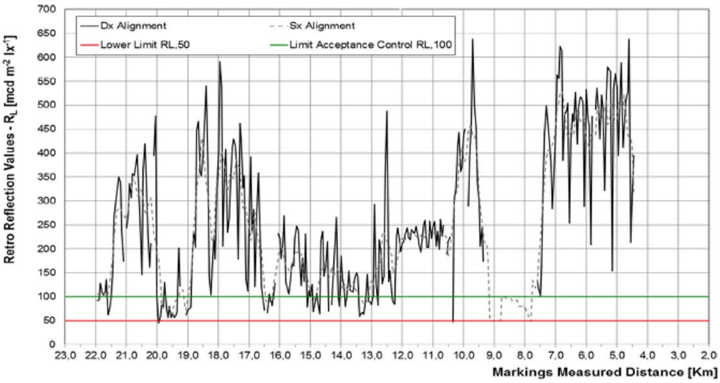

Figure 3 Retro reflection values. Stored measurements and mobile average

Fig. 4 reports the results obtained from the tests conducted in the first weeks of opening to traffic (T=0), together with the limits proposed by the classification in the standard (EN 1436). The first significant result regards the existence of values below the acceptance limits for new applications (100 mcd m^{-2} lux^{-1}). Although the average value of the performance is always above the limits (dashed line), the values are always above the minimum threshold on the entire lot only in 7 cases (nos: 1-2-4-11-12-27-28). Moreover, numerous points were observed with excellent values, above 300 mcd m^{-2} lux^{-1}, in class R5. Of these, only one was applied with paint (no: 32) and seven with thermoplastic material (nos: 12-15-19-20-21-22-23).

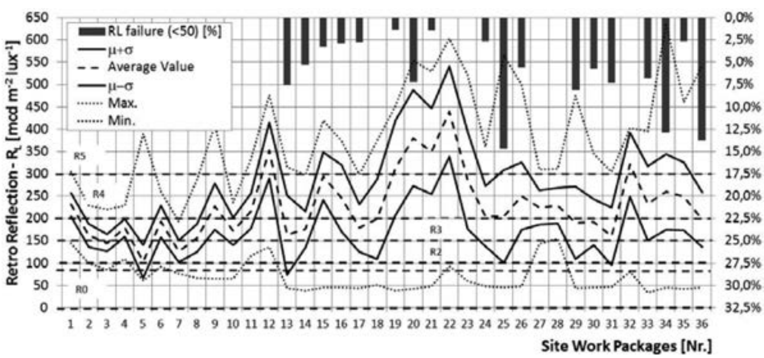

Figure 4 Retro reflection values. Statistics of all work packages (T=0)

Another important result occurs in the other sites where thermoplastic was applied (nos. 5-9-25-26-29-34-36): although there are stretches of excellent markings, in class R5, the average of the values of the initial performance is intermediate between classes R2 and R4. In site no. 5, the thermoplastic guarantees performances slightly above the threshold limit for acceptance, in class R1-2, i.e. below most of the paints (Fig. 4). The distributions of the retro-reflection values are not Gaussian and, for this reason, the indexes of dispersion, like the variance, lose statistical consistency. Despite this, if the intervals defined by the standard deviation around the average value are represented, it is possible to quantify the magnitude of the initial deficiency of the markings with greater detail. The sites with greatest problems have thermoplastic material applied (25-34 and 36): on average, more than 10% of the points surveyed are not acceptable.

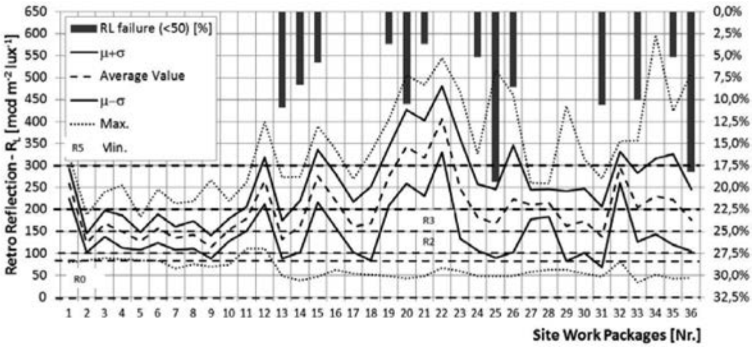

Figure 5 Retro reflection values. Statistics of performance failure (T=6)

For the surveys conducted within the first 6 months a premise should be made: the scarcity of robust and homogeneous information on traffic volumes and environmental conditions does not allow any speculation on the models of deterioration identified in the literature. The results of the elaborations demonstrate a general reduction of the performances, especially of the maximum values. Contemporarily, the number of not acceptable sections has diminished (nos. 16-17-29-30). Figure 5, while it represents the summary values of the statistics calculated on the surveys, shows that it is not simple to make a prediction that fits all the situations. There are anomalous values, both positive and negative. The distributions of the values are not symmetrical, or Gaussian, and the best results are again those offered by the thermoplastic materials. It is worth highlighting that the worst sites do not, in general, suffer an appreciable deterioration and the values of retro-reflection appear to be stable, if not actually improved (no.5). This is not surprising as the presence of walls, ditches, intersections and private accesses greatly affects the markings and cleanliness of the road surface and markings. Where unacceptable points were found after the application (T=0) on not negligible stretches, the situation has worsened (Fig. 4, points 13-14-15-19-20-21-24-25-26-31-33-35-36). Intersecting the data of the two distributions (T=0 and T=6), it appears obvious that the comparison between the two sets of values can only be made in average terms (Fig. 6). In this context, the first clear result regards the average level of the performances, which is worse than expected. The majority of thermoplastic materials applied allow medium-high performances to be obtained, in class R4 and R5, while the worst sites are nos. 5-25-29-36. The sites with the most obvious deterioration are applied with thermoplastic material (9 and 12). As regards the paints, the trend at 6 months after the application is not uniform: there are sites that improve (nos.1-3-7) and sites with deterioration of the performances (nos. 2-6-11-13-18). Despite the fact that a paint was applied in site 32 an excellent result was observed, as the values of the performance remain in class R5.

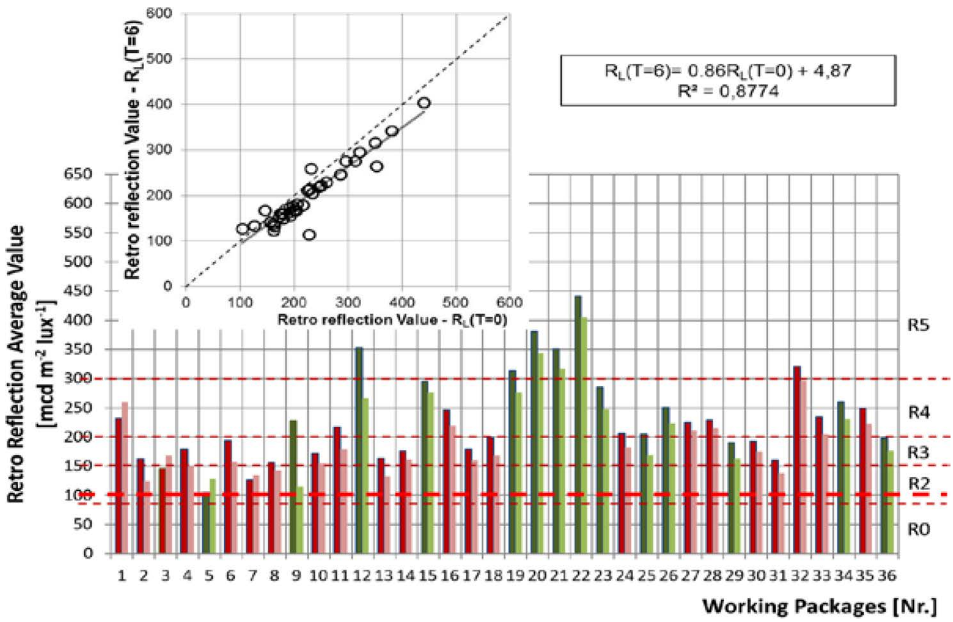

Figure 6 Retro reflection average values. Photometric performance falloff

5 Conclusions

This paper presents a detailed analysis of the performances offered by road markings, applied on roads in a prevalently extraurban context. In particular the phenomenon of deterioration of the retro-reflection has been investigated, immediately after the application and within 6 months. The sites have road markings applied with thermoplastic materials and liquid paints. The results obtained demonstrate that the modelling of deterioration curves based on the service life is not significant, because it does not take into account the numerous concomitant factors that are not considered at this level. Modelling with laws of the linear type does not allow the maintenance times adopted as standard practice to be confirmed: in the case of paints, a service life of 6-12 months is somewhat underestimated; while for the thermoplastic materials, a careful analysis is suggested at the inspection stage and the relationship does not adhere to a linear-type model. While highlighting localized anomalies, it appears clear that maintenance linked to performance characteristics should be tackled in terms of lot and with acceptance thresholds established on adequate distances. In this context it has been demonstrated that the material used, even if costly or of high quality, is not necessarily a sufficient condition to obtain high final performances and on the whole lot. While the paints offer discrete and stable performances, at least in the first months, the thermoplastic materials result as being rather delicate and variable. This suggests not only greater attention at the inspection stage but also more frequent checks, in particular where the results of the inspection fall short of the material used.

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