Extended Abstract
Rehabilitation of Pavement Surface Characteristics

Henrique Miguel Pimentel Carreiro Simas
henrique.miguel.simas@tecnico.ulisboa.pt

Department of Civil Engineering, Instituto Superior Técnico, Av. Rovisco Pais, 1049-001, Lisbon, Portugal, May 2018.

1 – INTRODUCTION

Besides bearing capacity, pavements should also provide a good surface condition. Pavement surface characteristics affect vehicle ride quality and, consequently, driver safety. In fact, pavement surface quality plays an important role in comfort, safety, fuel consumption and vehicle maintenance costs.

Skid resistance is one of the most important surface properties related directly to pavement surface adherence and, consequently, road safety. Several authors have demonstrated the relationship between skid resistance and traffic safety (Fernandes & Neves, 2013; Ivan *et al*., 2012).

Surface roughness is related to the irregularities in the road surface that can also adversely affect ride quality. The most common parameter used globally in surface roughness evaluation is the International Roughness Index (IRI), which is obtained from measured longitudinal road profiles (Sayers *et al*., 1986).

For management purposes, the establishment of performance indicators for road pavements is crucial (COST 354, 2008). The analysis of pavement conditions according to the limits of these indicators can help road management authorities maintain their road pavements. In the case of surface characteristics, pavement management systems can also be a useful tool for evaluating surface properties by using systematic and objective procedures to confirm conformity with established threshold values and, if necessary, recommend the best treatment technique for improving surface conditions (Fernandes & Neves, 2010; 2014).

Multiple treatment techniques are available for restoring surface conditions. In the case of skid resistance, traditional solutions consist of resurfacing with bituminous surface treatments, e.g. micro-asphalt, chip sealing, slurry sealing and asphalt concrete resurfacing (Charles & Behling, 2004; Lawson & Senadheera, 2009). Such solutions have the additional advantage in that they can improve other surface properties (roughness and road noise), and sometimes pavement structural condition is also increased.

Alternative solutions to resurfacing that are more environmentally advantageous can also be envisaged for skid resistance recovery by retexturing the existing surface, e.g. bush hammering, grooving/grinding, fine milling and water jetting (Gao *et al*., 2015; Pidwerbesky & Waters, 2007; Plati *et al*., 2014). Depending on technical, financial and environmental advantages/disadvantages, the most appropriate technique should be chosen based on a whole life cycle cost-benefit analysis (Gransberg, 2009; Gransberg *et al*., 2010; Fernandes & Neves, 2010).

This study investigates the technical efficiency of two surface treatment techniques: bituminous surface treatment using cold micro-asphalt; and abrasive shot-blasting process. These techniques were applied to asphalt and concrete pavements on a Portuguese motorway as a means of improving skid resistance and longitudinal roughness. The innovative contribution provided by this study is the extensive amount of data analyzed, monitored before and after treatment and in real conditions of pavements structures and traffic loading.

2 – PAVEMENTS AND TECHNIQUES

2.1 – Pavements structure and traffic

The case study is of a motorway that was built in the early 1990s. The carriageway surface width is 7,50 m, with outside and inside asphalt shoulders that are 2,50 m and 1 m wide, respectively.

This motorway has two types of pavements: pavements with a surface layer composed by a bituminous mixture (flexible and semi rigid pavements) hereafter “asphalt pavement”; and concrete pavement (rigid pavement). Asphalt pavements are predominant but concrete pavement exists in the case of high-volume sections.

Surface of asphalt pavements consists of a 5 cm asphalt concrete AC 14 surf 35/50 (EN 13108-1) layer. According to Portuguese specifications, the limits of Los Angeles (EN 1097-2) and microDeval (EN 1097-1) coarse aggregate resistances were 20 and 15, respectively. The limit of polished stone value (EN 1097-8) was 50.

The concrete pavement consists of a 22 cm slab of continuously reinforced concrete. The concrete’s composition includes siliceous sand and coarse aggregates, characterized by Los Angeles and micro-Deval limits of 20 and 25, respectively. The limit of polished stone value was also 50. The concrete surface texture was achieved by transversal grooving.

The Average Annual Daily Traffic volume of heavy vehicles (AADTh) between 2007 and 2010 varied along the total length of the motorway. In terms of mean values, the AADTh values for asphalt pavements were between 81 and 453, while the corresponding values on concrete pavement were between 503 and 718.

2.2 – Pavements surface conditions

The pavement surface characteristics monitored were longitudinal unevenness and skid resistance by means of the International Roughness Index (IRI) and the Coefficient of Friction (CF). These parameters were evaluated in all lanes and in both directions.

The pavement surface longitudinal profile was obtained by a standard laser profilometer (EN 13036-6). The IRI parameter was calculated based on these automatic inspections.

CF measurements were performed by two different of devices: Grip Tester in the case of abrasive shot-blasting process (BS 7941-2); and Sideway-force Coefficient Routine Investigation Machine (SCRIM) in the case of new bituminous wearing courses (BS 7941-1). Both are based continuous wet resistance to surface skidding measuring devices: the Grip Number (GN) is the longitudinal surface skid resistance measured by the Grip Tester, while the Sideway-Force Coefficient (SFC) is the transversal surface skid resistance measured by SCRIM.

Values of GN were converted to SFC values. Various relationships between GN and SFC are available in the literature, including the case of micro asphalt (Ellis *et al.*, 2009). In this study, and according to the Portuguese experience, Equation 1 from the technical specification prCEN/TS 15901-7, by the C.E.N 227/WG5 – Surface Characteristics, was considered.

$$SFC = 0{,}89 \times GN \tag{1}$$

where SFC = Sideway-force Coefficient; GN = Grip Number.

The SFC values correspond to the CF used in this study.

In general, the initial CF and IFI measured in all sections were outside the limits and general treatment was required to restore skid resistance and longitudinal roughness levels. Taking the values of Average Annual Daily Traffic volume of total vehicles (AADT) in each section into account, it did not prove possible to establish a relationship between the CF and IRI of existing surfaces and AADT. This conclusion was valid for asphalt and concrete pavements. In fact, asphalt pavements returned low volumes but they have presented during monitoring the lowest CF values.

FWD tests were performed on the surfaces in addition to the evaluation of these parameters. From these load tests, it was concluded the pavements had an adequate load bearing capacity taking into account the expected future traffic. This important conclusion confirmed that treatment was only required for the surface characteristics.

2.3 – Treatment techniques

Two surface characteristics treatment techniques were performed on the motorway: (1) resurfacing with a bituminous surface treatment involving the application of cold micro-asphalt (BST), and (2) retexturing the existing road surface by abrasive Shot-Blasting Process (SBP).

BST consisted of cold micro-asphalt concrete specified according EN 13108-2. This material was composed of gap-graded aggregate to form stone-to-stone contact and provide a rough surface course, modified bitumen emulsion, cement as a filler material, water and additive.

Table 1. Aggregate properties of micro asphalt.

Properties	Standards	Limits
Grading (Cumulative percentage of material passing the sieve)	EN 933-1	12.5 mm: 100 8 mm: 98–100 6.3 mm: 85–99
Flakiness index	EN 933-3	≤15
Methylene blue value	EN 933-9	≤1 g/kg
Micro-Deval coefficient	EN 1097-1	≤15
Los Angeles coefficient	EN 1097-2	≤20
Water absorption	EN 1097-6	≤1 %

Two types of BST were applied: Single Coat (SC), 14 kg/m², and Double Coat (DC), 22 kg/m², after the milling of the existing road surface. DC was used when the surface presented signs of severe distress. BST was applied in-situ as a thin layer by a specific paver. Table 1 presents the main aggregate properties established in Portuguese technical specifications based on EN 13043 (aggregates for bituminous mixtures and surface treatments), which directly or indirectly influenced the final BST texture.

SBP is a surface retexturing technique that can provide a quick, skid-resistant asphalt or concrete road surface. This technology involves the high-speed projection of graded steel. The result is surface retexturing by abrading and reprofiling aggregate and the removal of the bituminous matrix, fine aggregates and existing detritus on the road surface.

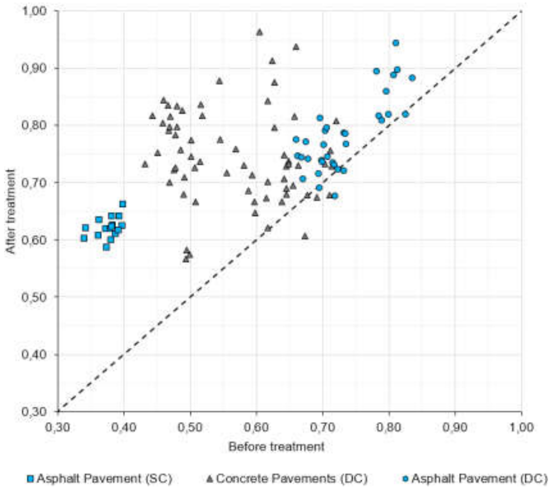
Surface monitoring of skid resistance and longitudinal roughness was performed before and more than over two months after the application of BST treatments. In the case of SBP, a preliminary evaluation of the efficiency was carried out on an experimental section immediately before and after treatment.

3 – RESULTS AND DISCUSSION

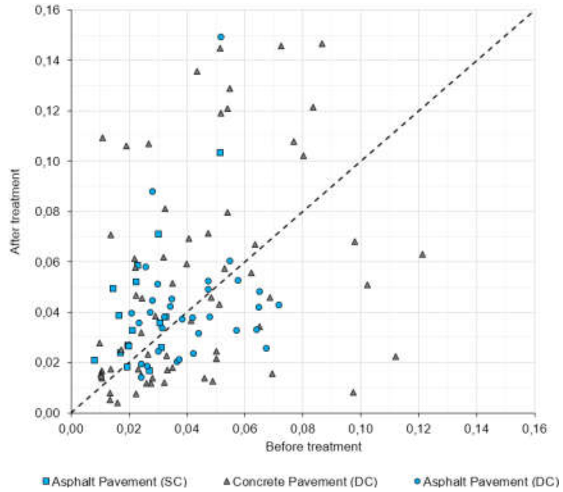
3.1 – Skid resistance

Figure 1 presents the results obtained before and after micro asphalt treatment. The values presented in Figure 1a are the mean values of CF measured in each lane. Figure 1b presents the correspondent standard deviation values. In general, and as expected, a positive rehabilitation effect was achieved. In fact, the BST presents a surface with micro- and macro-texture that was very favorable towards skid resistance in general.

The benefit of BST can also be dependent of other factors, not strictly associated to materials quality, such as curing time. Surface monitoring took place two months after treatment, so it is expected that after a longer period CF values will be greater and uniform as a consequence of the beneficial effect of the passage of traffic. Surface cleanliness is promoted, leading to the exposure of the aggregate and improvements to the surface texture.



(a) Average



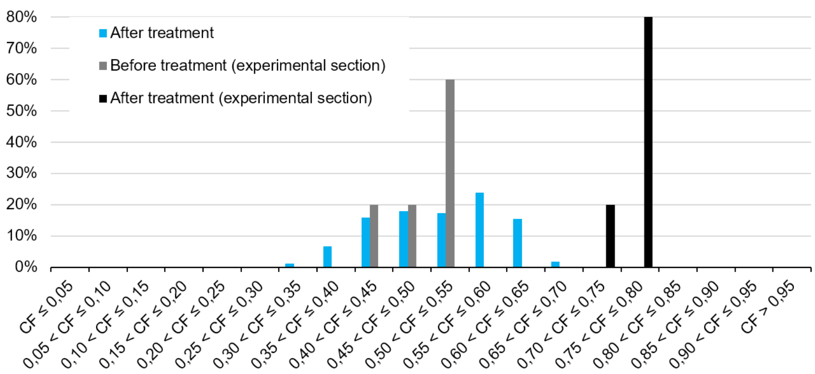
(b) Standard deviation

Figure 1. Effect of micro asphalt on CF.

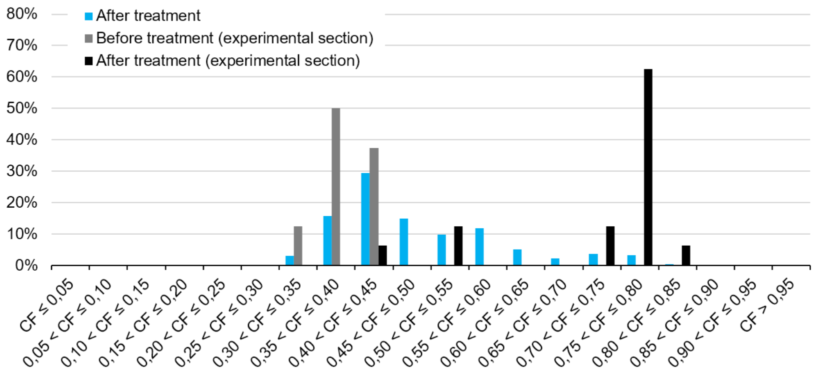
Figure 2 shows CF results concerning the monitoring of SBP treatment in asphalt (Figure 2a) and concrete surfaces (Figure 2b). Experimental stretches were studied before SBP application and then monitored.

In the short term, there was a significant and uniform improvement in skid resistance: the mean CF value increased from 0,50 to 0,79 for asphalt surfaces, and from 0,39 to 0,72 for concrete surfaces. However, monitoring skid resistance two years after treatment showed that the effect was significantly reduced with the passage of traffic. In fact, mean CF values were 0,52 and 0,49 on asphalt and concrete surfaces, respectively, with these latter values lower and similar to the initial values.

The application of the SBP treatment was, therefore, not so efficient for the skid resistance improvement, since the effect produced on the pavement surface macro-texture was not as durable as desirable.



(a) Asphalt pavement



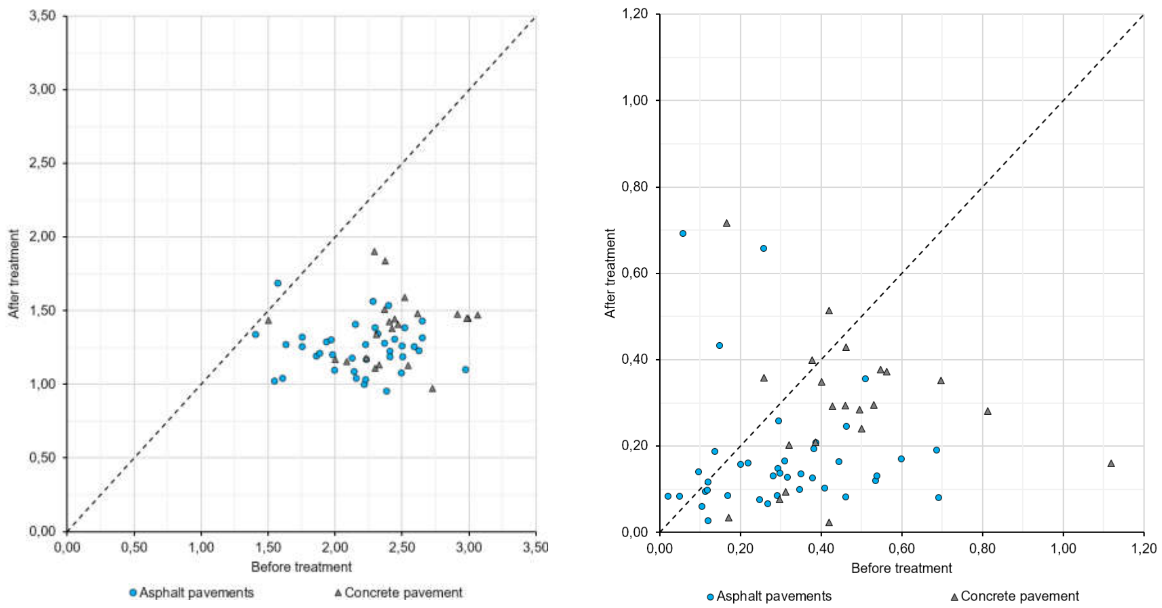
(b) Concrete pavement

Figure 2. Effect of shot blasting on CF.

3.2 – Longitudinal roughness

The treatment of the longitudinal roughness consisted in the application of a double coat resurfacing with micro asphalt, in both asphalt and concrete pavements.

Figure 3a shows the effect of monitored IRI decreases before and during the two months after treatment. The results presented are the mean values corresponding to each lane in either direction. In general, and as expected, a positive IRI reduction effect was observed: mean IRI values after treatment were 1,24 and 1,38 on asphalt and on concrete surfaces, respectively. The respective initial values before treatment were 2,18 and 2,45, respectively. Two years after the treatment, the IRI values still demonstrate good longitudinal unevenness.



(a) Average

(b) Standard deviation

Figure 3. Effect of micro asphalt on IRI (m/km).

Figure 3b presents the standard deviation values. It can be concluded that the scatter of final results decreased significantly after the application of BST.

4 – CONCLUSIONS

The study has described the application of two surface treatment techniques: bituminous surface treatment with cold micro asphalt as a new resurfacing layer (BST); short-blasting process to retexturing the existing road surface (SBP). These techniques were chosen to recover the skid resistance and longitudinal roughness of the existing motorway surface made up of two surface types: asphalt (flexible and semi-rigid structures) and concrete.

In fact, this motorway showed road surface distress with International Roughness Index (IRI) and Coefficient of Friction (CF) figures outside the limits set out in the technical specifications. In addition, the FWD load tests showed the surfaces had no structural problems.

In the case of skid resistance, the most efficient technique was BST. More than two years after the treatment, the CF values still demonstrate good skid resistance. However, in the case of SBP, the good effect measured immediately after the treatment performed in an experimental section no longer existed after two years. CF was generally reduced to values similar to those on the surface prior to treatment. BST also had the advantage of simultaneously restoring longitudinal roughness (decrease of IRI) and skid resistance (increase of CF). BST has increased the CF on asphalt pavements to an average value of 0,77. In the concrete pavements, the increase of CF was an average value of 0,75.

As for the longitudinal roughness, the application of BST (DC) generally reduced IRI mean values (m/km): from 2,18 to 1,24 on asphalt and from 2,45 to 1,38 on concrete. The assessment of the efficiency presented in this study was based on the strict monitoring before and after the application of the road surface treatments. The evaluation of this efficiency is desirable and should be supported on the basis of a complete life-cycle analysis that incorporates the financial and environmental factors associated with these treatments. If on the one hand, the bituminous resurfacing using micro asphalt is revealed to be the more efficient and durable technique, on the other hand, the initial costs and traffic disturbances are greater. The shot-blasting process can be a suitable alternative in the case of quick and temporary treatments while taking into account the economic and environmental advantages.

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