THE INFRASTRUCTURE OF ACTIVE MOBILITY – EVALUATION OF A SURFACE PAVEMENT SOLUTION

1. INTRODUCTION

Active mobility has come to acquire importance with the changes to the current mobility paradigm that aim to decrease the significance of individual transports in favour of a more sustainable and easily accessible way of transportation [1]. Also, it is important to adapt the infrastructure to people with reduced mobility [2]

The cycling infrastructures that have been created in cities to encourage bicycle use in transportation has proven ineffective due to the premature appearance of distresses that lessen the quality of the pavement surface and jeopardize the essential safety conditions in addition to the functional conditions[3].

The objective of the thesis is to knowledge the different solutions of active mobility infrastructures and comprehend the way of degradation of a cycling path surface through a simple experimental model.

Therefore, in laboratory were created different applying conditions that were analysed with the intent of creating a model that simulates the behaviour of a cycling surface treatment when applied in different support conditions and in different applying conditions.

Through this experimental model it will be possible to understand the distresses evolution, evaluate the way they evolve and in the future even predict their appearance and ways to detain it.

To validate the experimental model, four case studies including different cycling paths were analysed in terms of their surface properties, in order to make a comparison with the results acquired in the laboratory trials.

2. MATERIALS AND METHODS

2.1. MATERIALS

The cycle path surface is accomplished through the use of a coating mortar to which can be added an acrylic painting with resins in aqueous dispersion in whose use has more complementary character.

The mixture used as covering has for base a coating mortar composed of aggregates of controlled granulometry and synthetic resins whose ideal use is achieved by applying two coats. The acrylic painting must be used as a primer when in question is a bituminous pavement with poor ability to join the coating mortar.

Before being used in cycle path infrastructure, this type of mortars were used in road pavements to delay the appearance and evolution of disorders in the surface [4][5].

2.2. EXPERIMENTAL STUDY

Looking to the experimental study, the research showed that currently there's still no tests concerning the specificity of a cycle path surface. Therefore, it was necessary to adapt a test used in road pavements to comprehend the appearing and evolution of pathologies in the surface layer.

The objective was to create a model that simulates the behaviour a cycling path covering when applied in different surface conditions and with distinguished number of coatings.

The simulation was done with a traffic simulator used in the Wheel Tracking Test (Figure 1) that performs the EN 12697-22 2013 [6] and whose objective is evaluate the susceptibility of deformation of the bituminous mixtures with the passage of moving loads – representing in a simplified manner the successive passages of the wheelsets (Figure 2).

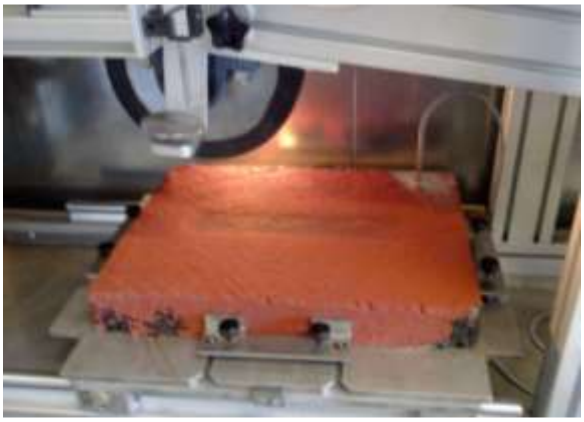

FIGURE 1 - ACCELERATED WEAR TEST

FIGURE 2 - SURFACE APPEARANCE AFTER THE ACCELERATED WEAR TEST

The trial accomplished in this work – that has as a goal of evaluating the evolution of the covering with the continuous passage of a tire calibrated for the purpose – underwent some adaptations to better represent the intent in study.

Firstly, the chosen temperature was 40ºC because it is superior to the 35ºC considered the limit for the application of the product and also because it is a very common temperature for the pavement surface during the warmer seasons.

Secondly, the trial was not accomplished continuously but in 1.000 cycle periods in order to assess the onset and evolution of surface pathologies with the continued passage of the wheelset.

Thirdly, the results acquired in the deformities were discarded since the analysis was focused on the surface and on the covering performance and not on the slab structural capacity.

It is stressed that simplifications were not taken in the tire weight since it was found in the test slabs that the rutting created were small and it didn't affect the surface results to be analysed. Regarding the conditions of each of the slabs to be tested, it can be found in Table 1 the different options:

TABLE 1 - TESTED CONDITIONS

Tested Conditions		Applying Conditions			
		Primer and 1 Coating	Primer and 2 Coatings	1 Coating	2 Coatings
Support Conditions	Clean	F2	D2	F1	D1
	Damp				E1
	Filler				C2
	Stone Powder				C1
	Damp and Stone Powder				E2

As can be seen demonstrated in the chart above, 5 different support conditions and 4 different ways of application are analysed. From the support point of view, the basic condition of having a dry and clean surface was analysed, as well as an unclean surface (accomplished with the use of filler and stone powder) and even the existence of moisture (which was individually analysed and still with stone powder present). In terms of application conditions, the use of two coatings was tested – considered the ideal condition – and possible variations to this condition.

To evaluate the surface more objectively macrotexture [7] and slip resistance [8] testing were done.

The first test (EN 13036-1) consists in spreading on the surface of a floor a certain volume of glass beads (it could also be thin sand, hence the name of the trial) with the help of a calibrated rubber. The surface cavities are filled with sand until it isn't possible to increase the diameter of the stain made. The trial surface must be dry and clean - and that should be accomplished with the use of a brush in the area that is expected to be occupied by the test stain in order to prevent tampering the obtained results. This trial even though it doesn't have as a result a direct value of friction between tire- pavement, is a good indicator since the result obtained is a direct macrotexture of the layer of covering from a cycle path.

The measuring of a surface's slip resistance through the pendulum test, EN 13036-4 from 2011, is used to measure in a sample way the friction between the tire and pavement or, as is the case of this dissertation, between the tire and the cycle path's surface covering. This trial translates into a fall from a horizontal position of a pendulum whose end has an eraser that absorbs the friction energy acquired in its passage through the wet surface of the pavement. The result is a measure of pontual skid resistance of the thin layer analysed.

The tests performed on the slabs were conducted with the goal of evaluating the behaviour of cycling paths, being able to understand the way commercial covering products behave in varied surface and applying conditions and how they react to the continuous passage of vehicles that occurs during their lifetime.

This model will later be validated with the analysis of real cycling paths that exist in the district of Lisbon (Lisbon and Cascais) and in which the coating used was the same as the one used in laboratory – in order to reduce the variability of results due to the use of different commercial products.

Through this model it will be possible to understand the degradations that appear in the covering and their evolution. In the future it will be possible to predict the appearance and the progression of pathologies to allow simpler and less costly rehabilitation.

3. RESULTS

3.1. RESISTANCE TO WEAR TEST

After the resistance to wear test where 10 000 rutting cycles were done to simulate the service conditions of the cycling path, we observed the appearance of degradation in different stages of the trial as well as progression of different pathologies.

In slab C (Figure 3) we see that after 10 000 cycles the degradation in the portion corresponding to the stone powder is higher than the portion in which was placed the filler.

In slab D (Figure 4), we see that the rutting is more pronounce in the area where the application of the primer was made before the two coatings of covering product. However, in the rutting of the portion where only 2 coats were made (Classified as "Optima" in the slab) we can see a place where there is greater disaggregation of material (bottom right of the rutting).

FIGURE 3 – SLAB C AFTER 10 000 CYCLES

FIGURE 4 - SLAB D AFTER 10 000 CYCLES

In turn in slab E (Figure 5) it's obvious the degradation of the damp and with stone dust portion. Indeed, the visible degradation is higher than in any other cases. Nevertheless, we can see in the damp portion a general breakdown of the lining material noticeable by the sharp black shading in the slab- that matches the colour of the bituminous mixture used as a base.

Finally, in slab F (Figure 6) there is a further deterioration in the portion where it was applied only one coat, in which the black shading is superior to any of the other visible portions of any slab.

FIGURE 5- SLAB E AFTER 10 000 CYCLES

FIGURE 6- SLAB F AFTER 10 000 CYCLES

Generally speaking, we can consider that the worst way of applying the covering is over a wet and dusty surface and that the best results happen with the application of two coatings over a clean and dry surface. Besides that, it is more resistant to breakdown a surface with primer application than without, especially in cases in where only one coat of the coating product is applied.

Concerning the human aspect, the result obtained after the 10 000 cycles was similar to the one with the application of two coatings over a clean and dry surface. However, the disaggregation in the previously humidified portion was more rapid in comparison with the control solution.

3.1.1. SURFACE CHARACTERISTICS

The results obtained in laboratory following the stain's volumetric technique show what can be seen in the Figure 7:

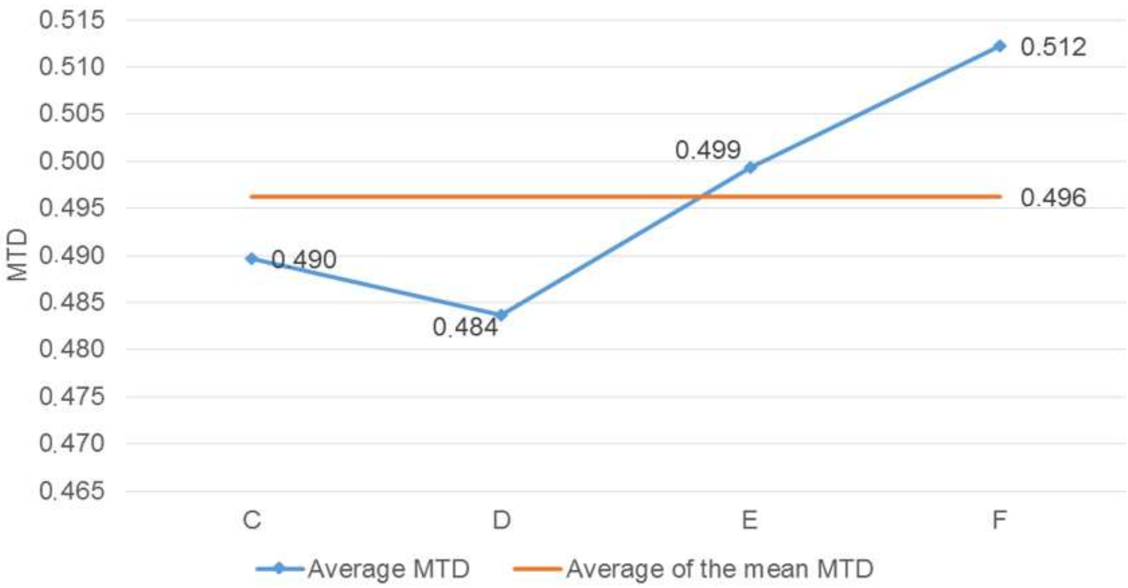

FIGURE 7- AVERAGE MTD OF EACH SLAB

Concerning the pendulum test, the results are in the Figure 8:

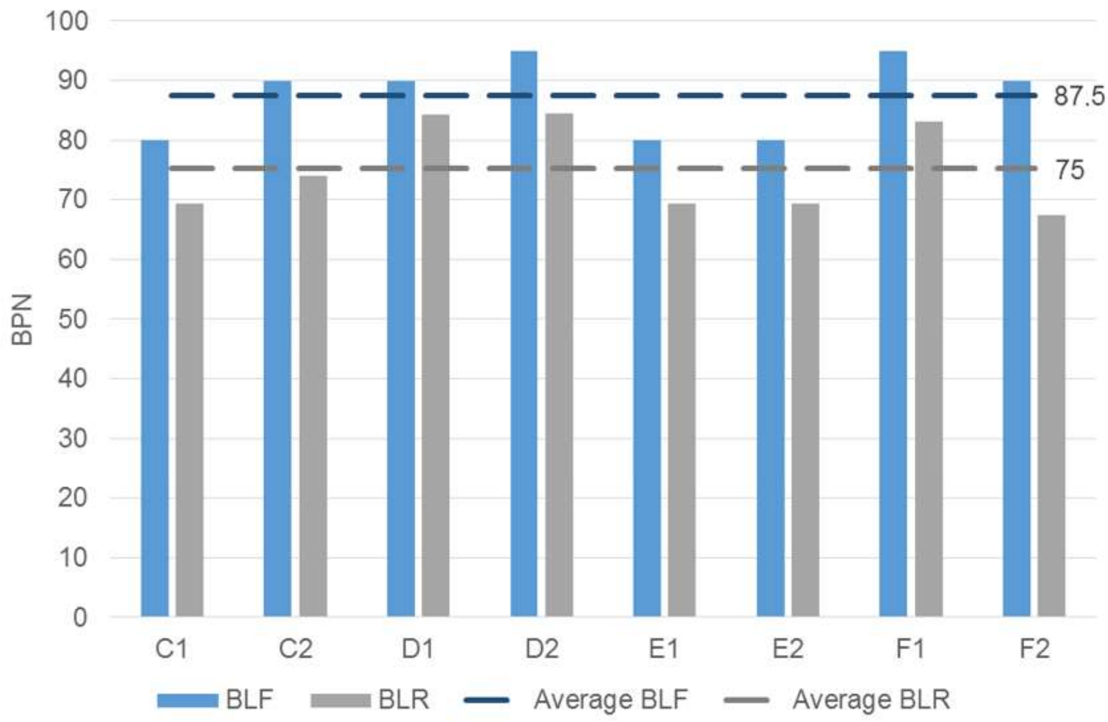

FIGURE 8- FINAL BPN RESULTS IN THE BRITISH PENDULUM TEST

It should be noted that the BLF values correspond to tests carried out with the standard rubber out of the rutting and the BLR values are related to the ones carried out with short rubber in the rutting which were later extrapolated values for the standard rubber by calculating a factor K corresponding to the ratio between the average test values out of the rutting with short and long standard rubbers.

Comparing the values inside and out of the rutting it can be seen that the values outside of the rutting – where the BPN value It refers to more friction surface in a surface point- they are higher than the trial values in the rutting, this is consistent with the fact that the wear and tear of the surface decreases its friction.

Only D1, D2 and F1 present both values higher than average, thus the ones that best retain the friction despite wear. It should be noted that the fact that only one coat of product is used gets good results because the mixture used to make the tiles have aggregate of granite origin which is very resistant to wear.

Now C1 and E1 both present exhibit both higher than average values so that either before or after the degradation their occasional friction is reduced. And so we can determine that the best solutions are the use of two coatings of covering product, as predicted in the product catalogue. It is also observed that the primer has a significant effect on product durability since D2 is the one that has the highest values.

3.2. CASE STUDIES

The case study, used to validate the behaviour model studied in laboratory, went through the analysis of 4 different cycle paths in the district of Lisbon.

For that, the surface characterization tests carried out previously in the laboratory were done on the field to assert the validity of the created model and the accuracy of the results.

It's important to mention that the cycle paths used were built with the same material used in laboratory, however, the use of other commercial coverings destined to the same job should not affect the results in any different way in comparison to the ones acquired in laboratory since the purpose they are intended to is the same.

Since the goal passed through evaluating different cycle paths, different aspects were taken into consideration when chosen:

i. The product used in the covering layer is the same;
ii. The cycle paths were separated meaning there wasn't any car or truck traffic;
iii. Have different characters: aimed at urban routes or recreational purposes;
iv. Find themselves in different stages of their useful life
v. The surfaces have different appearances.

As a result, 4 cycle paths that present the characteristics above were tested: Cycle Path A (Figure 9), Cycle Path B (Figure 10), Cycle Path C (Figure 11) and Cycle Path D (Figure 12).

In cycle path A because of its appearance it was possible to identify 2 parts with different characteristics and so two trial spots were considered, A1 and A2.

FIGURE 9- CYCLE PATH A

FIGURE 10- CYCLE PATH B

FIGURE 11- CYCLE PATH C

FIGURE 12- CYCLE PATH D

3.2.1. SURFACE CHARACTERISTICS

In the cycle paths the acquired results for stain's volumetric technique were (Figure 13):

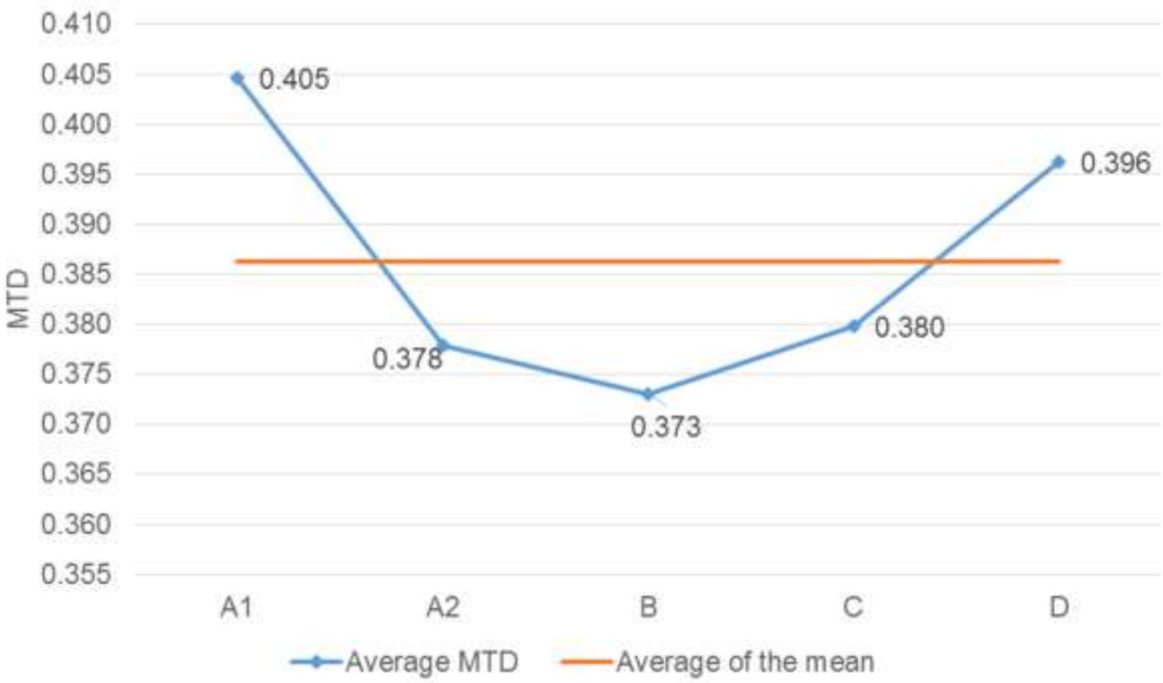

FIGURE 13- AVERAGE MTD OF EACH CYCLE PATH

It is observed the cycle path B is the one that has the most material degradation, the MTD value is the lowest, while cycle path D that was visually in better condition has a higher MTD.

For the pendulum trial the results were (Figure 14):

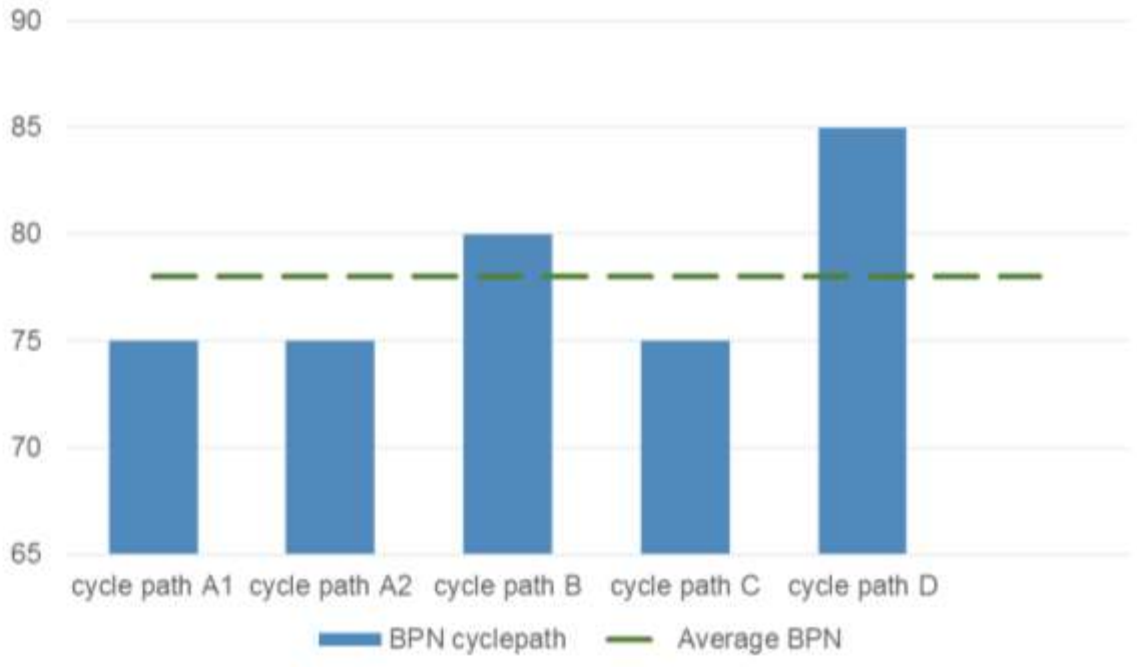

FIGURE 14- RESULTS OBTAINED IN THE BRITISH PENDULUM TEST

As can be seen, both parts analysed in cycle path A got the same BPN values, just like the part analysed in cycle path C. On the other hand, the trials done to cycle paths B and D obtained the higher values of 80 and 85, respectively. That means these two cycle paths have more friction that the other parts analysed.

We also discovered that the point relative friction is not as sensitive to the covering's condition since the two parts in different conditions from the same cycle path had the dame BPN value in the 10 made trials (5 in each).

4. CONCLUSIONS

After the analysis of all the trials it's possible to see a direct relationship between the conditions of application and durability of the covering which agrees with the model created in laboratory.

From the laboratory trial's point of view, we verified that the stain's volumetric technique is very much influenced by the covering's thickness.

Indeed, the slab with thinner covering (where only a coating of product) it matched the highest value of MTD and the slab that used two coatings which is considered to be the correct procedure corresponded to the lowest MTD value (0,484).

According to the field trials, the corresponding stretch with the best roughness characteristics corroborates what was verified during laboratory tests.

According to the British Pendulum test we saw that the BPN values to which corresponds the best solution is 85. Watching the analysed parts, the cycle path that was clearly in a better condition was the one that got the closest value to the one verified in the laboratory.

In a general way, taking into consideration the visual inspection, the stain's volumetric technique and british pendulum trial, it can be said that the cycle paths have similar behaviours to the ones simulated in laboratory it being a good way of assessing their behaviour and eventually predict their degradation mode.

5. REFERENCES

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