# DEVELOPING SURFACE TREATMENTS PERFORMANCE MODELS. APPLICATION FOR MICROGRINDING AND BLASTING.

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## ABSTRACT

The most recent specifications in tenders for toll motorway concessions in Spain contain very demanding requirements for the superficial characteristics of pavements, particularly as regards roughness and skid resistance. This new situation has led the various concessions to use techniques specially intended to comply with these requirements. In the case of longitudinal roughness, as well as following strict construction procedures, continuous measurement of roughness at all layers of the agglomerate has been introduced, making corrections when necessary using the microgrinding technique. As regards skid resistance, various techniques (microgrinding and blasting) have been applied in order to improve the skid coefficiente where the minimum levels are not attained. These techniques have, on first analysis, been successful and substantially improved the initial characteristics.

# 1. PRESENTATION

ITINERE, a subsidiary of the Sacyr Vallehermoso Group, is the 4th company at international level in terms of the number of concessions awarded. It is present in 7 countries (Spain, Chile, Portugal, Brazil, Costa Rica, Bulgaria and Ireland). Following its merger with Europistas, the new Itinere has a total of 43 concessions, of which 34 are motorways, 1 service area management entity, 1 motorway maintenance company, 2 transport hubs, 1 metro line, 1 airport and 3 hospitals. In total, more than 7,000 Km of carriageways with pavements to be managed, spanning a wide range of typologies, climates, traffic intensities and ages. Due to its high potential for growth, based on the generation of new projects or the purchase of projects already underway, the number of concessions run by the company is expected to rise.

# 2 THE NEED FOR A DETAILED STUDY OF CORRECTIVE PROCEDURES

## 2.1 SPECIFICATIONS CONTAINED IN TENDER DOCUMENTS

The most recent specifications in the tenders for toll motorway concessions in Spain contain very demanding requirements for the superficial characteristics of pavements, particularly as regards roughness and skid resistance. These requirements lead not only to higher standards at the stage of constructing the infrastructure, but also at the operational stage.

The specifications in the tenders called by the various Autonomous Community and State administrations present a significant variety of criteria and reference values, as depicted in tables 1 and 2.

In general, the requirements for construction are higher than during operation. In the concessions in which Itinere has a holding, there are two major groups in terms of the requirements for surface roughness:

- specifications that use PG-3 documents as the reference (indicated on the table with an asterisk *). In these cases, the IRI is calculated for a 100 m base and the mean value and its standard deviation are limited in each section (supposing that the values present a normal distribution). It maximum individual value is also limited. These limitations are established for all layers of the pavement (asphalt concrete, cement treated base, subgrade).

- specifications that do not use PG-3. In these cases, the IRI calculated for a 20 m base is used. Limitations are established for the mean and the deviation, as well as the individual values. In general, the limitations only affect the wearing course.

For the case of the sideway force coefficiente (SFC) , a minimum threshold for the point values is normally asked. On occasion, a minimum value is also specified for the mean and in some cases, a maximum standard deviation.

Table 1. Summary of IRI and SFC requirements in construction for wearing course

| | | |
|---|---|---|
| **IRI (20 m)** | Mean of subsection (mm/m) | ≤ 1.25 – 1.50 |
| | Typical deviation of sample at edge | ≤ 0.25 – 0.35 |
| | Maximum value of every measurement at edge (mm/m) | ≤ 2 - 3 |
| **SFC** | Mean of subsection | ≥ 0.55 – 0.65 |
| | Point value | ≥ 0.50 – 0.60 |

Table 2. Summary of IRI and SFC requirements in operation

| | | |
|---|---|---|
| **IRI (20 m)** | Mean of subsection (mm/m) | ≤ 1.30 - 2 |
| | Typical sample deviation | ≤ 0.25 - 0.30 |
| | Maximum value of each measurement (mm/m) | ≤ 2.4 – 3 |
| **SFC** | Mean of subsection | ≥ 0.45 – 0.50 |
| | Point value | > 0.35 - 0.45 |

As regards the requirements for operation, the variety of criteria is greater still and is practically specific to each technical specifications document.

It is important to point out that some cases, the IRI and SFC values have a direct impact on the income fee depending on the values that are reached. For example, the income fee is raised or lowered and penalties are applied when certain values are reached.

It is important to point out that some specifications define a threshold value for the typical deviation without linking it to the mean, which would allow to establish a confidence interval or a characteristic value, which is what gives meaning to this type of requirement. If the typical deviation is limited on an independent basis, the possibility arises that there may be one section with an excellent IRI mean (e.g. 0.9) and quite a high standard deviation (e.g. 0.26) which does not meet the specifications because its characteristic value is 1.16. On the other hand, another section with a high mean (e.g. 1.24) a strict deviation (e.g. 0.24) would meet them with a higher characteristic IRI (1.48).

In short, the specifications for superficial characteristics are increasingly strict and in several cases have a direct effect on the admission of the concession. This new situation has led Itinere and the various concessions in which it has a holding to use techniques aimed at constructing and preserving the pavements in order to meet these requirements.

**2.2 PERFORMANCE MODELS FOR THE PAVEMENT MANAGEMENT SYSTEMS**

The majority of users seek for a pavement management system to indicate the following:

- the type of measures they are going to take on their road network
- the cost involved
- the status of the network after these measures are taken

In order to meet this objective, it is necessary to model the performance of the network. In particular, for the case of the surface characteristics of the pavements contained in the majority of Specifications, it will be necessary to predict the evolution of the SFC and the IRI by means of performance models.

Considering that these models influence many aspects of pavement management, it is important that they should reflect as accurately as possible the evolution of these values in the existing pavements. On the one hand, the "effect" of the treatment will have to be defined and on the other hand, its subsequent evolution over time and depending on the traffic (figure 1).

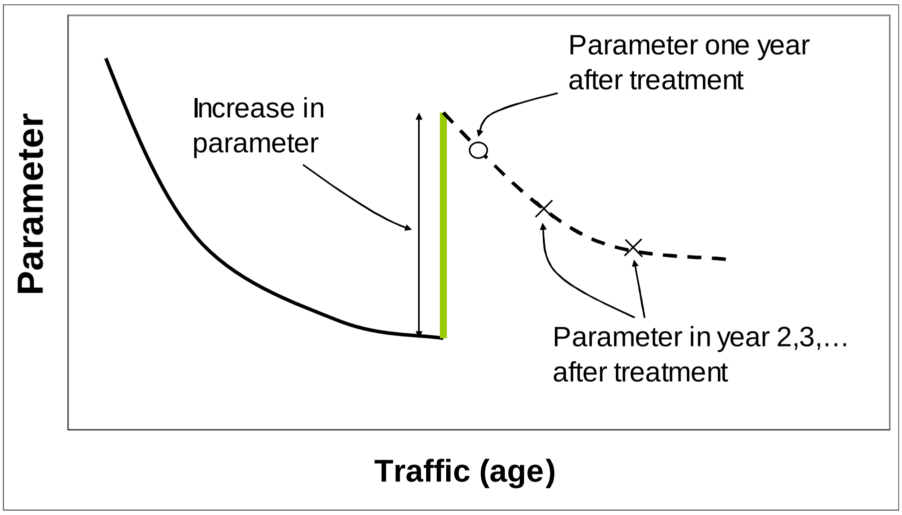


Figure 1. Effect of a maintenance treatment and performance.

# 3. TREATMENTS TO IMPROVE LONGITUDINAL ROUGHNESS

## 3.1. PREVENTIVE ISSUES

During the construction stage, tenders are starting to demand strict construction procedures and there is thorough control over the various variables that have an impact on correct and uniform density in all layers.

In the first place, the types of mixes defined in the projects are reviewed, as sometimes they are not feasible for the stated layer thicknesses.

The resources assigned by the construction company to the transport and spreading process in order to ensure the necessary synchronisation between production, transport and spreading. During transport and spreading, the elements that allow to eliminate the heterogeneities of the material are controlled, which may be caused by segregation during transport or temperature differences in the material.

In order to eliminate these problems, at the Itinere concessions whose specifications include roughness requirements, a remixing MTV (material transfer vehicle) is being used to facilitate the dumping of the mix from the lorries to the paver. This vehicle presents several advantages:

- It reduces the time in unloading the lorries
- It reduces the number of times the paver has to stop and eliminates the possible lorry impacts that cause defects in roughness
- It mixes the material again, thus eliminating possible segregations, temperature differences and surface crusts, leaving the material with a level of homogeneity and temperature that are similar to those of the product at the plant, which is more easily compactable.

Figure 2. Roadtec SB-2500 Shuttle Buggy MTV

Moreover, the temperature values at which the material is to be used in the work are monitored, paying special attention to cases of adverse climatology or large transport distances. Once the material is compacted, the densities of the controls are contrasted to the reference densities included in the work formula. In addition, the compacting procedures are monitored to ensure that they are adequate.

As regards the end product, continuous measurement of roughness has been incorporated in all layers of the agglomerate from the base layer by means of laser profilograph. For the cases in which the required values are not met, the corrective measures described in the following section are taken:

### 3.2. CORRECTIVE MEASURES

In a section of newly-built highway, after the intermediate/binder layer was placed, the corresponding roughness measurement was performed, with high IRI 20 values. In order to be able to place the 3 cm surface course layer with guarantees of being able to meet the requirements stated in the specification, it was decided to perform a microgrinding operation to correct the roughness.

In order to do so, a Wirtgen W2000 system was used. This system has a special 2m wide drum for correcting roughness and the Multiplex level control system. The ground material is poured using a belt into a lorry located at the front of the system. Behind the grinder, there is a street-sweeping machine, to eliminate any excess material. Therefore, the equipment that is needed to carry out the work consists of three vehicles.

The depth of grinding varies depending on the roughness existing; in this case, it was between 5 and 10 mm depending on the section. With this system, it is possible to cover 5000 m2 in an 8-hour day if there are no interruptions in the work.

Figure 3. Final result of grinding to improve roughness.

Once the work was done, the roughness was measured again to verify that the values required in the intermediate layer had been complied with.

Before the grinding, a software was used to see the final effect of the grinding. Thus a first approximation of the definitive IRI is obtained. These outputs from the software are compared to the actual roughness and they are used by Itinere to study the validity of the grinding simulations. This tool is very useful for studying in the various concessions if grinding is a valid option for recovering the roughness of a pavement and for obtaining an approximate value for the final status. In bids for new concessions, these values allow to study the minimum layer thickness to be placed on the ground surface in order to attain a particular value required in the specifications. The following are comparative graphs that are generated to compare the simulated profile and IRI after grinding with what is actually obtained.

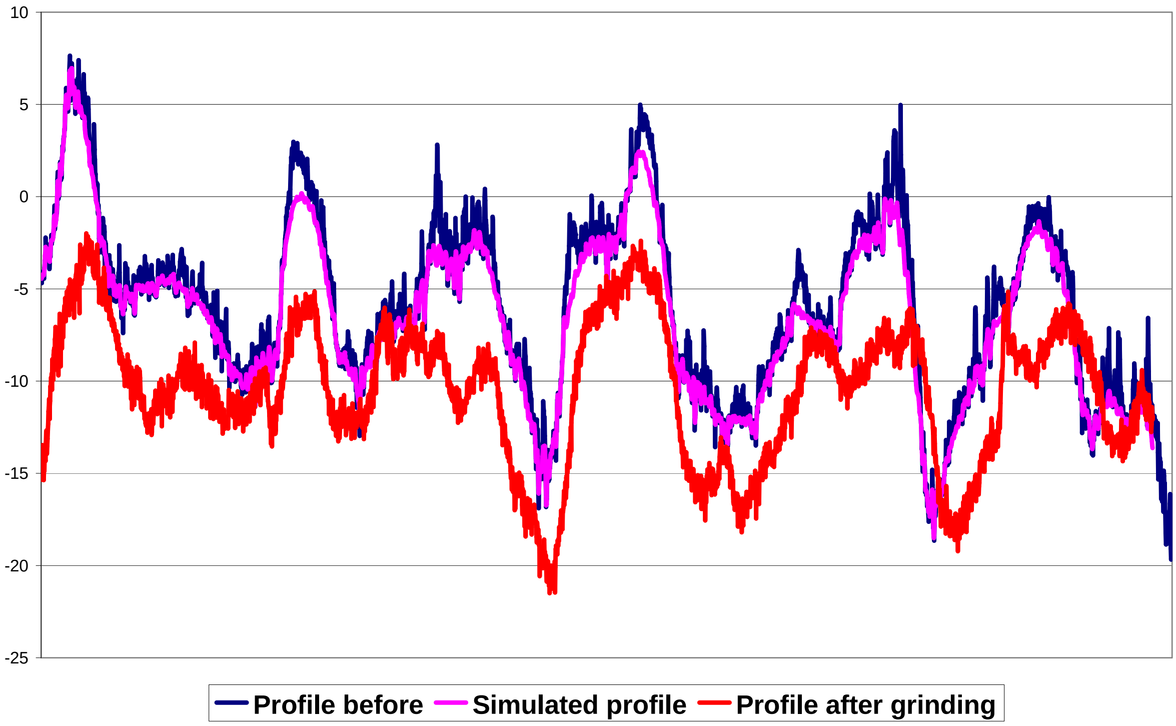


Figure 4. Comparison of profile simulated after grinding and profile actually obtained.

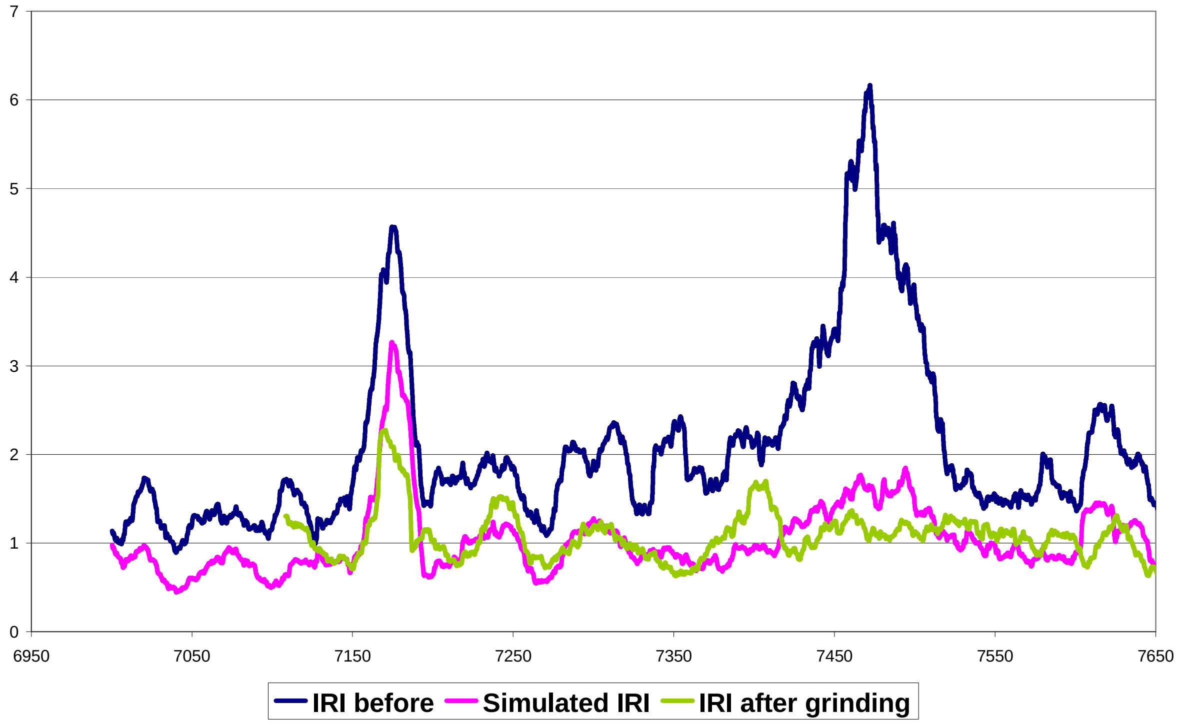


Figure 5. Comparison of IRI simulated after grinding and IRI actually obtained.

This data has been used in studies to model the effect that grinding has on IRI. In order to define this effect, not only is it necessary to reduce the mean IRI of a section, but also to reduce the point values, as both values are important because they are stated in the specifications.

On the basis of the results obtained in various projects of this kind in Itinere concessions, the following values may be considered to be guidelines for use in a pavement management system. They may be used to obtain the effect of including microgrinding as part of a maintenance strategy.

Table 5. IRI reduction values from microgrinding

| Indicator | Range | Reduction (%) | Absolute reduction |
|---|---|---|---|
| **Mean IRI** | IRI < 2.5 | 40-50 % | 1 – 1.5 |
| **Point IRI** | IRI < 1.5 | 0-20 % | 0.1 – 0,3 |
| | 1.5 < IRI < 3 | 25-50 % | 0.5 – 1.5 |
| | IRI > 3 | > 50 % | 1.5 - 5 |

We should insist that these values must be used to model this type of treatments for studies at network level. At project level, a computerised simulation should be performed with the actual profile of the road.

# 4 TREATMENT TO IMPROVE SKID RESISTANCE

In the case of skid resistance, various new techniques have been applied in order to improve the values of the coefficient of transverse friction (SFC) at points where a low value has been detected. To be specific, the microgrinding and blasting techniques have been used. These opportunities have been used to put these techniques into practice and to monitor their effectiveness in order to obtain conclusions that allow them to be applied subsequently in other concessions, particularly in those in which the specifications require minimum skid resistance values.

These techniques were successful in the first analysis and substantially improved the initial characteristics.

Moreover, a plan has been established for monitoring these measures in order to follow their evolution in the medium and long term. Thus the intention is to gather more information on the cost and duration of these treatments, in order to improve the reliability of the studies to analyse the life cycle cost of the various conservation strategies.

## 4.1. BLASTING

A section inside the tunnel of a motorway operated by Itinere presented some points with low SFC values. There were various conditioning factors for not carrying out a conventional operation involving grinding and replacement of the mix. Grinding produces dust, which accumulates inside the tube and means that it must be completely closed, that traffic will not allowed in the left-hand lane and will have to be diverted to the other entrance. Moreover, because of the type of ventilation in the tunnel, it is not possible to place the asphalt concrete using conventional lorries due to the limitations of clearance when tilting. As regards the slurry  solution, there is the problem of the low temperatures in the tunnel, which extend the time for the emulsion to break and set and mean that the time that the lane is closed is further prolonged. For this reason, the possibility of using blasting as a technique for renewing the surface and which would prolong the life of the wearing course at least until structural renewal was carried out was proposed.

Blasting presents the following advantages:

- It allows for traffic to circulate on a simultaneous basis along the left-hand lane, as it does not generate dust, as grinding and replacement or microgrinding do
- It allows the surface to be opened to traffic on an immediate basis
- There are no problems involving height clearance
- It may be performed regardless of the temperature inside the tunnel
- It is a environment friendly solution as it makes the most of the aggregate existing in the surface course.

Blasting is an impact treatment technique that may be used to achieve correct surface finishing. In general, this technique is also used for the following:

- Cleaning components of ferrous and non-ferrous foundry components, forged elements, etc.
- Mechanical stripping of wires, bars, plates, etc.
- Shot Peening (increases resistance to fatigue of springs, elastics, clockwork, etc.)
- Cleaning and preparation of surfaces to which subsequent coatings are to be applied (paint, rubber, etc.)

Blasting is a closed-cycle technique that uses steel micro-spheres whose diameter is between 1.3 and 2.0 mm to bombard a surface made of metal, concrete and asphalt concrete at high speed (65 - 110 m/s).

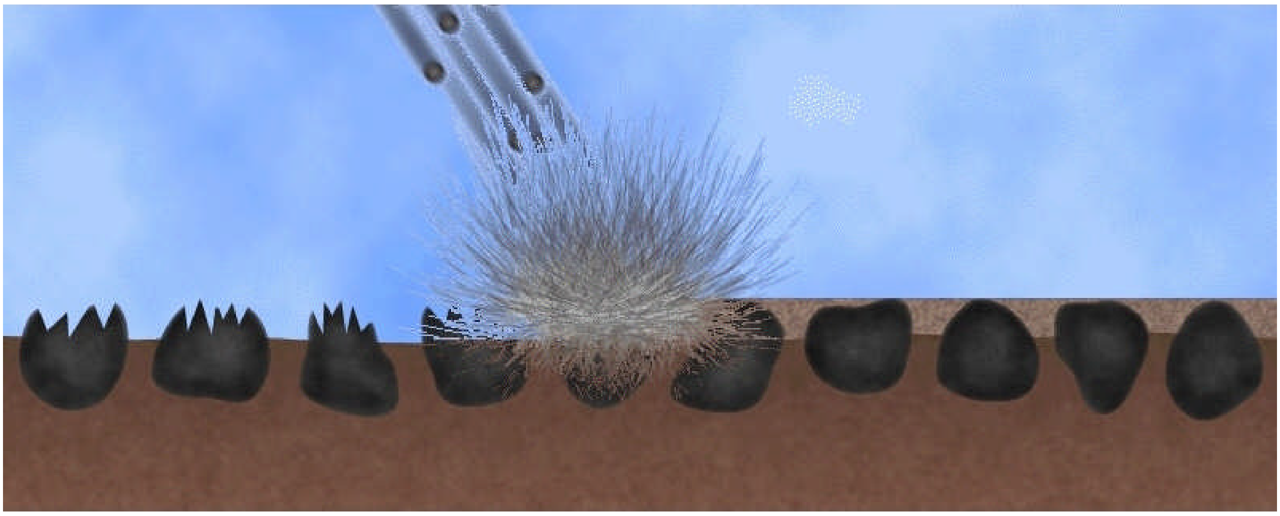

Figure 6. Detail of improvement in micro- and macro-texture by means of blasting.

When blasting is applied to asphalt concrete, the impact of the microspheres removes the soft parts of the surfaces, releasing the non-binding material and dirt and improving the macrotexture. As well as being cleaned, the aggregate is left micro-rough because of the hammering action of the microspheres. This is the only technique that acts on the macro- and micro-texture at the same time, leaving the surface clean and grease-free.

The microspheres are retrieved by means of a bouncing and sucking process that takes them along with the waste to a retrieval chamber. The spheres are separated using a magnetic drum. The waste that is sucked off is stored in a deposit in the rear unit of the lorry, which should be emptied when the work is finished. The separation process takes place at the blasting head at the front of the vehicle. This head allows to blast a width of 1.14 m and it may be freely placed at any part of the width of the lane. It is necessary to go over the surface three times to cover the total width of a lane. First of all the two edges are done and then the intermediate area. The work is done at a speed of between 1.5 and 2 km/h. With these speeds, it is possible to cover 14,000 $m^2$ per 8-hour working day.

The vehicle allows to include a Griptester at the back to measure the skid resistance coefficient that is obtained after finishing the work. With this data, it is possible to alter the blasting strength in order to obtain the values that are sought.

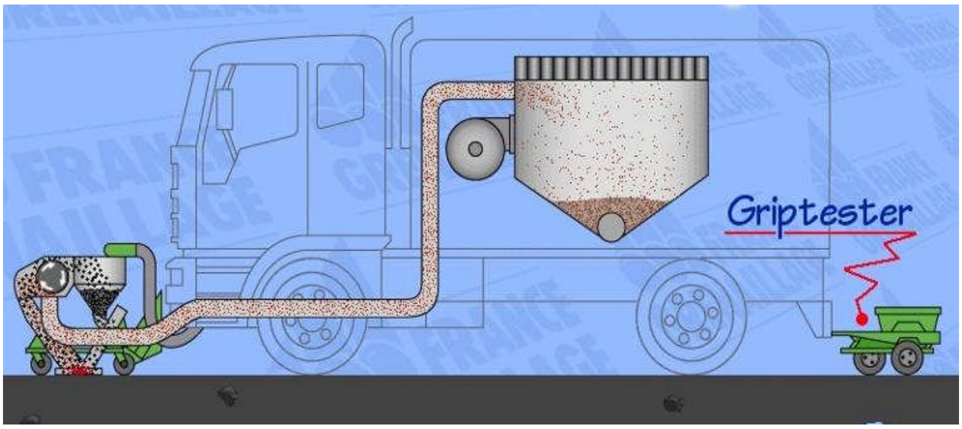


Figure 7. Diagram of the blasting vehicle.

The blasting test was performed by the company “Rever Conceitos”, which also uses this technology to remove road markings, rubber from airport runways and in other applications.

As regards the visual result achieved, we should highlight that the treatment is not aggressive and it does not appear to affect the durability of the surface course at all as the thickness that is affected is practically negligible.

The following photograph shows the appearance of the surface after blasting has been carried out.

Figure 8. Detail of improvement in micro- and macro-texture after blasting.

Measurements were made using the following equipment on the section being tested, comparing the values obtained on the same pavement before and after performing the treatment:

- SCRIM : 51% improvement in SFC (from 46 to 70)
- Griptester at 1 kmph : 54% improvement in GripNumber (from 62 to 96)
- TRL Pendulum: 30% improvement in SRV (from 33 to 43)

On the basis of the results obtained, it may be observed that an improvement of between 30% and 50% on the initial value is obtained and that the SFC values attained are similar to the initial values of this D12 mix in the year 1997. The values obtained with the Griptester are reflected in the following graph:

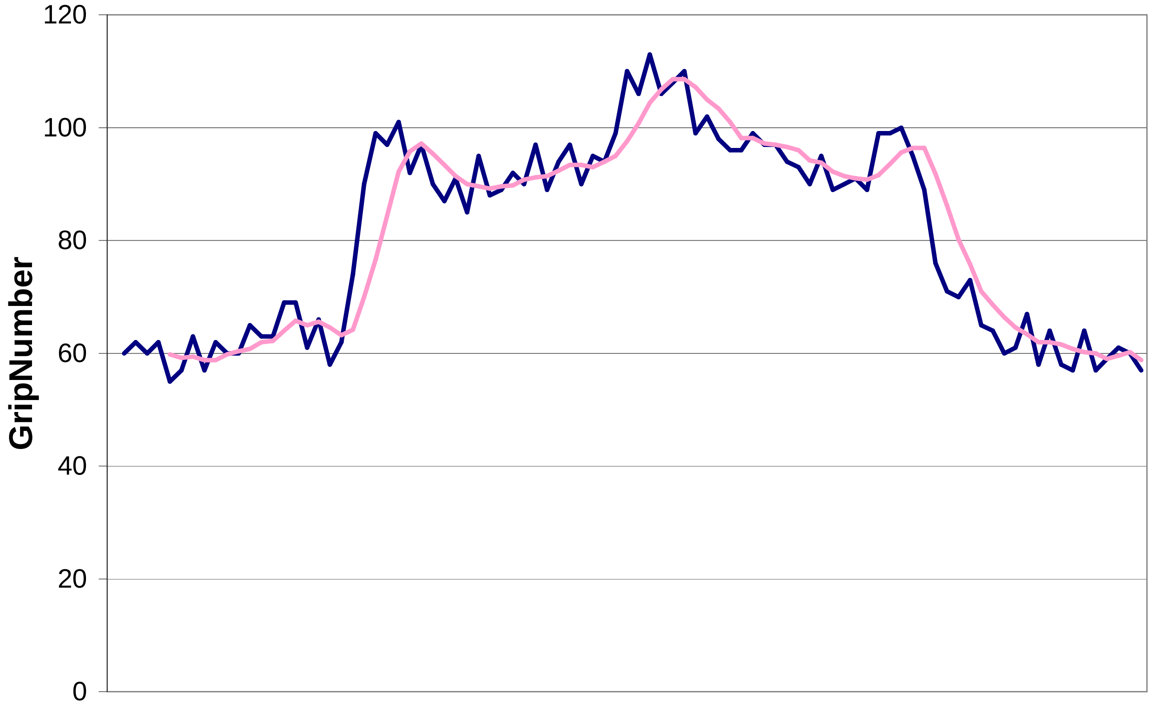


Figure 9. Difference between the section to which blasting was applied and adjacent sections.

In order to carry out a comprehensive analysis of the effectiveness of the treatment, two further details are required. The first is the cost, which varies depending on the surface to be treated, with discounts that increase according to the surface that is treated. The price varies between 2.20 €/m$^2$ for small jobs to 1.60 for work covering more than 300,000 m$^2$ (approx. 85 km of lanes). This work is offered with a two-year guarantee that covers all of the blasting operations that are necessary in order to maintain a particular GripNumber value that is specifically established for each contract depending on the type of pavement that is treated (type of mix, properties of the aggregate, historical values of SFC,..). In this regard, this type of guarantee is new because it allows an administration or concessionaire to transfer certain risks to another company.  In the end, the contract is according to the indicator and not according to the operation.

The second detail that is necessary in order to complete the study on the life cycle cost of the treatment is its durability, which depends on the treatment, the traffic that exists and the aggregate that is used in the asphalt concrete. In this regard, it will be necessary to take new measurements in the future in order to verify this aspect. This will allow to complete the full performance curve.

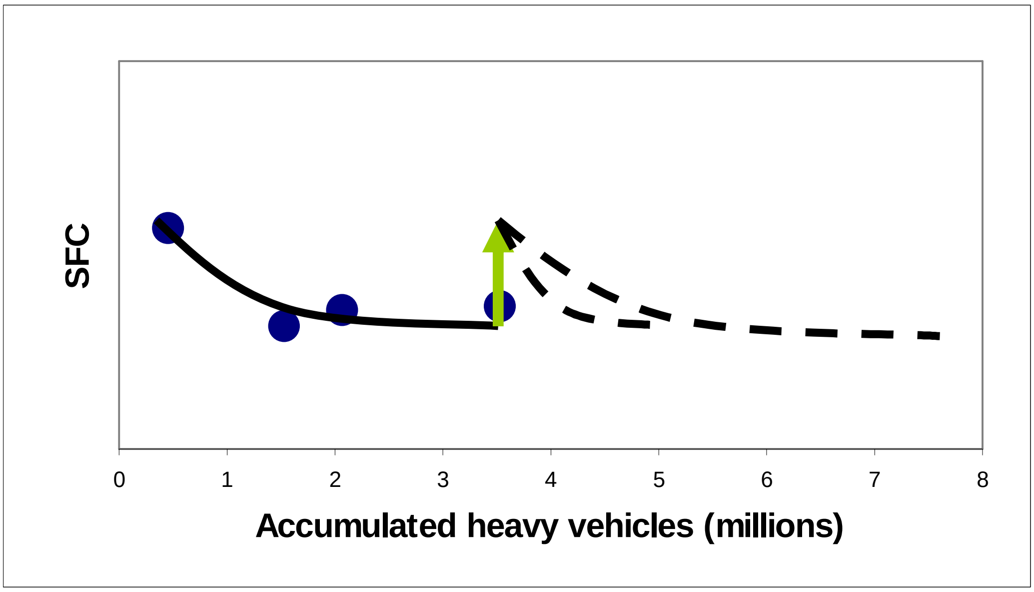


Figure 10. Performance curve for the blasting technique.

**4.2. MICROGRINDING**

There were problems of accidents involving vehicles coming off the road on a downward right-turning bend on an Itinere motorway. Although it had been verified that the drivers had been travelling too fast and that the SFC values were not excessively low, the decision was made to take action on the pavement in order to reduce the accidents insofar as possible.

To do so, a microgrinding operation was performed using the Wirtgen 2000 system. This system is identical to the one that is used for correcting IRI, but in this case a special drum with a certain number of picks is used in order to achieve the desired macrotexture. This system also incorporates the multiplex level control system.

As regards the visual appearance obtained, the final appearance is very rough due to the crests formed by the impact of the picks. It was considered to be necessary to follow up on the evolution in order to monitor the possibility of durability problems.

The following photographs depict the final appearance of the texture of the surface course after the microgrinding operation.

Figure 11. Final appearance after microgrinding

When the work had been done, SFC and SRV (skid resistance value, pendulum tester) measurements were taken in order to monitor how they varied from the previous values. In the case of SFC, there was a 29% increase. The following graph includes the SFC values after the operation and the increase is clearly visible compared to the adjacent sections.

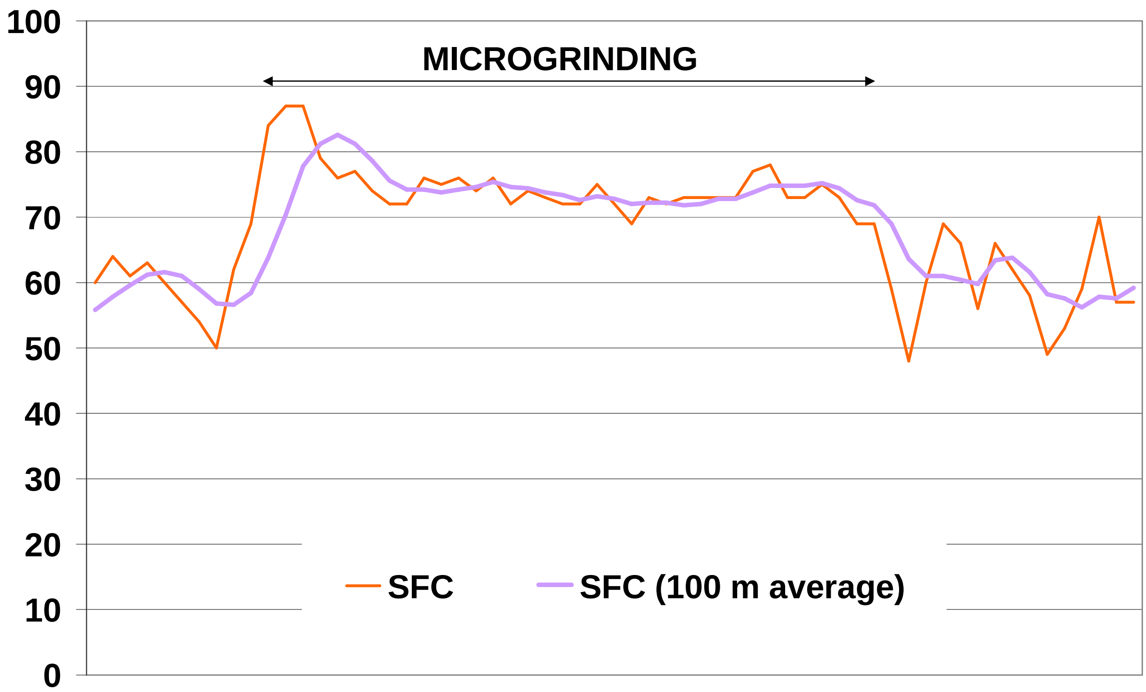


Figure 12. Effect of microgrinding on SFC

In the case of the measurements taken with the TFL pendulum, the increase was not the same for the right edge and the centre of the lane. In the case of the right edge, the increase was just 8%, while it was 22% in the centre of the lane, closer to the increase recorded in the SFC. The explanation for this important difference in values is that the curve has a slight rut and because the microgrinding is performed at a set depth along the width of the lane, it hardly acts on the depth of the edge that is left almost as it was at the start. The data for the right edge and the centre of the lane may be seen in the following graph:

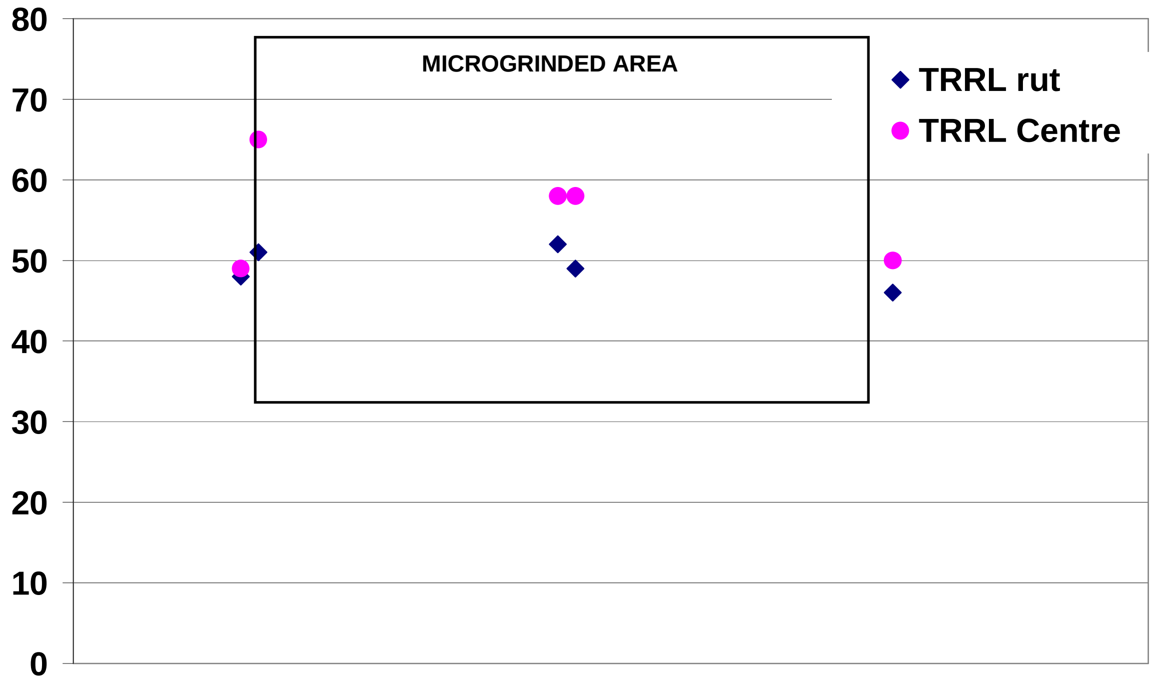


Figure 13. Comparison of the effect of microgrinding transversally

The following photograph depicts the rut on which microgrinding was not applied:

Figure 14. Right-hand rut to which microgrinding was not applied.

The cost of this application to a small surface area is 1.80 €/m$^2$. No type of guarantee on maintaining a particular macro- or micro-texture value is offered.

Just as in the case of the blasting, the section will be monitored by taking measurements to verify the durability of the treatment in terms of the traffic circulating on the surface. The following graph includes the shape of the performance curves until the treatment is made and the effect of the latter. The performance curve for the actual treatment would be required in order to have a complete model for the pavement management system.

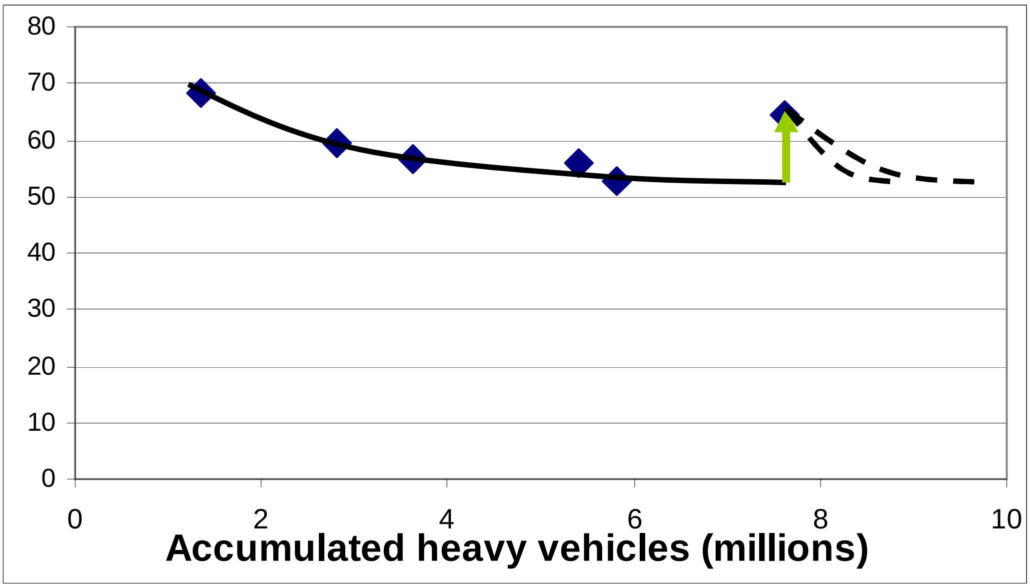


Figure 15. Performance curve of the microgrinding measure.

The accident rate following this operation is also being monitored. So far, since it was opened to traffic in February, the number of accident has decreased drastically, which may be considered to be a success.

## 5 CONCLUSIONS

Nowadays, the specifications for motorway concession tenders require that high levels of service be maintained. SFC and IRI are two of the values that have a direct influence on user comfort, safety and costs. In order to maintain adequate levels for these parameters during operation, as well as employing good construction practices and complying with the values stated in the specifications, Itinere has been studying the application of various corrective treatments (microgrinding and blasting) when necessary. Moreover, these treatments have been monitored to verify their functioning and to obtain models for the “effect” and performance that may be included in the pavement management system.

Where roughness needs to be corrected, the only technique currently in existence has been tested, i.e. microgrinding, which has in some cases reduced the available IRI value by more than 50%. One advantage of this technique is that it may be modelled in advance in order to study the values that may be reached.

In the case of skid resistance, the company has resorted to using two techniques, each of which has advantages and drawbacks. These are two options that exist in the market and which are valid for certain applications, if their durability is informed. Microgrinding with a special drum has increased friction coefficient value by up to 30% and drastically reduced accident rates in the areas where this technique has been applied. Although it is true that it is a technique with major advantages, the drawback is that it is not recommended on pavements with transverse deformation as it does not achieve sufficient effects on the ruts. As regards blasting, it leads to a higher increase in the friction coefficient (up to 50%), it does not generate dust and may be applied on rough surfaces with rutting. The major drawback to blasting is the lack of experience in our country in verifying the duration of its effects. The cost is lower than that of microgrinding.

## 6 ACKNOWLEDGEMENTS

This work was possible thanks to the collaboration of Raúl Martínez (EUROPISTAS) and the maintenance and road serviceability personnel at AUCALSA and EUROPISTAS. Technical personnel from AUDENASA also collaborated in taking data with the TRL pendulum.