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# FLOOR RESTRUCTURING PROJECT FOR FEASIBILITY OF WEIGHING IN MOTION SYSTEMS – WIM

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**Abstract:** Given the economic expansion in Brazil, there was an increase in the volume of cargo vehicle traffic on the highways, which may be associated with the early wear and tear of pavements. Aiming at monitoring, studies are being studied for the implementation of direct and automatic inspection through high-speed weighing-in-motion (WIM) systems, considering the guideline speed of the lane. WIM systems rely on sensor technology, cameras, scanners, among others, responsible for identifying vehicle loads and their distribution by axle during displacement, in addition to monitoring damage caused to the pavement. So that this automation did not depend on the construction of new highways, the objective was to implement the system on existing highways and verify its functionality, a decision taken mainly because of the cost of a paving work. The project for the installation of WIM sensors, a cooperation between the National Department of Transport Infrastructure and the Transport and Logistics Laboratory of the ''Universidade Federal de Santa Catarina", took place on a stretch of BR-101 South. Monitoring of the test lane was maintained for approximately 5 years, however, the highway presented premature defects and required constant restoration, which made it difficult to acquire data from the WIM system. Thus, the need for restructuring the track for accuracy in data acquisition was designed considering two constructive options. An alternative in continuously reinforced concrete and another in thick asphalt pavement with a 30/45 binder that were implemented in the WIM test area, keeping the rest of the road free of interventions. This way, existing highways can be optimized in certain areas to compose these systems and, with that, perform the function of supercharge inspection. The test track features two restructuring projects, one on a continuously reinforced concrete pavement and the other on an asphalt pavement using a conventional 30/45 binder.

**Keywords:** Asphaltic pavement. WIM. Project. Restructuring.

## INTRODUCTION

Cargo transport in Brazil is significantly represented by road transport, although rail and water transport have also received heavy investments over the years. The decision to invest extensively in the development of the road network took place in Brazil in the 1950s with the arrival of the automobile industry in Brazil and the decision to build the new capital in the interior of the country. From then on, the extensive national road network began to require effective maintenance and control of the infrastructure to provide conditions for trafficability, production logistics and cargo flow. In the early 1970s, given the economic growth registered in Brazil, there was a strong increase in the traffic of cargo vehicles on the country's highways, leading the institutions responsible for supervising overweight on the highways to implement the Weigh-in-Motion System in Low Speed (Low Speed Weigh in Motion - LS-WIM), becoming the first country to implement this system for direct inspection of weight in commercial vehicles.

This rapid growth in the fleet was associated with the early wear and tear of the pavements, making it necessary to monitor it in order to preserve public property and user safety. Thus, in 1975, the Master Plan for Weighing was launched, providing for the implementation of cargo monitoring technologies in the country. Over the years, the construction of fixed weighing stations composed of two fronts, (i) infraction pre-selection stage, with a scale for speeds of up to 60 km/h and (ii) inspection system, speed of up to 10 km/h.

Heavy vehicle traffic, in addition to inducing excessive loads on the pavement, is also responsible for a large number of accidents. According to the National Confederation of Industry, in 2019, 16,802 accidents with cargo vehicles were recorded on federal highways, representing 25% of the total for the year, and of these almost 50% involved overturning (CNI, 2022). This type of accident is due to several variables, however the excess load and its distribution in the vehicle are considered as aggravating factors.

This way, the need to implement effective monitoring systems with regard to cargo transport associated with the safety of operations and users has become imminent. In order to minimize the number of accidents, several strategies can be adopted, in addition to awareness and education in traffic, such as inspection of loads on the highways. Inspection then becomes an ally in terms of safety and maintenance of the pavement's useful life, and must occur optimally, whenever possible, so that it does not cause impacts on the user. As improvements to the weighing system, in Brazil, studies are underway for the implementation of direct and automatic inspection through High Speed Weigh in Motion - HS-WIM, considering the speed runway guideline. The HS-WIM weighing-in-motion systems rely on sensor technology, cameras, scanners, among others, and are responsible for identifying vehicle loads and their distribution by axle during displacement, in addition to monitoring damage caused to the pavement.

Monitoring is essential as heavy vehicles have evolved in terms of configuration and load capacity, while the road infrastructure has been scaled for loads that today can be considered obsolete. The design technique of the Flexible Pavement Dimensioning Method by the Instituto de Pesquisas Rodoviárias aims to calculate the thicknesses and make the materials compatible so that the useful life of the pavement corresponds to a certain number of repetitions of a standard load per axle. For the validation of this method, it is necessary to control the vehicle axle weight limit.

The automation process from LS-WIM weighing systems (inside the weighing stations) to HS-WIM (on the track) is dependent on several factors, in addition to investments in technologies. The initial impact of this alteration is perceived by the pavement, which must present characteristics specific mechanical structure to make possible the implementation of HS-WIM systems. For the implementation of these systems, a survey is carried out of the mechanical and structural conditions of the highway, associated with incident traffic and other classification factors.

So that this automation would not depend on the construction of new highways, the initial objective of the research was to implement the system on existing highways and verify its functionality. This decision was made mainly based on the cost of the work itself, which has an average of 1 million reais per built kilometer. Thus, the initial idea was to instrument existing and suitable highways in terms of geometry and the average daily volume of vehicles to develop and improve WIM systems. Another factor considered was the volume of cargo vehicles traveling on these highways, since the monitoring of excess cargo was and analyzed simultaneously, in order to control legal infractions.

Thus, the WIM sensor installation project was developed through a cooperation agreement between the National Department of Transport Infrastructure (DNIT) and the Transport and Logistics Laboratory (LabTrans) of the ''Universidade Federal de Santa Catarina" (UFSC), in a section of

BR-101 south, close to the weigh station at km 418. The definition of this test track also considered that a large part of the high-volume highways in the country were designed using the Flexible Pavement Design Method (DNIT, 2006) and thus present similarity in the composition and materials of the layers.

The monitoring of the test track was planned to be completed together with the end of the useful life of the sensors, which on average is 5 years. However, the highway presented premature defects and required constant restoration, which made it difficult to acquire data from the HS-WIM system, since the sensors underwent several interventions. Thus, it became evident the need to restructure the track so that there was both accuracy in data acquisition and advancement in research, in view of the search for new materials and construction processes aiming at direct inspection.

Finally, since the installation of HS-WIM sensors on existing roads was not satisfactory, from the point of view of data acquisition and mechanical resistance, this article presents two pavement restructuring projects to adapt them to receive HS-WIM systems. WIM. The restructuring alternative does not target the pavement in its entirety, but the area where the weighing sensors are installed. This way, the existing highways can be optimized in certain areas for the use of these systems and with that, perform the function of monitoring excess loads. The test track features two restructuring projects, one on a continuously reinforced concrete pavement and the other on an asphalt pavement using a conventional 30/45 binder.

## TEST TRACK USING THE EXISTING PAVEMENT

To monitor the behavior of the HS-WIM sensors when implemented on a highway with conventional characteristics, a test track was installed on the BR-101 south highway, km 418, in the municipality of Araranguá/SC (Figure 1). The existing pavement has a configuration similar to that of several Brazilian highways and according to the Flexible Pavement Sizing Method, consisting of (i) coating layer in asphalt mixture using a 50/70 binder, (ii) base layer in graded gravel, (iii ) sub-base layer in dry macadam and (iv) subgrade layer partially reconstituted with sand. The sizing project is not presented, given the focus on installing the sensors in the coating.

In order not to affect traffic on the BR-101, the test track and the HS-WIM sensors were installed in the third lane, separated from the main lanes of the highway by means of new jersey type barriers. During the operation of the HS-WIM systems, heavy vehicles and buses were diverted to travel on this lane at the maximum speed allowed on the road, in this case 80 km/h.

The evaluation took place after the installation of four groups of 16 sensors (quartz, ceramic, polymer and optical), totaling 64 sensors, including information transmission systems. One of the main aspects of the experiment on the test track, with multiple WIM sensors using four technologies, is the evaluation of the ability of such systems to provide consistent information about the loading caused by traffic and the degradation of the pavement according to the technology used, in addition to using the data in strategic planning and legal oversight.

The runway was kept in operation and over the five years of monitoring, several fissures, cracks and other defects were observed, as shown in Figure 1b. Considering that the performance of HS-WIM systems is dependent on the behavior of the structures in which they are integrated, it was verified that this type of pavement is capable of supporting these systems.

a) After installing the sensors: HS-WIM.

b) Track after sensors end of life.

Figure 1. test track.

During the monitoring, the appearance of new defects occurred simultaneously with the restoration of the old ones, which made the maintenance of the HS-WIM system highly expensive and unfeasible. This way, it is concluded that conventional highways do not perform well when targeted for the installation of weighing systems, making the restructuring of the pavement inevitable, or even a new construction being considered.

Thus, two runway restructuring projects were designed in order to provide for the construction of a road capable of withstanding the effects of traffic requests and the installation of HS-WIM sensors, maintaining the durability characteristics and performance of the instrumentation.

## TEST TRACK RESTRUCTURING PROJECTS

Since the existing test track did not perform as expected, two options for restructuring projects were designed. Both considering the type of technology adopted, the configuration of sensors and the type of pavement, as required by the installation of HS-WIM systems. The site must follow performance criteria regarding the geometry of the segment, the radius of curvature, the longitudinal/transverse slopes, the type of structure, the surface of the pavement, the deflection and the irregularity.

Based on this information, the test track restructuring project was prepared. This project will also allow for the installation and analysis of new technologies for measuring and identifying vehicles, such as detecting the magnetic signature of vehicles, size and length of vehicles, inspection of the brake system and wheels on vehicle axles.

Considering the restructuring of the test track, as a way to monitor the performance of the sensors along the traffic requests and load application, two projects are presented. In addition, the objective is to evaluate the behavior of the materials and the appearance of defects over the projected useful life. Alternative A deals with a continuously reinforced rigid concrete pavement, which followed the guidelines of the Rigid Pavements Manual – IPR 714 (DNIT, 2005) and of *Federal Highway Administration* (FHWA, 2009). Alternative B deals with a flexible pavement using a conventional binder of the 30/45 type, using the dimensioning guidelines of:*Catalogue des Structures Types de Chaussées Neuves* (SETRA, 1998).

## ALTERNATIVE A – CONTINUOUSLY REINFORCED CONCRETE FLOOR

For the execution of alternative A, 70 cm of the existing floor underwent adaptations.

As removal area, 55 cm of the pavement were considered, being 17 cm of coating in asphaltic concrete, 18 cm of base in granular material, 20 cm of sub-base, in addition, 15 cm of subgrade were recomposed with the material itself, homogenized and 5% hydrated lime added. The continuously reinforced concrete pavement, dimensioned for this application, does not have a transversal construction joint, relying only on continuous longitudinal reinforcement.

Considering the FHWA standard (2009), a minimum amount of 0.6% of the cross-sectional area of the concrete slab and a minimum transverse reinforcement of 0.085% of the longitudinal sectional area of the concrete slab were stipulated. Thus, the projected test track has a thickness of 25 cm, a length of 135 m and a transition slab of 1.2 m. The calculation procedures for obtaining the longitudinal and transverse reinforcement were carried out according to the manual: *Continuously Reinforced Concrete Pavement Design & Construction Guidelines* (FHWA, 2009).

The structure of the restructuring pavement A is composed of a coating of 25 cm of continuously reinforced concrete, 15 cm of rolled concrete base, 15 cm of graded gravel sub-base and 15 cm of lime-treated sub-base, as shown in Figure 2. the base layer of rolled concrete and the continuously reinforced concrete was painted with a bonding paint of the RR-2C type.

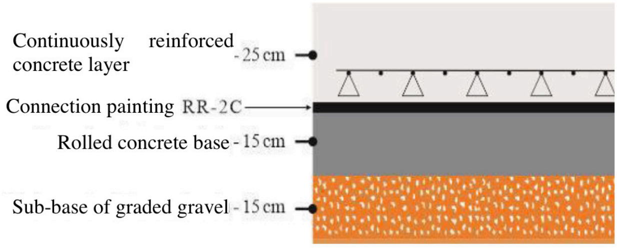


Figure 2. Floor sizing Alternative A.

To determine the amount of longitudinal reinforcement, (i) cross section of the plate measuring 5 m by 0.25 m, resulting in an area of 1.25 m², (ii) reinforcement area corresponding to 0.7% of 18 cm²/m, (iii) 25 mm steel gauge with an area of 4.9 cm² spaced at 23 cm, resulting in the use of 25 CA-50 steel bars. Figure 3 shows the cross section of the dimensioned plate.

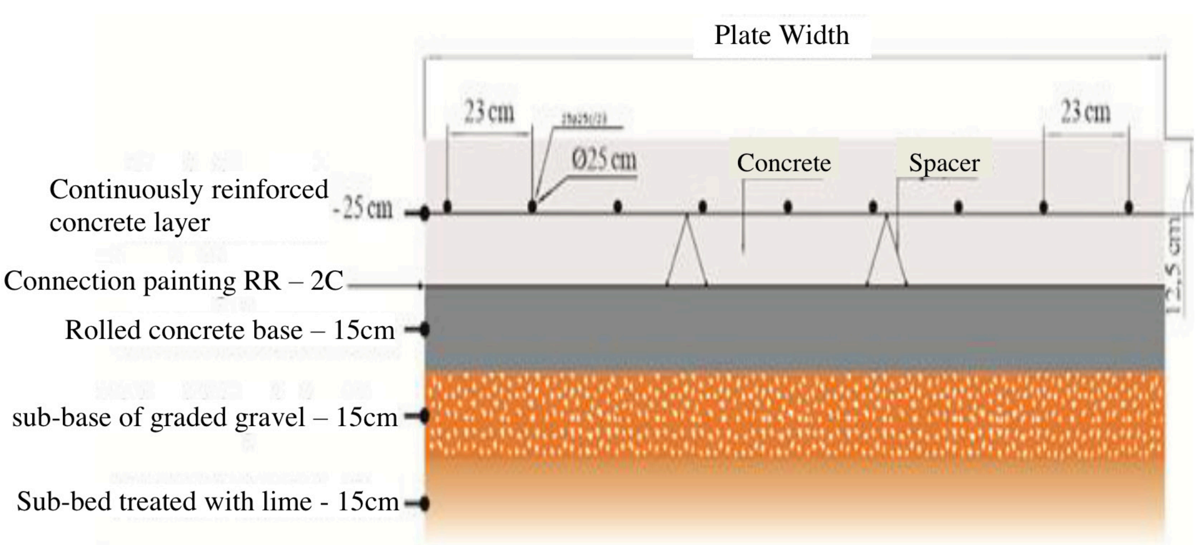


Figure 3. Cross section of the board used in the pavement of alternative A.


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## ALTERNATIVE B - ASPHALT PAVEMENT WITH CAP 30/45

A thick asphalt pavement is presented as alternative B, where the removal of 47 cm of the existing pavement is considered, being 17 cm of asphalt concrete, 18 cm of granular base and 12 cm of sub-base. As for the subgrade, there was a change in 100 cm, and in 92 cm there was the recomposition with the material itself homogenized with 5% hydrated lime, and in 8 cm the recomposition with commercial sand, in addition to the treatment with lime.

Sizing was performed using: *Catalogue des Structures Types de Chaussées Neuves* (SETRA, 1998). The section was composed of 6 cm of flexible concrete, 10 cm of bonding layer, 31 cm of binder-treated base, blocking layer and 100 cm of lime-treated subgrade. Figure 4 shows the pavement layers and their thicknesses.

## FINAL CONSIDERATIONS

This article presents the elaboration of projects of two types of pavements with appropriate behaviors for the installation of HS-WIM systems, since it allows the inspection of overload. This project was approached since the installation of the HS-WIM system on conventional pavements of Brazilian highways did not present satisfactory results on the test track. The design concepts followed the Rigid Pavements Manual - IPR 714 (DNIT, 2005) from: *Federal Highway Administration* (FHWA, 2009), and of *Catalogue des Structures Types de Chaussées Neuves* (SETRA, 1998).

The two types of dimensioned pavement structures were continuously reinforced concrete and thick asphalt concrete with conventional CAP 30/45. Both test tracks performed were dimensioned to achieve the best mechanical characteristics for the HS-WIM systems.

In order to satisfy the implementation area of HS-WIM systems, the restructuring projects were implemented since the highway undergoes interventions only in the weighing area. This way, there is an economic bias from the point of view in which several existing Brazilian highways can be adapted for the use of these systems. Thus, the construction project considers the two alternatives, maintenance of the conventional construction in traffic areas and reinforced structure only for the weighing areas.

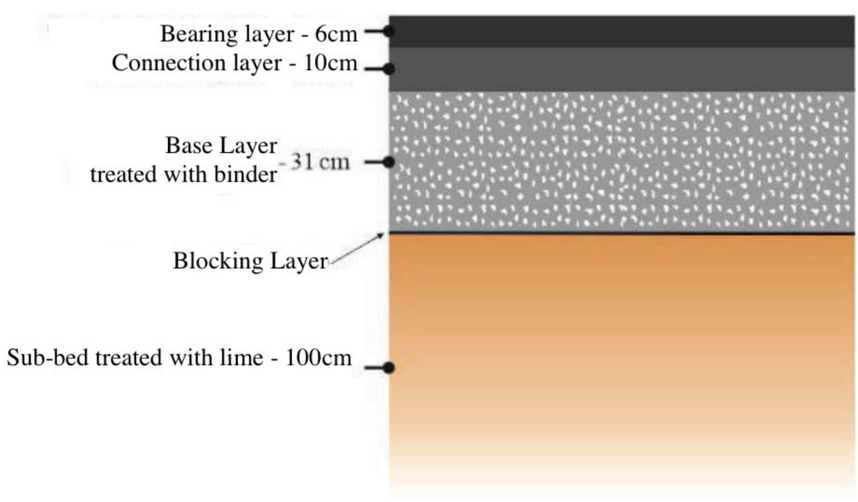


Figure 4. Floor sizing Alternative B.


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The surveillance system for overloading vehicles at high speed optimizes the management and planning process in the transport sector, and can be responsible for ensuring effective performance of the highway over the estimated useful life of the project. On the restructured and presented test tracks, LabTrans continues its monitoring and is also developing a catalog of solutions for pavements that aim to install HS-WIM systems. At the end of both surveys, the catalog aims at the solution both in terms of pavement dimensioning and in relation to the need for restructuring so that the pavement follows the full desirable mechanical performance.

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