8th SIIV ARENA

Proceeding of Long Abstracts

8 SEPTEMBER .23

Università degli Studi di Perugia

Department of Civil and Environmental Engineering
Main Hall

The 8th SIIV Arena

SIIV (Società Italiana Infrastrutture Viarie) and the Department of Civil and Environmental Engineering of University of Perugia organize the 8th edition of the SIIV ARENA.

The SIIV ARENA is an occasion for idea sharing and comparison, in which PhD candidates and young researchers present specific and interesting topics in the fields "Roads, Railways and Airports" (SSD ICAR/04). Therefore, the proposed presentations are not limited to the topics discussed in the XIX International SIIV Summer School.

The Scientific Committee of the 8th SIIV ARENA will award three prizes based on the following criteria:

- best technological impact;
- best innovative idea;
- best experimental activity.

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Contacts

siivsummerschool2023@gmail.com

Prof. Gianluca Cerni +39 3397144674
Dr. Alessandro Corradini +39 3491412122

Event Contents

It is possible to find the details of the contents of the event on the SIIV institutional website at the following link: https://www.siiv.net/new/6786-2/

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Laboratory assessment of microsurfacing bonding: Characterization of the application surface and Leutner Shear Testing

Filippo Balzano[1], Piergiorgio Tataranni[2], David Woodward[3] and Cesare Sangiorgi[4]

[1]*University of Bologna, Bologna, Italy, filippo.balzano2@unibo.it*
[2]*University of Bologna, Bologna, Italy, piergiorg.tataranni2@unibo.it*
[3]*Ulster University, Belfast, United Kingdom, wdh.woodward@ulster.ac.uk*
[4]*University of Bologna, Bologna, Italy, cesare.sangiorgi4@unibo.it*

ABSTRACT: The main aim of this research is to propose a simple methodology for the laboratory evaluation of the interlayer bonding strength for microsurfacing mixtures. The phenomenon will be investigated focusing on the relationship occurring with the surface texture variability, involving a basic and an advanced approach based on the close-range photogrammetry for the support surface description. An adapted direct shear test will be also proposed, along with a complete procedure for the laboratory application of the microsurfacing layer. All the main results and correlations will be in-depth discussed, aiming to provide significative opportunities for future researches.

KEYWORDS: Microsurfacings, interlayer bonding, surface texture

INTRODUCTION

Road pavements construction and maintenance are energy-consuming and gas-emitting activities that have an incontrovertible impact on climate change [1]. In light of this, preventive and low-impact maintenance techniques have been developed through the recent years to reduce the need of deep interventions in favour of targeted solutions aiming to extend the service life and restore the functional performance of pavements. Microsurfacings are widely recognized as a valid solution [2] that involves a smaller amount of production energy and emissions, as well as less material than conventional Hot Mix Asphalts, while providing the intrinsic properties of skid resistance, road noise reduction, surface drainage and impermeability of the pavement in a cold applied material. A high performance microsurfacing requires a well formulated mixture, which needs to be designed to override the variability of the existing pavement surface texture aiming to a long-lasting bond at the interface of the newly applied layer [3]. There is a lack of unified standard methods for the assessment of thin layer bonding. This can lead to poorly bonded microsurfacings that can jeopardize the overall quality of the intervention. The aim of this paper is to propose a simple methodology to characterize the existing pavement surface texture prior to testing the interface bonding strength using an adapted common shear testing procedure.

EXPERIMENTAL PROGRAM

This section aims to summarize the methodological approaches followed during this research. The first phase has seen the collection of a large number of specimens, representing real mixture applications on existing road pavements. Following, a laboratory evaluation of their top surface texture has been conducted. For the assessment of macro-texture, an adapted version of the Sand Patch Test is proposed. In order to estimate the micro-texture roughness, a standard British Pendulum Test has been performed. The same surfaces have been then analysed involving a cutting-edge CRP technique. This process comported the collection of a wide database of photos, which were then combined using a software obtaining high-resolution 3D models of the support surfaces. An advanced topographic analysis of the models has been conducted determining a long list of texture descriptors. Each specimen has been then covered with a constant layer of microsurfacing mixture, following any time the same procedures for conditioning, containment, application and curing. The double layered specimens have been tested to direct shear by using the Leutner Apparatus. In the end, the data from the texture analysis have been compared with the Direct Shear Test results, discussing the main correlations and commenting the conclusions.

RESULTS [AND/OR] EXPECTED OUTCOMES

The standard and advanced approaches have been compared, showing a high correlation, as shown in Figure 1 by way of example.

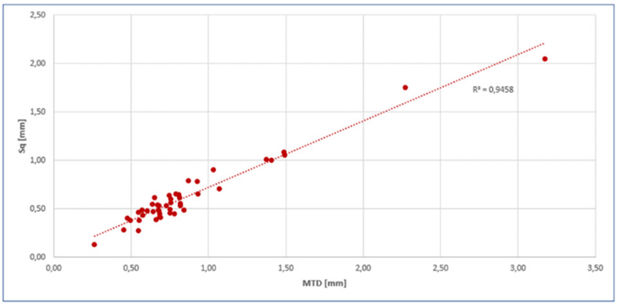


Figure 1. Correlation between the standard and the CRP based texture evaluation approach

The results of the interlayer bonding for the different support surfaces have been studied in terms of texture level, showing interesting behaviour trends and correlations as shown in Figure 2.

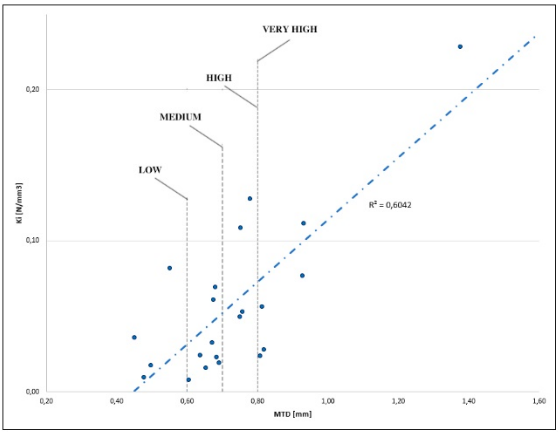


Figure 2. Correlation between the surface texture (MTD) and the resistance modulus of Goodman (Ki)

CONCLUSIONS

- The bonding resistance of microsurfacing mixtures is highly related with the variability of the supporting pavement;
- CRP can lead to advanced results in the surface texture characterization;
- The Leutner Shear Test can be adapted to represent a valid solution in the laboratory assessment of bonding strength for Microsurfacing mixtures.

REFERENCES

[1] C. Queiroz, R. Haas and Y. Cai. "National Economic Development and Prosperity Related to Paved Road Infrastructure". Transp Res Rec, vol. 1455, pp. 147-152, 1994.

[2] P. Lok and K. Takamura. “Microsurfacing for preventive maintenance: eco-efficient strategy”. Proceeding of the International Slurry Seal Association Annual Meeting, Maui, Hawaii, USA, 2001.
[3] A. Al-Hosainat, M.D. Nazzal and S.A. Talha. “A comprehensive laboratory evaluation of the factors affecting the Micro-surfacing interlayer bond strength”. Constr Build Mater, vol. 323, 2022

Pavement Management System for small road Administrations: procedures for monitoring, planning and design

Alex Balzi[1]

[1]*University of the Republic of San Marino, San Marino, alex.balzi@unirsm.sm*

ABSTRACT: In the last decades, Public Authorities are facing to a growing demand of more environmental sustainability transportation framework and infrastructures. Especially for small road Administrations (SRA), the Green Transition is a tough challenge because frequently they have very limited economical, technical and specialised human resources. In this regard, great benefits can be reached proposing an improvement of road pavement maintenance process using standardise procedures and eco-friendly techniques instead of conventional repairs and rehabilitations works.
This research aims at providing a tailored Pavement Management System (PMS) to support SRA towards a more sustainable and effective road pavement maintenance monitoring, planning and design. For this purpose, Geographic Information System (GIS) represents an accessible and powerful technical resource to implement customised tools for the digitalisation of road inventory information, standardisation of monitoring activities, ranking maintenance priorities and identification of cost-effective maintenance works, considering SRA peculiarity and requirements.

KEYWORDS: Pavement Management System (PMS), Small Road Administrations (SRA), Geographic Information System (GIS)

INTRODUCTION

Road maintenance is one of the essential activities to be performed to ensure adequate levels of rideability and safety performance of road pavements. Small road Administrations (SRA) manage large and fragmented road networks, with constant growing of management issues related to both the progressive wearing of in use pavement and the design and construction of new road routes. Therefore, considering the goal of sustainable development, the adoption of Pavement Management System (PMS) can be a solution to gradually reach a more sustainable and effective road pavement maintenance [1]. However, the implementation of PMS concepts and procedures has to be applied considering SRA real potentials and requirements. In this regard, Geographic Information System (GIS) represents an accessible and flexible technology for spatial analysis and data management [2].
This paper summarises the principles, procedures and customised tools acquired over time from several collaborations with SRA in central Italy on road pavement maintenance monitoring, planning and design topic.

METHODOLOGY

This research was focused on the identification of an effective and customised PMS for a SRA, which manage road network ranging from 200 to 900 km, employing about two technicians every 200 km, and have significant economical constrains and technical limitations. To facing road management issues, the proposed methodology has been articulated into network and project levels, using step-by step phases and activities (Figure 1) [3, 4].

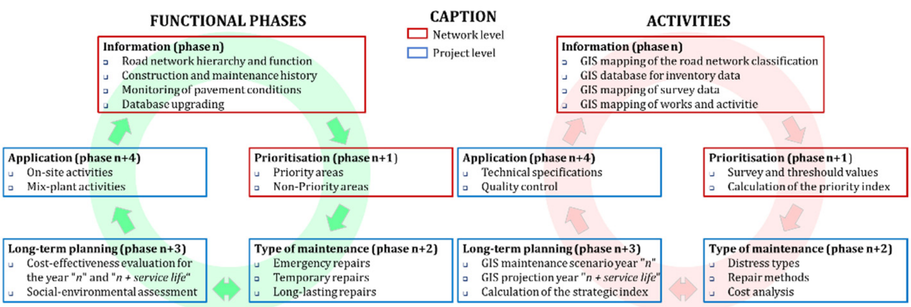


Figure 1. PMS methodology: functional phases and activities [4].

RESULTS

Knowledge gather through, practices, tools and technical manuals were selected and implemented to fit the identification and application of the PMS approach described above. In details:

- Road inventory data (network classification, road type, pavement materials etc.), monitoring data (pavement condition, roughness, traffic volume, accident etc.) were collected and digitalised on a road database using GIS tailored tools. All the recorded data are assigned to the respective homogenous and inspection road segments, obtained from the subdivision of road network;
- Maintenance prioritisation was performed, considering the road information of every inspection unit, using a Priority Index (PI);

- Maintenance repairs and rehabilitation works were standardised into a catalogue and implemented in the GIS database to supporting project evaluations (Figure 2);
- Long-term planning was assessed using specific deterioration models to predict the evolution of pavement conditions over time. Customised routines were implemented on GIS database to determine a Strategic Index (SI), with which compare alternative maintenance scenarios on long-term perspective [5].

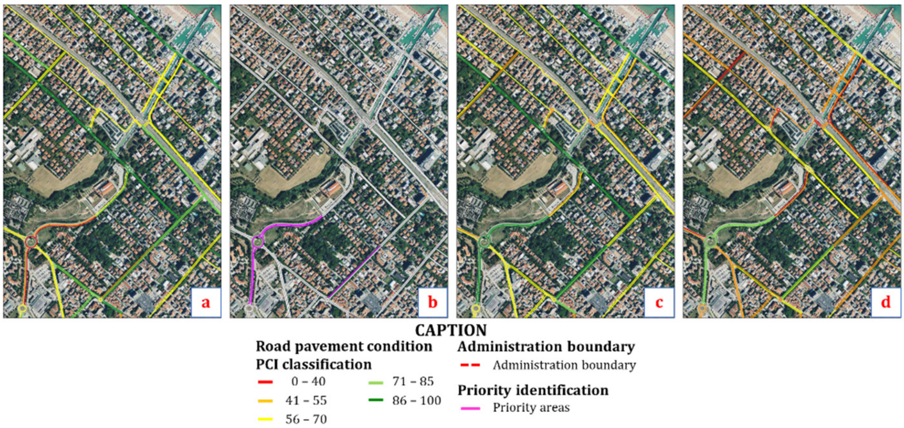


Figure 2. GIS mapping of current pavement conditions (a), priority areas (b) and maintenance scenario with pavement conditions after two years (c) and six years (d) from the maintenance works.

CONCLUSIONS

Starting from the growing requirement of sustainable road infrastructures, this research aims at providing an effective PMS to supporting SRA [4, 5]. The following main outcomes have been collected:

- Standardise technical procedures and activities for road pavement monitoring, planning and design were identified;
- Standardise repairs and rehabilitation works were defined, also considering eco-friendly techniques;
- Digitalised road data repositories were created using GIS capabilities;
- Tailored GIS tools were implemented to support priority ranking, to plan maintenance works on long-term perspective and to compare alternative maintenance strategies.

These findings encourage the use of PMS, meeting the sustainability needs.

ACKNOWLEDGEMENTS: This work was supported by the University of the Republic of San Marino, Research Project UniRSM 2022.

REFERENCES

[1] Hudson W.R., Haas R., Daryl Pedigo R., Pavement management system development, NCHRP Program Report 215, Transportation Research Board, Washington D.C., 1979.

[2] National Cooperative Highway Research Program, Pavement management applications using Geographic Information System, Transportation Research Board, Washington D.C., 2004.

[3] Grilli A., Balzi A., Ciotti A., Tura P., Casali M., "Pavement management system for local governments: case study in the Republic of San Marino", CETRA 7th International Conference on Road and Rail Infrastructure, Pula, Croatia, May 2022.
[4] Grilli A., Balzi A., Methodologic recommendations to implement Pavement Management Systems and Eco-Sustainable solutions for Local Road Administrations. Infrastructures 2023, 8(2), 25.
[5] Balzi A., Grilli A., Pavement management system: implementing project evaluation for local road administrations. TRANSCOM 2023, 15th International Scientific Conference on Sustainable, Modern and Safe Transport, May 2023.

Driver's perception of roadwork signs

Claudia Brasile[1*], Annalisa Zoli[1], Valeria Vignali[1], Claudio Lantieri[1] and Andrea Simone[1]

*[1]Department of Civil, Chemical, Environmental and Material Engineering (DICAM), University of Bologna, Viale Risorgimento 2, Bologna, Italy; *claudia.brasile2@unibo.it*

ABSTRACT: The presence of roadwork sites is the cause of many accidents today and one of the main causes for increasing road accidents is driver's inattention. In fact, the driver's workload changes significantly as the user approaches an obstacle. In this study the kinematic data and visual behaviour of users were recorded on a stretch of a road under the presence of a road construction site. The case study consists in 12 users crossing a road stretch in Faenza, Italy, wearing a Mobile Eye Tracker in a car equipped with a Racelogic Video VBOX device. The objective was to investigate the perception of the users in presence of the roadwork site, and especially in relation of the roadwork signs. The results show that speed limits are mostly unrespected and that users do not act as the signs suggest to do. In terms of road safety, the user's behaviour was detected to not be sufficiently safe for the surrounding road conditions.

KEYWORDS: Roadwork zones, Roadwork signs, Visual behaviour, Speed.

INTRODUCTION

The deterioration of road infrastructure requires frequent maintenance which causes an increase in traffic and of accidents' frequency, and create greater threats to the safety of drivers, passengers, and workers. Two of the main factors contributing to road accidents in a scenario with a roadwork site are speeding and inattention to temporary roadwork signs [1]. Speeding not only increases the risk of accidents involving drivers and workers on roadwork sites, but also creates a damage to the site structure, signs, and infrastructure. Accidents and fatalities can be prevented using appropriate temporary or non-temporary signs [2]. Signs play a fundamental role as they alert road users, of the correct behaviour to adopt to avoid dangerous situations and accidents. Temporary signs are necessary to adequate situational awareness (SA) for the driver and make the right decisions in order not to make any mistake [3].
In the present work, two parameters were placed side by side. The speed of the vehicle and the visual behaviour of the user were recorded and analysed using innovative technologies.

METHODOLOGY

The parameters of the moving vehicle and the visual behaviour of the drivers were recorded for a segment of an urban road in presence of a roadwork (Fig. 1). The segment where is the roadwork analysed is divided into 5 elements named T6 – T10, and each of them is characterized by the presence of temporary signs (Fig. 2).

Element	Signs in presence of roadworks	Signs in normal conditions
T6	Alert beginning of roadworks	
T7	50km/h speed limit sign 30km/h speed limit sign	50km/h speed limit
T8	Lane closure No overtaking	
T9	No overtaking (second sign) Lane closure (second sign) Blu arrows (x4)	
T10	50 km/h speed limit End of roadworks sign	70km/h speed limit

Figure 1-2. Area of the test and position of signs.

Twelve individuals were enlisted and asked to wear a Mobile Eye Tracker and to drive a car equipped with a Racelogic Video VBOX device. The Mobile Eye Tracker (ME) is an instrument designed for continuous monitoring and tracking of the user's sight while moving. The ME XG software records videos that show the eye movement of a driver. The VBOX device is needed to register the information connected to the motion of the vehicle. It is made of a GPS and a high quality multicamera made of two cameras located outside the vehicle.

RESULTS

The merge of the results from the speed analysis with the fixations to roadwork signs of each user has been developed to understand at what point the driver decides to reduce his speed in relation to the site configuration. The ideal speed trend that should be assumed by the user if all imposed speed limits are respected, has been defined and five types of timings in respect to actions were defined: M1 (Initial braking), M2 (Constant speed), M3 (Second braking), M4 (Constant speed), M5 (Start acceleration). Figure 3 shows the ideal speed trend, the speed trend of user 12, the position of each sign and the position of each timing (M1-M5).

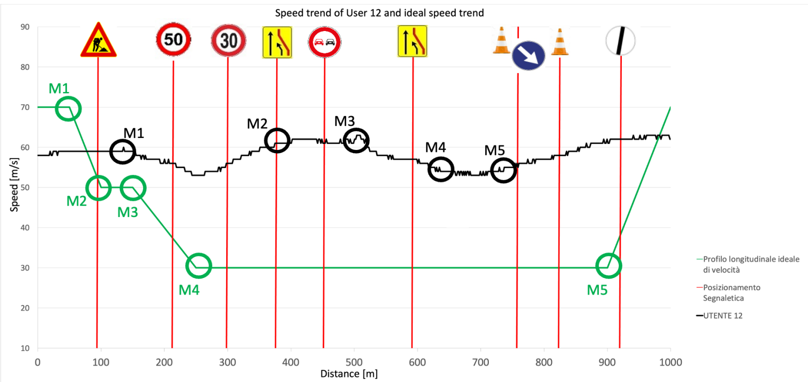


Figure 3. User 12 speed trend and ideal speed trend.

The output from ME have been used to compare the speed trend with the user's sight to understand if the timing of the user (M1-M5) is related to the road sign that the user is looking at, in that same moment (M1-M5). For instance, the 36% of users had its first braking (M1) just before the work in progress sign, and only the 25% was looking at that sign while slowing down. The 73% of total users has the acceleration (M5) in the area delimited by cones, instead of after the end of roadworks. Here, the 63% of users that was accelerating, was looking at the end of roadwork sign.

CONCLUSIONS

The present work aims at studying the driver's perception near a roadwork, especially in relation to the signs, through an analysis of the vehicle kinematic data and driver visual behaviour. Thanks to the collected data from the test, it was possible to observe that the speed trend of the users, in most cases, is different from the ideal one. The reason it could happen is that, although users fix more signs than infrastructure, as the videos of the mobile eye tracker show, they do not adapt their behaviour, and therefore their speed, to what they suggest to do. In conclusion, in terms of road safety, it can be argued that the user's behaviour was detected to not be sufficiently safe for the surrounding situation.

REFERENCES

[1] Ermagun, A., Kelarestaghi, K. B., Finney, M., & Heaslip, K. "Speed Up to Hit the Worker": Impact of hacked road signs on work zone safety. International journal of transportation science and technology, 10(1), 49-59, 2021.

[2] Banerjee, S., Jeihani, M., & Morris, D. Impact of Work Zone Signage on Driver Speeding Behavior: A Driving Simulator Study. Transportation Research Board 98th Annual Meeting, 2019.

[3] Costa, A. T., Figueira, A. C., & Larocca, A. P. C. An eye-tracking study of the effects of dimensions of speed limit traffic signs on a mountain highway on driverś perception. Transportation research part F: traffic psychology and behaviour, 87, 42-53, 2022.

Urban road pavements assessment using low-cost monitoring systems

Salvatore Bruno[1]

[1]Department of Civil, Constructional and Environmental Engineering, Sapienza University of Rome, Via Eudossiana 18, 00184 Rome, Italy

ABSTRACT: The lack of a continuous monitoring system over time and space is among the causes of critical issues in urban road pavement management. Research progress and prospect in road distress detection exploit the latest technology advances and suggest innovative procedures to assess pavement conditions. In this study, monitoring systems based on the integration of low-cost sensors managed by a single-board computer (SBC) are developed. Python scripts have been implemented to collect data and time-synchronized with millisecond resolution. The challenge and special features of the novel systems are cloud-based data backup and remotely managed to avoid safety hazards to workers during field surveys. Data post-processing has been aimed to integrate the comfort perception of road users (frequency-weighted vertical acceleration a_{wz}) with image data and measurements of noise levels. As test-vehicles, a scooter and bike have been instrumented to provide a monitoring system also for those paved surfaces where no automated monitoring systems are available (e.g., paving stones, pedestrian pavements, cycle lanes). Finally, within the H2020 InfraROB project (Grant Agreement n. 955337), an autonomous and remote-controlled robot has been configured for potholes 3D model reconstruction and patching quantity estimation.

KEYWORDS: road surface monitoring and maintenance, urban road networks, low-cost sensors

INTRODUCTION

Maintaining appropriate performance levels for road infrastructure has a direct impact on people's lives by providing mobility and connectivity. A proper monitoring activity is preparatory to postpone the occurrence of degradation phenomena (or at least contain them within acceptable thresholds) in order to satisfy specific functional and structural requirements of the infrastructure. The early detection of road distress enables appropriate maintenance activities to be planned in time. In this regard, the Pavement Management System (PMS) is the systematic process for scheduling road maintenance activities [1]. PMS-scheduled maintenance promotes preventive maintenance to preserve pavement's optimal condition during its service life, saving resources by mainly operating on surface layers. However, reactive maintenance remains widely adopted, addressing emergency

conditions or significant road surface deterioration. To overcome these critical issues, the latest research progress and prospect in road distress detection exploit technology advances (i.e., advanced image acquisition technology, smartphone sensors, data recorded by on-board sensors in modern vehicles, or design and development of custom solutions from scratch based on low-cost sensors).
The design of low-cost monitoring systems to assess urban road pavements is the main objective of this interdisciplinary research project. The challenge and special features are to manage data from various sensors via a single board computer (SBC), and then integrate and analyse the different data on the pavement conditions of urban road networks.

EXPERIMENTAL PROGRAM

The Raspberry Pi® technology has become popular due to its affordability, versatility, and easy-to-operate [2]. The proposed low-cost and easy-to-operate monitoring systems involve the integration (in different configurations) of the following consumer-grade components managed by a Raspberry Pi 4 Model B SBC:

- Camera module;
- 6DOF 3-axis gyroscope and accelerometer module;
- Rotary encoder;
- Magnetic hall effect sensor module;
- Ultrasonic distance sensor module;
- Sound level meter;
- GPS module.

Python® scripts have been designed to acquire data from various sources while ensuring seamless alignment of timestamps, guaranteeing the temporal coherence of the collected information.
The novel systems also involve cloud-based data backup and remote management, to mitigate safety risks to personnel during field surveys.
The assessment of geometric surface unevenness by measuring vibrations enable the identification of certain road distress (e.g., cracks, raveling) only if at a significant severity level. This study aims to overcome the weakness of vibration-based systems. Data post-processing has been then finalized with the main objective of integrating road users' perception of comfort – the frequency-weighted vertical acceleration a_{wz} [3], Equation 1 - with image data and noise level measurements. Data positioning has been achieved too.

$$a_{wz} = \sqrt{\sum_{i=1}^{23} \left(W_{k,i} \cdot a_{z,i}\right)^2} \tag{1}$$

where $W_{k,i}$ is the i-th frequency weighting in one-third octave bands and $a_{z,i}$ is the vertical RMS acceleration for the i-th one-third
octave band. A MATLAB® code has been written to automate the calculation, considering a time analysis equal to 2s.

RESULTS

The novel monitoring systems have been mounted on two-wheeled vehicles (i.e, bike and scooter, Figure 1) and their efficiency has been tested.

Figure 1. Raspberry-based system configurations. (a) bike; (b) scooter.

H2020 InfraROB project

The H2020 InfraROB project focused on the design of a 3D printer able to extrude a bitumen-based mixture for filling in potholes. As a task of this project, ad-hoc configuration of the Raspberry-based system has been mounted on a robot for photogrammetry analysis [4].

CONCLUSIONS

The proposed approach can be considered as a valuable tool for road agencies to assess pavement conditions in urban road networks and implement preventive maintenance strategies within budget constraints.
Moreover, paved surfaces where no automated monitoring system currently exists can be investigated (e.g., pedestrian pavements, cycle lane).

REFERENCES

1. Kenyon, J. Implementation of Pavement Management Systems.; 1987.
2. Ghael, H.D.; Solanki, L.; Sahu, G. A Review Paper on Raspberry Pi and Its Applications. Int. J. Adv. Eng. Manag. IJAEM 2020, 2, 4.
3. ISO2631-1; Mechanical Vibration and Shock—Evaluation of Human Exposure to Whole-Body Vibration—Part 1: General Requirements. ISO: Geneva, Switzerland, 2014.
4. Bruno, S.; Loprencipe, G.; Di Mascio, P.; Cantisani, G.; Fiore, N.; Polidori, C.; D'Andrea, A.; Moretti, L. A Robotized Raspberry-Based System for Pothole 3D Reconstruction and Mapping. Sensors 2023, 23, 5860.

Multiscale characterization of Cold Recycled Asphalt Mixtures for base layers comparing different types of bitumen emulsions

Carlo Carpani[1], Edoardo Bocci[2] and Maurizio Bocci[1]

[1]*Affiliation, Department of Construction, Civil Engineering and Architecture, Università Politecnica delle Marche, 63131 Ancona, Italy , c.carpani@pm.univpm.it (C.C.), m.bocci@univpm.it (M.B.)*

[2]*Faculty of Engineering, Università degli Studi eCampus, 22060 Novedrate, Italy, edoardo.bocci@uniecampus.it*

ABSTRACT: Cold recycling has been gaining more and more importance in recent years due to its numerous environmental advantages over hot recycling techniques. The aim of the research work was to verify whether the use of a polymer-modified bitumen emulsion rather than an unmodified one resulted in a real improvement in the performance of Cold Recycled Asphalt Mixtures (CRAM) such as to justify the higher cost. To do this, the different binders were investigated at the level of residual bitumen, bituminous mastic, and mixture. As a further assessment, the three different types of emulsions were then used in a test field.

KEYWORDS: Cold mixtures, recycling, polymer-modified bitumen emulsions

INTRODUCTION

Nowadays, the production of cold-recycled base layers in Italy is mainly carried out with emulsions modified with SBS polymers, since the better performance at the level of the bituminous binder [1] is thought to also guarantee a better performance at the level of the final mix compared to unmodified binders. However, there are no studies in the literature that have investigated this aspect in detail.
This research aimed at investigating the three different types of bitumen emulsions most commonly used in Italy in the field of cold recycling for base layers, namely SBS-modified bitumen emulsion (P) and latex-modified bitumen emulsion (L), and then comparing them with the unmodified type (R). To do this, the different binders were studied with rheological and mechanical tests at three levels: residual bitumen, bituminous mastic, and mixture.

EXPERIMENTAL PROGRAM

The performance comparison at the level of residual bitumen and bituminous mastic was carried out using the Dynamic Shear Rheometer (DSR) in order to determine:

- linear viscoelastic (LVE) behaviour, investigated by means of strain sweep and frequency sweep tests for the construction of the complex modulus and phase angle master curves;
- resistance to permanent deformations, examined through multiple stress creep and recovery (MSCR) test;
- fatigue behaviour, studied through linear amplitude sweep test (LAS).

The comparison at the mechanical level on the scale of mixtures was carried out in order to determine:

- stiffness and strength, investigated by means of Indirect Tensile Stiffness Modulus (ITSM) test at 20 °C and Indirect Tensile Strength (ITS) at 25 °C after 3, 7, 14, 30, 60, 120, 240 and 360 days of curing;
- complex modulus, determined through uniaxial cyclic compression (UCC) tests on 30-days and 270-days cured specimens at 5, 20, 35 and 50 °C and at frequencies ranging from 0.1 to 20 Hz;
- fatigue resistance, measured on 30-days and 270-days cured specimens by means of Indirect Tensile Fatigue (ITF) test at 20 °C.

In order to verify the results obtained, a trial section with a length of 1150 metres was built. The test section was divided into three different subsections, each of which was made with a different emulsion to realise the cold base layer. During the paving process, part of the material was sampled to produce cylindrical specimens, which were cured for 60 days at 40 °C and tested in terms of stiffness (ITSM), strength (ITS) and fatigue resistance (ITF). In addition, 3 months after paving, the Falling Weight Deflectometer (FWD) was used to evaluate any difference between the subsections.

RESULTS

For reasons of space, only part of the research results will be described in this section. Figures 1 and 2 show the results in terms of master curves, resistance to permanent deformation, and resistance to fatigue at the scale of residual bitumen and bituminous mastic. It is evident that emulsion P provided the best performance at both scales of investigation. The L emulsion, on the other hand, had an intermediate behaviour, but was closer to the R type, denoting that the emulsion modification process leads to differences in performance.

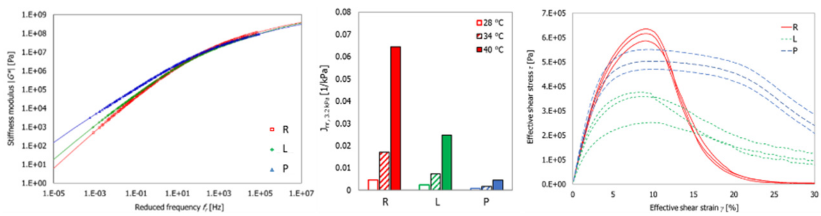


Figure 1. Master curves, MSCR, and LAS results at binder scale

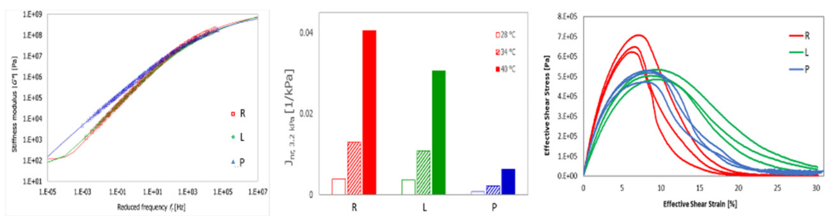


Figure 2. Master curves, MSCR, and LAS results at mastic scale

Figure 3 shows the results at the scale of mixture in terms of master curves and fatigue resistance. As can be seen, there were no substantial differences between the mixtures when varying the type of binder used.

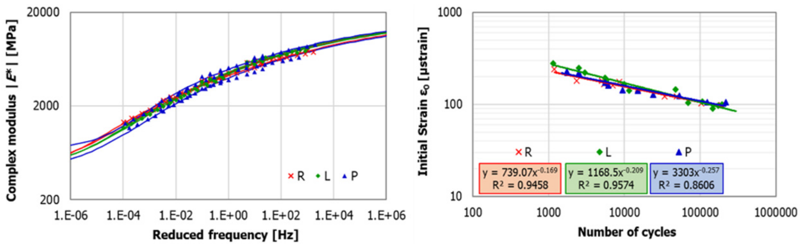


Figure 3. Master curves and fatigue curves comparison at mix scale

These results were then confirmed by FWD test results (Figure 4) carried out three months after the paving (E_1 values). It should also be emphasised that the small differences that can be seen between the different sections depend more on the execution of the test than on the different mechanics.

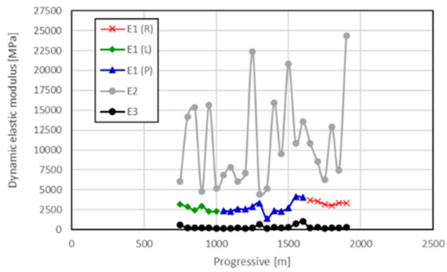


Figure 4. Results of the FWD test after 3 months from paving

CONCLUSIONS

The results of the research showed that, although there are differences between the various bituminous binders when compared at the level of residual bitumen and mastic, these differences are not visible at the level of the mix due to the numerous variables that are involved in defining the properties of cold mixes (the aggregates effective distribution, the actual water and cement contents, and the type and content of bitumen in the RAP used to produce the mix). In addition, the amount of virgin bitumen in the mix (coming from the emulsion), which is 2.4% (4.0% bitumen emulsion), is much lower than the binder content in the hot mix asphalt (4-5%), and therefore the incidence of bitumen emulsion modification is lower.
These results are confirmed by the results of the trial section. However, further investigations will be carried out one year after the laying and thereafter.

REFERENCES

[1] C. Carpani, E. Bocci, and M. Bocci. Rheological and performance characterization of the bitumen recovered from different emulsions for cold mixtures. Road Materials and Pavement Design, 2021.

Performance characterization of rubberized warm mix asphalt for porous wearing course

Simone D'Angelo[1]*, Fabrizio Cardone[1] and Francesco Canestrari[1]

[1]*Marche Polytechnic University, via BrecceBianche 12, 60131Ancona, Italy*
**corresponding author: s.dangelo@pm.univpm.it*

ABSTRACT: The steady worldwide increase in road transport has contributed to global warming, environmental pollution, and a huge number of end-of-life tires (ELTs) hard to land-filled. In this context, to mitigate the environmental impact of the new pavements, a promising and environmentally solution could be the WMA technology combined with the use of crumb rubber (CR) from ELTs, without compromising the mixture performance as compared to traditional bituminous ones. In this regard, this research describes the results of performance characterization of CR modified mixture by dry method and produced with WMA technology for porous wearing course, with the aim of developing a green and low-noise solution. In detail, the experimental investigation involves the analysis of several CR-WMAs and a reference WMA by means of traditional (Indirect Tensile Strength and Stiffness Test, Cantabro test) and innovative (Scuffing-Device and Wehner-Schulze machine) mechanical tests. ITS, ITSM and Cantabro results demonstrate that there is a critical bitumen and CR content for the performance, while the innovative tests show comparable performance to the reference mix when using the optimal bitumen and CR content.

KEYWORDS: Crumb Rubber, Warm-Mix Asphalt, Scuffing-Device, Wehner-Schulze

INTRODUCTION

The use of the WMA technology and the CR in asphalt mixture has some economic, environmental and performance advantages. The researches have shown that the combined use of WMA and CR technology works well [1], even on porous hot mix asphalt [2]. The aim of this research is to evaluate WMA technology combined with CR, also through innovative tests [3,4], to optimize a mixture to be used on motorway porous wearing course and provide an eco-friendly alternative to traditional mixes.

EXPERIMENTAL PROGRAM

The laboratory investigation involved four rubberized warm mixtures (RWP_A, RWP_B, RPW_C and RWP_E) for porous wearing course produced with four different contents of total SBS-polymer modified bitumen (5.5, 6.0, 6.5, and 7.0%) and 2% CR added by dry method, moreover the most performing mixture, in terms of optimal bitumen content, was also modified with 1.5% CR (RWP_D). A WMA mixture without CR (WP_ref) was also investigate as a reference. The mixtures were produced at 130 °C, by dosing a WMA chemical additive at 0.45% by bitumen weight, and immediately compacted at 120 °C using gyratory compactor and Marshall equipment. Finally, to evaluate the mixture water sensitivity, some laboratory tests were performed in both dry (conditioning: 72 h @ 25 °C) and wet (conditioning: 72 h @ 40 °C in water plus 3 h @ test temperature in air) conditions. The experimental program included more than 200 tests (Table 1).

Table 1. Testing program.

	CEI [5]	ITT		Cantabro		ITSM	Scuffing-Device		Wehner-Schulze
Mixture	Dry	Dry	Wet	Dry	Wet	Dry	Dry	Wet	Dry
RWP_A	10	5	5	5	5	-	-	-	-
RWP_B	10	5	5	5	5	-	-	-	-
RWP_C	10	5	5	5	5	10	2	2	3
RWP_D	10	5	5	5	5	-	1	1	-
RWP_E	10	5	5	-	-	-	-	-	-
WP_ref	10	5	5	5	5	10	2	2	3

RESULTS

Figure 1 shows the main outcomes for the mixtures tested.

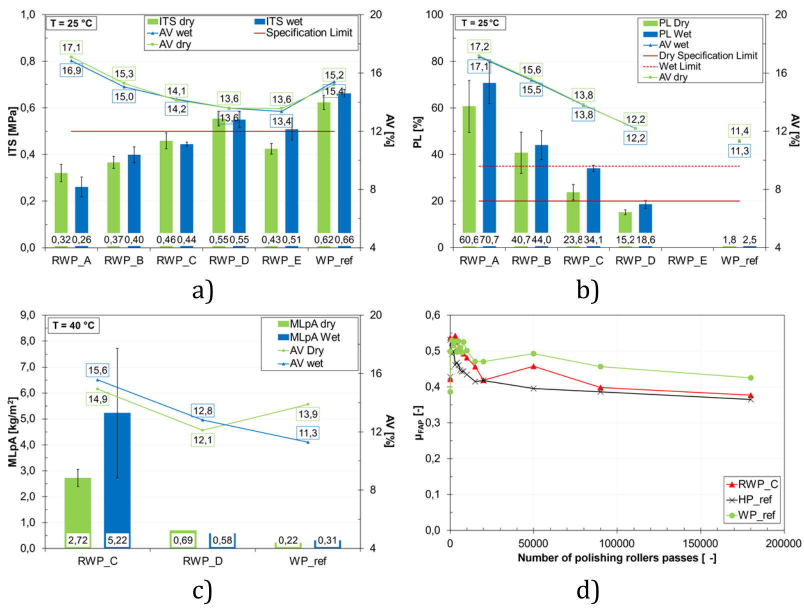


Figure 1. Main findings related to a) Indirect Tensile Test, b) Cantabro Test, c) Scuffing-device, and d) Wehner-Schulze machine.

The analysis of the results in terms of ITS (Figure 1a) and PL (Figure 1b), allows to state that the bitumen content affects the mechanical performance and the volumetric characteristics of the rubberized warm mix asphalt. In this sense, the best performing mixture is RWP_C, characterized by a bitumen content of 6.5% that was chosen as the optimal one to produce subsequently the reference mix (WP_ref) and the RWP_D modified with 1.5% CR. The innovative mechanical tests, conducted on the RWP_C, RWP_D and WP_ref mixtures, show that as regards the scuffing resistance (Figure 1c) there is a critical content of CR equal to 1.5%, beyond which performance deteriorates. Furthermore, this result is in line with that obtained by the Cantabro Test. As far as skid resistance is concerned, the tests conducted with the Wehner-Schulze machine (Figure 1d) show comparable performances between the mixture RWP_C and a hot porous asphalt mixture (HP_ref) currently used on the Italian motorway network.

CONCLUSIONS

The experimental results allow to draw the following conclusions:

- Laboratory investigation demonstrate the effectiveness of combining WMA technology with CR from ELTs for motorway porous wearing course, employing a WMA chemical additive.
- However, there are critical content of bitumen and CR which influence the mechanical, durability, volumetric and workability performance of the rubberized warm mix asphalt for porous wearing course.
- Nevertheless, the results of the innovative mechanical tests do not discourage the use of rubberized warm mix asphalt for porous wearing course, therefore a full-scale trial section on A1 motorway is planned.

REFERENCES

[1] Yang, Xu, et al. "Environmental and mechanical performance of crumb rubber modified warm mix asphalt using Evotherm." *Journal of Cleaner Production* 159 (2017): 346-358.

[2] Sangiorgi, Cesare, et al. "A complete laboratory assessment of crumb rubber porous asphalt." *Construction and Building Materials* 132 (2017): 500-507.

[3] Beltzung, Françoise, Christiane Raab, and Manfred N. Partl. "Evaluating raveling susceptibility of asphalt by Pull-off tests." *Construction and Building Materials* 364 (2023): 129939.

[4] Pomoni, Maria, et al. "Polishing behaviour of asphalt surface course containing recycled materials." *International Journal of Transportation Science and Technology* 11.4 (2022): 711-725.

[5] Mo, Liantong, et al. "Laboratory investigation of compaction characteristics and performance of warm mix asphalt containing chemical additives." *Construction and Building Materials* 37 (2012): 239-247.

Microsurfacing: a study on the modelling, assessment and evolution of surface performance

Manuel De Rose[1] and Rosolino Vaiana[2]

[1]*University of Calabria, Rende, Italy, manuel.derose@unical.it*
[2]*University of Calabria, Rende, Italy, rosolino.vaiana@unical.it*

ABSTRACT: The present research proposes a methodological approach for a comprehensive evaluation of microsurfacing surface performance. The objectives of this study consist mainly of three tasks: task 1) the development of an empirical predictive model to forecast the expected mean texture depth (MTD) as a function of mix composition; task 2) a mix design optimization of three microsurfacing mixtures subjected to polishing action by a laboratory traffic simulator for evaluating the evolution of surface performance; task 3) the design, development and patenting of a prototype for paving microsurfacing mixtures indoor. Main results | Task 1: The predictive model works adequately and shows a good correlation between the observed and predicted macrotexture. Task 2: The polishing action by the traffic simulator allows collecting interesting data on the evolution process of microsurfacing surface performance. Task 3: The development of the "U-Micropaver" will ensure a laboratory-scale fast paving method to collect a larger set of data and confirm or refine the discovered correlations between mix design parameters and surface texture.

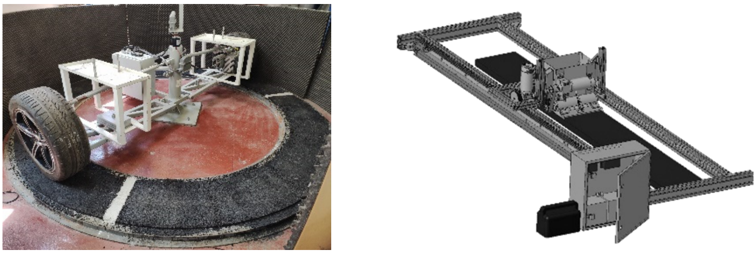
KEYWORDS: Microsurfacing; macrotexture predictive model; surface performance;

INTRODUCTION

The main functional characteristics of road pavement (friction, noise, drainability) relate to the surface texture. Hence, it would be appropriate to consider surface texture as a key parameter for road engineering already at the design stages [1]. Different macrotexture prediction models were developed for wearing courses, however few studies deal with modelling the macrotexture for surface treatments. Besides, among the other maintenance treatments, microsurfacing (MS) has gained scientific and practical interest in the last years. A properly designed MS applied on a prepared surface ensures remarkable surface texture characteristics and provides a waterproof coating for the under layers, promoting road safety and environmental sustainability [2]. Several laboratory researches and road applications achieved accurate mix design, mainly focusing on mechanical performance, assuming that good mix design and systematic production are the keys to ensure an effective and durable MS [3]. Thus, further investigation is needed to evaluate and optimize expected MS surface performance, identify how they are influenced by the mix design, and understand the deterioration behaviour to predict future performance during the MS lifespan.

EXPERIMENTAL PROGRAM

The main objectives of this research can be summarized in three different tasks: task 1) the development of a macrotexture prediction model for MS based on mix design-related factors; task 2) study on MS mix design and on the evolution of its surface performance; task 3) design and implementation of a laboratory scale device for laying MS indoor. To fulfil the first objective, a wide analysis of the literature aimed at building a dataset of MS applications, gathering information about the aggregate gradation, bitumen emulsion, and mineral filler percentage, and the macrotexture achieved. Then, a macrotexture model (multiple linear regression) was set up in terms of one main equation based on a volumetric approach; a K-fold cross-validation technique was used to evaluate the statistical performance and confirm the rationale behind the modelling phase. Finally, the model accuracy was evaluated by means of several statistical metrics. In the second phase, the research focused on the manufacturing of three different MS mixtures, basalt 0/8, basalt 0/6 and granite 0/8. The mix design process was carried out according to the EN 12274 standard series. Once the optimization phase was completed, the mixtures were laid above a track and subjected to a laboratory traffic simulator (Figure 1a) in order to study the evolution of MS surface performance, especially in regard of macrotexture and friction. At each step of conditioning, measures of sand patch, British Pendulum Number (BPN), 3D laser and circular laser were collected. As last step, in order to collect a larger dataset and confirm or refine the discovered correlations between the mix design and the surface texture, the authors are involved in the implementation and patenting of a laboratory prototype (Figure 1b), "U-Micropaver", for producing MS mixtures indoor. This device will allow for a fast paving method, obtaining a small laboratory-scale test field for the study of MS surface performance.



a) b)

Figure 1. a) laboratory traffic simulator; b) design of the U-Micropaver;

MAIN RESULTS

The logical framework followed to define the proposed macrotexture prediction model is shown in Figure 2a, whereas Figure 2b reports the results obtained by applying the model to the whole dataset gathered from the literature. Figure 3a and Figure 3b show respectively the evolution of the skid resistance, in terms of BPN, and the macrotexture (MTD) obtaining after the conditioning of MS mixtures by means of the laboratory traffic simulator.

$$MTD^* = V_C - (\alpha_A \cdot V_A + \alpha_B \cdot V_B + \alpha_F \cdot V_F) + \alpha_{MTD} \cdot MTD^*_{pre}$$

$$MTD = h_C - (\alpha_A \cdot h_A + \alpha_B \cdot h_B + \alpha_F \cdot h_F) + \alpha_{MTD} \cdot MTD_{pre}$$

$$MTD^* = MTD \cdot A_c$$

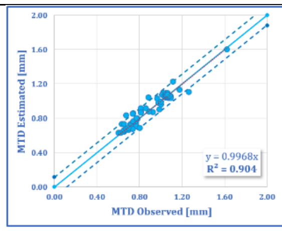
$$V_C = h_c \cdot A_c \text{ where } h_c = \begin{cases} 10\ mm & (Type\ III) \\ 7\ mm & (Type\ II) \end{cases} \qquad h_A = f(ARs; \gamma_A; Grading\ Curve)$$

$$V_A, V_B, V_F \text{ referred to } A_c \qquad h_B = f(ARs; \gamma_B; P_B)$$

$$Ac = 1\ m^2 \qquad h_F = f(ARs; \gamma_F; P_F)$$

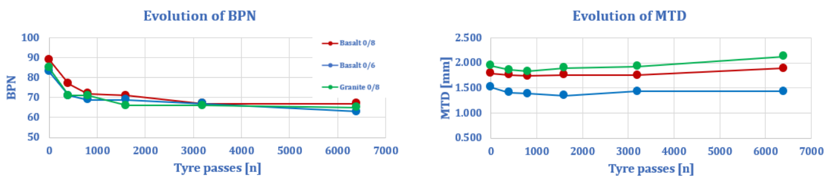
$$MTD = h_C - (\alpha_A \cdot h_A + \alpha_B \cdot h_B + \alpha_F \cdot h_F) + \alpha_{MTD} \cdot MTD_{pre}$$

a)



b)

Figure 2. a) modelling; b) MTD observed vs MTD estimated;



a) b)

Figure 3. a) evolution of BPN; b) evolution of MTD;

CONCLUSIONS

- The model works adequately, showing a high correlation coefficient; results could benefit both researchers and practitioners.
- The traffic simulator allowed to collect a good database for the purpose of defining a possible decay model for MS surface performance.
- The implementation of the laboratory device will ensure a fast paving method to study and optimize MS already at the design stage.

REFERENCES

[1] F.G. Praticò, P.G. Briante. Prediction of surface texture for better performance of friction courses. Construction and Building Materials. 230 (2020) 116991.

[2] A. Grilli, A. Graziani, A. Carter, C. Sangiorgi, L. Pivoto Specht, S. Copetti Callai. Slurry surfacing: a review of definitions, descriptions and current practices. RILEM Tech Lett. 4 (2019) 103–109.

[3] D.D. Gransberg. Microsurfacing. (Vol. 411). Transportation Research Board, (2010).

Methodological approach via Visual Programming Language for stone-paved roads automated BIM.

Mattia Intignano[1], Salvatore Antonio Biancardo, Gianluca Dell'Acqua
Department of Civil, Construction, and Environmental Engineering
University of Naples Federico II, Napoli, Italy
[1]*mattia.intignano@unina.it*

ABSTRACT: In the wake of the primary role of Building Information Modelling (BIM) in the Architecture, Engineering, Construction, and Operation (AECO) industry, this paper presents a novel approach for the complete automation of the development of a geometric Building Information Model and semantic digital representation of a stone-paved road by means of the exploitation of a Visual Programming Language Environment (VPLE) for procedural parametric modeling.

KEYWORDS: BIM, VPL, stone-paved road.

INTRODUCTION

The new technological frontier in the world of civil engineering is the digitisation of works from the planning and design phase to the asset management phase using BIM methodology and tools is required also from National and International laws and standards (**1**). It is not easy for companies, public administrations, and freelancers to adapt to this new paradigm, having to invest many resources in specific training, and given the complexity of BIM-based IT tools. This is even more evident in the field of linear infrastructure engineering, such as roads, as in the past the focus was mainly on vertical/punctual structures and buildings. On the other hand, the tangible economic and technical advantages of BIM are such that it is important to try to reduce this gap, as many tried before, also by exploiting automation empowered approaches (**2, 3**). The aim of this paper is to promote a workflow for the fully automated modelling of road infrastructure by means of an algorithm realised with a visual programming language, i.e. based on the development of graphs, in which nodes are instructions linked by logical links.

METHODOLOGY

Figure 1 presents the proposed methodology, composed of four phases. Phase 1 consists in the Dataset Definition by preparing a spreadsheet with road design data about topography, road geometry design, the pavement structure, and the maintenance plan. Phase 2 consists in the Geometric Modelling of the asset by the use of Dynamo, VPL Environment extension of the BIM Authoring Software Civil 3D, from Autodesk, leader in roads design. Data of topography and road geometry design are used to model the Digital Terrain Model, the Horizontal Alignment, the Vertical Profile, and the Corridor Baseline, that corresponds to the road 3D axis and it is used as an extrusion path for the cross section, which is modelled starting from the pavement structure data. Phase 3 consists in 6D Modelling, i.e. BIM dimension for maintenance and operation phase, by means of the maintenance plan. Phase 4 consists in the export in IFC 4x3 format, realising what is defined as Semantic Enhancement, when IFC is integrated with information from external sources, as in this case.

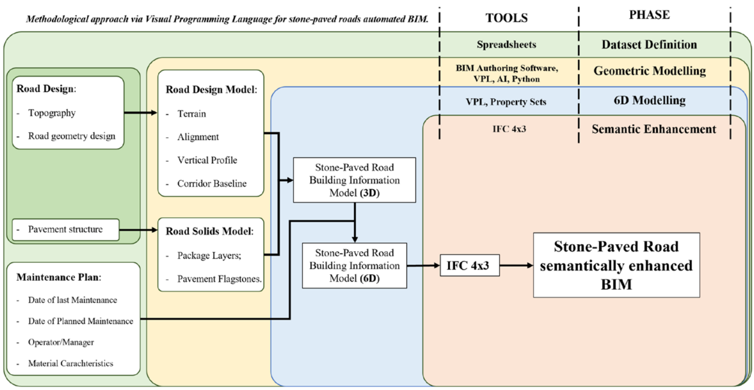


Figure 1 - Methodology

RESULTS

Figure 2 shows the VPL algorithm realised in Dynamo, Civil 3D extension. The final result is a stone-paved road semantically enhanced BIM in IFC 4x3, the file format chosen to ensure interoperability in BIM, as showed in Figure 3. The algorithm runs in less than 1 minute, completing modelling tasks that can take hours or days, depending on the user's skills. Furthermore, the quality of the model is very high, considering that the scientific literature and engineering practice concerning BIM modelling of road pavements made of modular stone elements is very scarce if not non-existent.

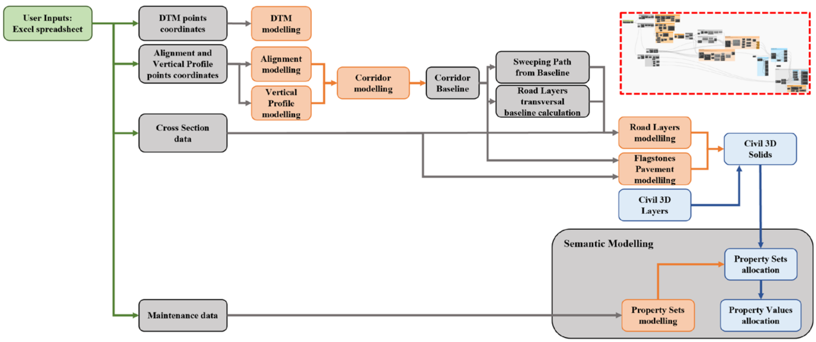


Figure 2 - VPL algorithm.

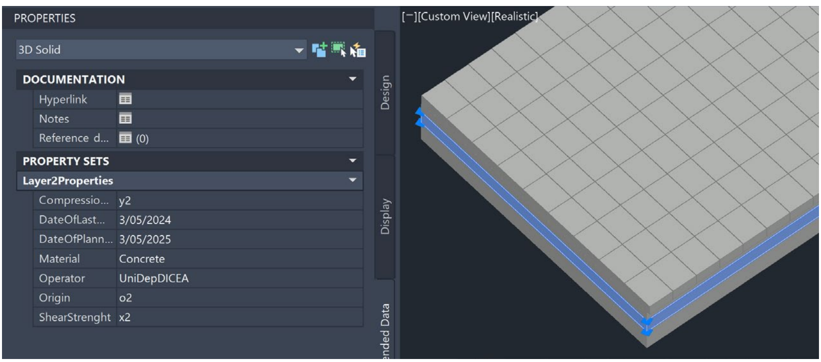


Figure 3 - 3D/6D BIM model.

CONCLUSIONS

This research provided a modelling tool that transforms the data contained in an Excel file into a complete model of information about the maintenance plan of a street.

The strengths are:

- reduction of modelling time from hours/days to seconds;
- the specific application to a stone-paved street, that demonstrates a great potential for application to the modelling of existing assets with a cultural-historical character;

The innovative contribute has to be found in the following:

- full automatic modelling through VPL, replacing the main BIM Authoring Software interface;
- specific focus on stone-paved roads, of which there is a strong lack of precedent.

The limitations and future developments of this work are related to its novelty. In fact, this workflow only reproduces one type of geometric pattern for the surface distribution of flagstones. A future development could concern precisely the extension to different patterns, while maintaining the automatic and independent character of the algorithm. Another limitation is that the algorithm works for a specific template of an Excel file. Therefore, future research should explore the possibility of making the algorithm adaptive to other templates, giving users more freedom to define it independently.

REFERENCES

[1] Eastman, C. M., Teicholz, P., Sacks, R., Liston, K. (2018). BIM Handbook: A guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors. John Wiley & Sons.

[2] Biancardo S.A., Intignano M., Viscione N., Guerra De Oliveira S., Tibaut A. (2021). Procedural Modeling Based BIM Approach for Railway Design. Journal of Advanced Transportation, 8839362. https://doi.org/10.1155/2021/8839362

[3] Oreto, C., Massotti, L., Biancardo, S. A., Veropalumbo, R., Viscione, N., Russo, F. (2021). BIM-Based Pavement Management Tool for scheduling urban road maintenance. Infrastructures. https://doi.org/10.3390/infrastructures6110148

Analysis of a monitoring systems to evaluate the gap value in bonded insulated joints

Aldo La Placa[1]

[1]Dipartimento di Ingegneria e Architettura, Università degli Studi di Parma, Parma, Italy, aldo.laplaca@unipr.it

ABSTRACT: The monitoring of bonded insulated joints makes it possible to overcome the limits dictated by cyclical scheduled maintenance, helping the infrastructure manager to anticipate the formation of possible failures. A field monitoring system that measures the gap value was investigated, using optical fibres with Bragg gratings placed at the head of the two adjacent jointed rails. Through the application of the Zimmermann analytical model, a first quantitative validation of the data recorded by the monitoring systems measuring the gap value was proposed. Based on the different types of failure of a bonded insulated joint, the debonded of insulating element of the joint was identified as a typical condition. Starting from this through a finite element analysis, some characteristic limitations of these monitoring systems were identified by assuming four different bonding scenarios.

KEYWORDS: Bonded insulated rail joint, Automatic monitoring system, rail transport

INTRODUCTION

The rails of a railway track are manufactured in pre-defined lengths and directly welded together on site, having to respect construction and transport constraints. When the rails are not welded, joints are used to connect them to form a jointed track configuration. Bonded insulated joints not only minimise the negative effects of physical discontinuity, but also provide the necessary electrical insulation when two rails are located at the end of track circuits [1]. The failures of a bonded IRJ can be classified as mechanical problems and issues involving the loss of the joint's insulating capacity. In the first case, the failure concerns the steel parts, i.e. the joint bar or fasteners or the rail itself, while in the second case, it relates to the freely flow of electric current, i.e. lipping or spalling or the loss of the insulating properties of the material used to separate the metal parts [2]. In general, the effect of the "typical failure" is the partial or complete detachment of the epoxy from the rail, the joint bar or both. The bonded IRJ layout makes a visual inspection often ineffective for assessing its condition since the joint bars cover up any cracks that start from the rail holes. In this perspective, an automatic monitoring system installed in the field could facilitate the tasks of operators who must provide the full efficiency of the railway superstructure. Therefore, this study analysed the potential application ad use of a monitoring system on an IRJ able to measure the longitudinal displacement of two adjacent rails using fibre-optic sensor. This technique could be easily implemented in rail networks by exploiting the multiple options currently available on the market of tailored sensors. Using the Zimmermann model, an analytical method was proposed to validate the data recorded by this monitoring system. Then, by means of finite element analysis, some aspects were exposed that could not be detected by the devices monitoring the gap opening variation in relation to the different bar-rail interaction scenarios corresponding to the "typical failure".

EXPERIMENTAL PROGRAM

The monitoring system is configured using fibre-optic Bragg grating sensors placed in the rail heads of two adjacent rail sections. The validation of the registered data, i.e. the continuous measure of the gap value of a bonded IRJ (ΔL), was performed using Zimmermann model [3]. In fact, ΔL can be derived by following the Zimmermann's assumptions, which are based on Winkler's theory once the distance between the neutral axis of the rail and the axis of application of the sensor is known. Kerr and Cox [4], like other researchers, demonstrated the validity of such an approach to model the problem with a single wheel load acting at the centre of the joint.

The measurement of ΔL contributes to the development and calibration of FEM models of mechanical joints such as bonded IRJs, changing the interface condition between the joint bar and the rail when the resistance of the adhesive layer is exceeded. For the case study, the bonded isolated joint was modelled with the commercial software Abaqus/CAE, considering the exact geometry of all the joint components relative to the 50 UNI rail type. The model was then created by virtually assembling two 0.3 m long rail sections, interposed between two joint bars, and connected by four fish bolts. Between each bolt and the rail-joint bar element there is the bolt insulator bushing, omitting the interposition of resins and fibres at the rail contact, which is substituted by cohesive interfaces having mechanical properties that replicate the behaviour of the materials they replace, leaving the overall response unchanged. Different joint bar-rail interaction scenarios were analysed.

Therefore, always assigning the same order-of-magnitude displacement as measured during train transit, i.e., 0.1 mm in the axial direction, we proceeded by analysing the behaviour of the IRJ for the following cases (Fig. 1 – Table 1).

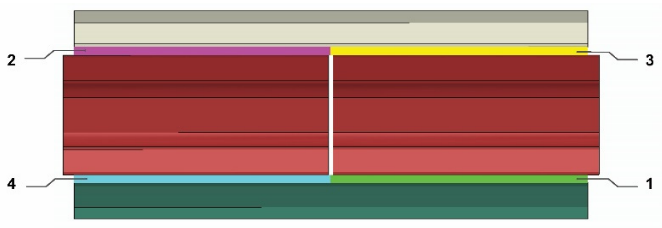


Figure 1. Scheme of the analysed case.

Table 1. Analysed conditions.

Condition	Cohesive bonding	Hard contact
A: Full Bonded	1-2-3-4	-
B: Total debondig	-	1-2-3-4
C: Symmetrical partial debondig	1-3	2-4
D: Asymmetrica partial debondig	1-2-3	4

RESULTS

Application of the Zimmermann model gave values comparable to the expected change gap value. The results of the FEM analysis showed that the deformations at the holes increase the progress of the detachment. An amplification of these effects could lead to the onset of mechanical failure, causing ovality of the holes and, ultimately, the formation of cracks, which would make it necessary to anticipate maintenance intervention.

CONCLUSIONS

In this study after an initial quantitative validation of the recorded data, a finite element analysis was carried out by simulating the detachment of the epoxy resin and observing the axial deformations directly correlated to the measurements recorded by the monitoring system under investigation. These simulations show how these devices fail to capture all aspects of the deterioration of this railway joint, but they provide useful support for maintenance operations [5]. Furthermore, these monitoring systems can be useful in acquiring data to calibrate appropriate forecasting models that will be the subject of future studies.

REFERENCES

[1] Esveld, C., 2001. Modern Railway Track, 2nd Edition, MRT-Productions, The Netherlands.

[2] Davis, D.D., Akhtar, M.N., 2005. Improving the performance of bonded insulated joints. Railw. Track Struct. 101.

[3] Zimmermann, H., 1888. Die Berechnung des eisenbahnoberbaues.

[4] Kerr, A.D., Cox, J.E., 1999. Analysis and tests of boned insulted rail joints subjected to vertical wheel loads. Int. J. Mech. Sci. 41.

[5] La Placa, A., Freddi, F., Giuliani, F., 2023. Bonded insulated rail joint monitoring using gap opening variation with fibre optic sensors: analytical validation and limits. Transp. Res. Proc., In press

8a SIIV ARENA

Monitoring Air Pollution and Aerosol Concentration Using Single Photon LiDAR

Jhon Romer Diezmos Manalo[1], Luka Mamic[2,3]

[1]Department of Civil, Computer Science and Aeronautical Technologies Engineering, Roma Tre University, Via Vito Volterra 62, 00146, Rome, Italy, jhonromerdiezmos.manalo@uniroma3.it
[2]Department of Civil, Building and Environmental Engineering, Sapienza University of Rome, Via Eudossiana 18, 00184 Rome, Italy, lmamic@uniroma1.it
[3]Department of Land, Environment, Agriculture and Forestry (TESAF), University of Padua, Viale dell'Università 16, 35020 Legnaro, Italy

ABSTRACT: This study aims to create a 3D Building Information Model (BIM) and measure aerosol concentrations in the surrounding residential area, using Single Photon LiDAR data. The methodology includes the use of Autodesk InfraWorks Model Builder and Opals software to create a highly accurate BIM model of a residential area located in Vienna. Subsequently, the extraction of 'noise' from laser scanner data of the residential and forest areas is used to calculate the point density which was then compared with aerosol satellite data from Sentinel-5P, highlighting an existing correlation between the two datasets. Ultimately, BIM, residential aerosol data, and point density layers were integrated into a comprehensive 3D model to monitor aerosol concentrations specifically within Vienna's 4th district. Continued advancements in this project have the potential to contribute to a future monitoring of air pollution within 3D environments, supporting urban management and planning endeavours. Moreover, it is possible to apply the same methodology to monitor and increase sustainability in transport infrastructures and road construction sites.

KEYWORDS: Single Photon LiDAR, BIM, Sentinel-5P, Aerosol.

INTRODUCTION

Air pollution from infrastructure and construction sites is a significant environmental concern, and this paper aims to analyze the pollutants emitted, their sources, and their impacts on the environment. By understanding the contributing factors, strategies can be developed to mitigate and control emissions. In addition, this article explores the concept of using single photon LiDAR data, which was developed during a group project at the GATHERS-hack datadive event in April 2023 at TU Vienna, Austria. This innovative approach serves as an inspiration for future studies to fully validate and improve the monitoring of aerosol concentration levels, and potential monitoring techniques will be explored to assess air pollution levels and guide effective pollution management practices.

EXPERIMENTAL PROGRAM

The data used were collected on 29 July 2018 with a Leica SPL100 laser scanner and the data owner is the City of Vienna and the data acquisition was performed by COWI [1]. Two raw point clouds from this dataset were provided to the hackathon participants by TU Vienna. The first one was related to the residential area of the 4th district of Vienna, while the second one was related to the forest area of Vienna. The methodology of the developed approach is shown in **Figure 1**.

Both point clouds were pre-processed using the OPALS software, where an additional attribute called ptCounts was calculated to extract the "noise". The idea that these points could represent tiny particles in the air from natural and man-made sources that affect air quality, climate and health, known as aerosols, was tested using remote sensing data from the Sentinel-5P mission [2], the satellite provides atmospheric monitoring capabilities. To correlate the calculated point density with the aerosol data, we merged all height layers and calculated the average point density for both areas.

Therefore, aerosol data in the form of Aerosol Index (AI), Absorbing Aerosol Index (AAI), Aerosol Optical Depth (AOD) and Aerosol Layer Height (ALH) have been obtained for our two coverage areas. AI and AAI represent a measure of the prevalence of aerosols in the atmosphere.

The Sentinel-5P data used are shown in **Table 1** below. Moreover, **Table 2** shows point densities calculated from single photon LiDAR data.

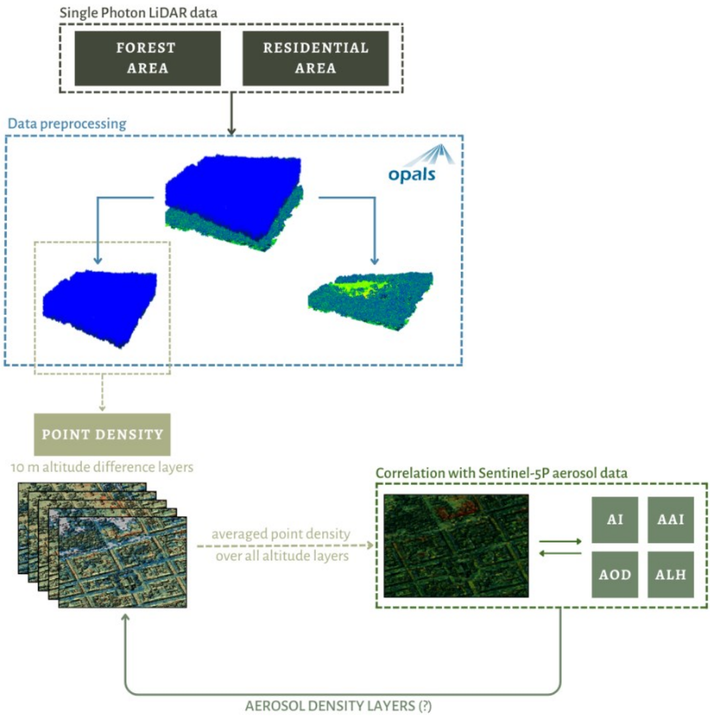


Figure 1. Flowchart of the proposed approach.

Table 1. Sentinel-5P aerosol data used.

	AI (S5P AER AI)	AII (S5P SO2)	AOT (S5P AER LHI)
CITY	-0.712	-1.330	0.322 Pa
FOREST	-1.448	-1.935	0.099 Pa

	ALH (MIN)	ALH (MEAN)	ALH (MAX)
CITY	176 m	762 m	4941 m
FOREST	232 m	872 m	5094 m

Table 2. Calculated point density data from the single photon LiDAR dataset.

	pDENS (MIN)	pDENS (MEAN)	pDENS (MAX)
CITY	0.04	1.34	3.76
FOREST	0.04	1.90	2.64

Firstly, it can be seen that the heights of our two study areas fall within the range of minimum to average aerosol layer height. Secondly, lower AI, AAI and AOD values are found in the forest area and they correlate with point densities calculated from LiDAR data, whereas we have higher point densities in the residential area. These results don't prove that point densities from single photon LiDAR data represent aerosols suspended in the air, but they point in that direction and it is up to future studies to try to prove this by integrating more data into this approach.
In the meantime, a preliminary information model was reconstructed utilizing Infraworks 'Model Builder' instrument, which incorporates data from Bing maps. However, recognizing the preliminary nature of this data, it was supplemented with information derived from the post-processed point cloud. Starting with the terrain, a Digital Terrain Model (DTM) was reconstructed, utilizing OPALS to extract only points classified as 'Ground'. Additionally, parametric models were employed to represent the buildings in the Vienna district, with their heights obtained from the point cloud proving highly valuable. By establishing a comprehensive Building Information Model (BIM) for the entire area, it became feasible to incorporate the previously acquired data due to the observed correlation between point density and information obtained from the Sentinel-5P satellite.

CONCLUSIONS

This research contributes to the field of air pollution monitoring by showcasing the potential of single photon LiDAR data and its integration with satellite-based aerosol measurements. The developed methodology and the BIM model provide a foundation for future studies and support urban management and planning efforts, also contributing with a possible effective mitigation of air pollution in infrastructure and construction sites.

REFERENCES

[1] G. Mandlburger, H. Lehner, N. Pfeifer. A comparison of single photon and dull waveform lidar. ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Volume IV-2/W5, 2019.
[2] Sentinel-5P, European Space Agency's Copernicus programme. https://sentinels.copernicus.eu/web/sentinel/missions/sentinel-5p

Innovative monitoring of asphalt surface characteristics

Eugenio Mariani[1], Lorenzo Paolo Ingrassia[2] and Francesco Canestrari[3]

[1]Università Politecnica delle Marche, Ancona, Italy, e.mariani@pm.univpm.it
[2]Università Politecnica delle Marche, Ancona, Italy, l.p.ingrassia@pm.univpm.it
[3]Università Politecnica delle Marche, Ancona, Italy, f.canestrari@staff.univpm.it

ABSTRACT: Road safety is a hot topic nowadays. Tyre-pavement friction is a crucial property for road safety, therefore finding a reliable method to evaluate the pavement friction is of utmost importance. In this research, the friction properties of 14 different in-plant produced asphalt mixtures (including Porous Asphalt, Semi-Porous Asphalt and Asphalt Concrete) were tested through an innovative test method based on the use of the Wehner – Schulze device. The preliminary results suggest that the measured friction is mainly influenced by the contact area between rubber and aggregates. The next step will be to correlate the obtained friction values with the aggregate and bitumen properties as well as the surface macrotexture. Future activities will also focus on correlating laboratory and field friction/polishing properties.

KEYWORDS: Wehner – Schulze, Pavement friction, Road safety

INTRODUCTION

Asphalt surface characteristics play a crucial role in the tyre-pavement friction. The Wehner – Schulze device is a relatively new test method to study the friction properties of asphalt mixtures as well as mosaics of aggregates. Previous studies have mainly focused on aggregate mosaics, in the attempt of finding a correlation between Friction After Polishing (FAP) and Polished Stone Value (PSV) [1]. The present research project aims at finding a more reliable method to evaluate the pavement friction characteristics, correlating the laboratory and field friction/polishing properties, and ultimately introducing a limit of FAP for the Italian technical specifications.

EXPERIMENTAL PROGRAM

14 different in-plant produced asphalt mixtures were tested: 7 Porous Asphalt (PA), 4 Asphalt Concrete (AC) and 3 Semi- Porous Asphalt (SPA) mixtures. The mixtures were heated for 3 hours at 160 °C and then compacted with the roller compactor in slabs of 40x30x5 cm^3 (width x length x height). Then the slabs were cut to final dimensions of 22.5x22.5x5 cm^3. For each asphalt mixture minimum 2 specimens were tested with the Wehner – Schulze device (Figure 1,a) [2]. The device is made of two units: the polishing unit and the measurement unit. The polishing unit (Figure 1,b) simulates the effect of the poshing of the tyres on the pavement surface by means of three rubber rollers (which rotate at 500 rpm) and a blend of water and quartz powder. The measurement unit (Figure 1,c) measures the friction value through the braking of three rubber sliders on the surface of the specimen, whose initial velocity is 100 km/h.

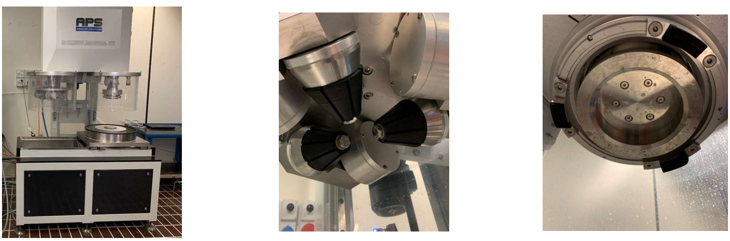


Figure 1. (a) Wehner – Schulze device, (b) Polishing unit with rollers, (c) Measurement unit with sliders.

RESULTS AND EXPECTED OUTCOMES

The main result of the Wehner-Schulze tests is the parameter known as Friction After polishing (FAP). Figure 2a shows the result of one single measurement during the braking of the sliders. Friction increases as the velocity decreases, as expected. This experimental curve is then interpolated with a 6th order polynomial to find the friction value at 60 km/h ($F60=\mu_{FAP}$). Figure 2b shows the results of two specimens of the same mixture. The curves in Figure 2b are obtained by determining μ_{FAP} at increasing numbers of polishing passages. The average between the two repetitions is the FAP parameter.
Figure 3a shows the FAP curve for each asphalt mixture: PA mixtures show lower values of FAP with respect to SPA mixtures, which in turn exhibit lower FAP values than AC mixtures. After 180000 polishing passages, the FAP values are between 0.28 and 0.34, between 0.29 and 0.36, and between 0.36 and 0.42 for PA, SPA and AC mixtures, respectively. This finding may be due to the reduced contact between rubber and aggregates as the air void content increases. These preliminary results will be analysed more in detail, with the aim of correlating the friction values with the aggregate and bitumen properties as well as the macrotexture. As an example, Figure 3b shows a specimen after 180000 polishing passages.

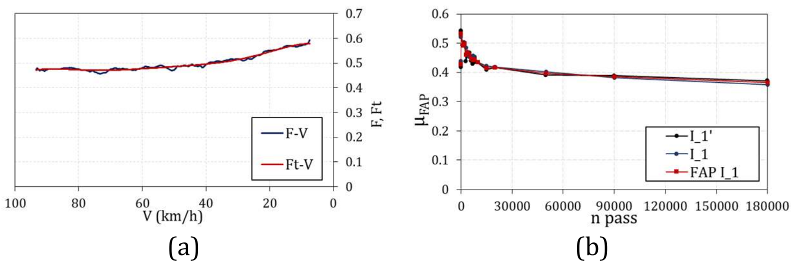
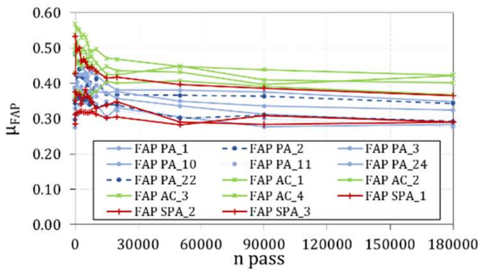
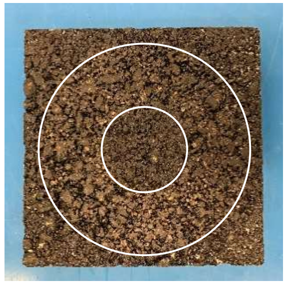


Figure 2. Wehner – Schulze results: (a) single measurement, (b) FAP curve.





(a) (b)

Figure 3. Wehner – Schulze results: (a) comparison between the asphalt mixtures, (b) surface of the specimen after the test.

CONCLUSIONS

Asphalt surface characteristics play a crucial role in the tyre-pavement friction. This study investigated the friction properties of 14 different asphalt mixtures with the the Wehner-Schulze device. The preliminary results and future work are as follows:

- Porous Asphalt and Semi Porous Asphalt mixtures show lower friction values than Asphalt Concrete mixtures, likely due to the reduced contact between sliders and aggregates.
- The friction properties of the mixtures will be correlated with the aggregate and bitumen properties as well as the macrotexture.
- Future activities will seek a correlation between the Wehner-Schulze polishing and the polishing due to traffic as well as between laboratory and field friction measurements (for example, with the Sideway-Force Coefficient Routine Investigation Machine, SCRIM).

REFERENCES

[1] Arampamoorthy H., Patrick J. Comparison of the Wehner – Schulze and PSV test for estimate the polishing resistance of New Zeland chip seal aggregate. 3th International Surface Friction Conference, Australia, 2011.
[2] UNI EN 12697 – 49, 2022, Bituminous mixtures – Test methods – Part 49: Determination of friction after polishing.

Preliminary study of development bio-based extended bitumen

Alessio Musco[1], Giulia Tarsi[2] and Cesare Sangiorgi[3]

[1] *University of Bologna, Bologna, Italy, alessio.musco@unibo.it*
[2] *University of Bologna, Bologna, Italy, giulia.tarsi2@unibo.it*
[3] *University of Bologna, Bologna, Italy, cesare.sangiorgi4@unibo.it*

ABSTRACT: The paving industry is moving towards the reduction of its carbon footprint focusing the experimental research on the development of new road materials and techniques that can make the sector more sustainable. These also include the use of binders for the production of paving mixtures where the fossil fraction is gradually replaced by wastes or by-products. In this preliminary study, various bituminous binders were developed replacing the $50\%_w$ of the total amout of bitumen (i.e. extended bitumens). The remaining $50\%_w$ mainly comes from biological products. These extended bio-based bitumens were rheologically analyzed showing comparable trends to those of traditional bitumen.

KEYWORDS: extended bitumen, bio-based, bio-binders

INTRODUCTION

The main cause of climatic change is linked to the emissions of greenhouse gases (GHGs), in particular CO_2. To counter this phenomenon, countries worldwide are providing decarbonization plans within 2070 (1). The transport infrastructures' sector also contributes to the GHG emissions. During the production and processing operations of asphalt mixtures, high temperatures (160-200°C) release VOC (volatile organic compounds) that are toxic for operators and for the environment (2). Many studies have reported the possibility of using new techniques where the asphalt mixes are processed at lower temperatures than those used in traditional methods. On the other hand, the development of different kinds of paving binders with a lower percentage of the fossil fraction can mitigate GHGs emission. Commonly, there are three different type of binders:

- Modified bitumens (bitumen replacement <10%);
- Extended bitumens (bitumen replacement25-75%);
- Alternative binders (bitumen replacementr>75%) (3).

Initially, polymeric materials have been used to improve the performance of bitumen. Subquensely, to make the pavement industry more sustainable, researchers have studied the possibility of using bio-masses and end-of-life materials to partially replace the fossil fraction in traditional bitumen (4). This study aims to develop the bio-binders by replacing $50\%_w$ of the bitumen content and assessing their performances.

EXPERIMENTAL PROGRAM

Three bio-based extended bitumens were developed in the laboratory replacing $50\%_w$ of the base bitumen. To obtain these bituminous binders, a 50/70 penetration grade bitumen (PEN 50/70) is mixed at 160°C with an eco-friendly extender, in fact the $80\%_w$ of its composition comes from biological sources. In the extender's composition, there are compounds such as Rosin pitch, acid pitch and SBS polymer.

The three extended bitumens were analyzed by means of the Dynamic Shear Rheometer (DSR). In **Table 1** the mass proportion of the extenders' bio-products are reported.

Table 1. Mass proportion of compounds in the developed extenders.

Sample	Rosin pitch	FAMEs	SBS polymer
E1	8	1	1
E2	7	2	1
E3	6	3	1

RESULTS

The rheological tests on the developed bio-binders have shown promising results.
The *temperature sweep tests* on the extended bitumens with E1 and E2 extenders showed a similar behaviourof a polymer modified bitumen with SBS.

Thanks to the *frequency sweep tests*, the Black diagrams were plotted to check the validity of the time-temperature superposition principle (TTSP) and, therefore, the possible construction of the master curves. As shown in **Figure 1**, the obtained G* master curves were compared with those of the traditional PEN 50/70.

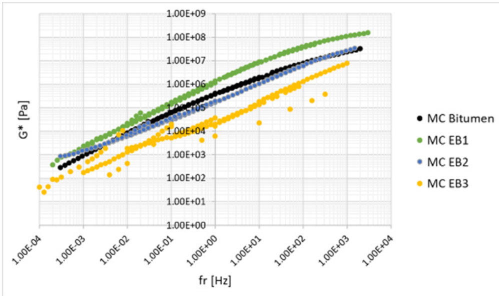


Figure 1. Comparison of master curves.

CONCLUSIONS AND FUTURE DEVELOPMENT

Based on the experimantal testscarried out in this preliminary study on extended bitumens it is possible to conclude:

- By substituting the 50%$_w$ of the standard bitumen, the rheological tests on the extended bitumens EB1 and EB2 showed comparable propertiesto those of PEN 50/70. Hence, these developed binders may represent a promising basis to further improve the formulation.
- Addition rheological tests to fully characterize the developed extended bitumens are on-going;
- The development of new formulations, changing the type and amount of each bio-based product, increasing their amount,will be performed;
- The final goal of the research is the further reduction of the bitumen fraction.

REFERENCES

1. Olhoff A, Christensen JM. Emissions gap report 2020. 2020;
2. Dhasmana H, Sanchez X, Romero L. An Exploratory Study on the Use of Biobinder Derived from Brewer's Spent Grains as an Asphalt Modifier. Journal of Materials in Civil Engineering. 2023;35(5):04023070.
3. Raouf MA, Williams RC. Temperature and Shear Susceptibility of a Nonpetroleum Binder as a Pavement Material. Transportation Research Record. 2010 Jan 1;2180(1):9–18.
4. Cooper III SB, Mohammad LN, Elseifi M. Evaluation of Asphalt Mixtures Containing Renewable Binder Technologies. International Journal of Pavement Research & Technology. 2013;6(5).

Investigating the safety benefits of red LED strips at mid-block crosswalks under distracted driving conditions

Alberto Portera[1], Marco Bassani[1]

[1] *Department of Environment, Land, and Infrastructure Engineering (DIATI), Politecnico di Torino, Corso Duca degli Abruzzi, 24 - Torino, 10129 – Italy*
alberto.portera@polito.it

ABSTRACT: The study aimed to assess the safety benefits of a smart crosswalk with red LED strips that highlights the presence of a crossing pedestrian at midblock crosswalks. During the driving drivers were engaged in a cognitive Non-Driving Related Task (NDRT) to divert their attention from the road. Our findings revealed promising results with the use of this technology. Participants reacted faster facing a smart crosswalk compared to a conventional one. The minimum Time-to-Collision increased significantly with the smart crosswalk, indicating safer interactions between drivers and pedestrians. Finally, the smart crosswalk was effective independently of the NDRT complexity.

KEYWORDS: *Smart Crosswalks, Vehicle-Pedestrian interaction, road safety*

INTRODUCTION

Pedestrian safety is a major concern for public health and road safety since pedestrian fatalities represents the 20% of total death on European roads (European Commission, 2021). One of the main causes is driver distraction. Smart Road Technologies (SRT) have shown promising benefits in addressing road safety issues. Previous studies examined various SRT able to protect pedestrians at crosswalks, such as flashing beacons, LED panels, and crosswalk warning systems, obtaining positive results (Angioi et al., 2023). However, no studies have explored the impact of smart crosswalks in the context of distracted driving. This study investigates the effectiveness of smart red LED crosswalks under different non-driving related task (NDRT) conditions, using surrogate safety measures and subjective mental workload assessment.

EXPERIMENTAL PROGRAM

We designed a 2 (smart vs. conventional crosswalk [Figure 1]) × 2 (low vs. high NDRT complexity) within-subject experiment involving thirty-six participants. Four urban night-time scenarios were simulated to replicate the combination of the two experimental factors.
The pedestrians were always hidden by a parked vehicle near the crosswalks and started crossing with a time gap acceptance (PTGA) of 4 s alternatively and randomly from left and right sides (Angioi & Bassani, 2022). Only data referred to crossings from the right side were analysed.
During the Low Complexity NDRT, participants mentally performed a series of two-digit arithmetic operations involving additions without regrouping, while with the High Complexity NDRT, the arithmetic operations involved additions with regrouping and memory component (Harbluk et al., 2007). The NDRT was administered always 200 m before the crosswalks. The observed variables were analysed with the repeated measures ANOVA.

(a) (b)

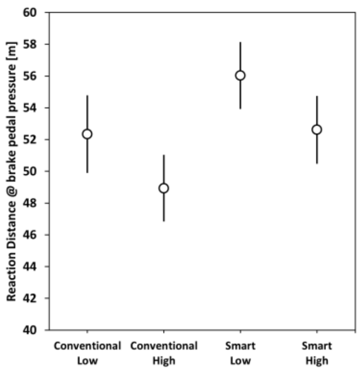
Figure 1. Crosswalks (a) without, (b) with smart red LED strips. In the smart crosswalk, the light was activated when the pedestrian stepped inside an area monitored by a set of virtual cameras.

RESULTS

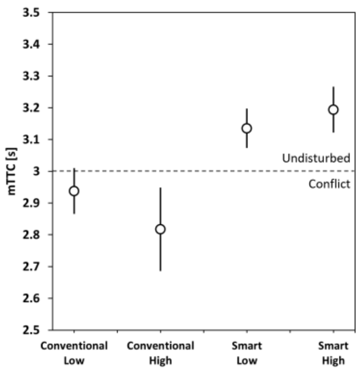
We measured (i) the speed at the first brake pedal pressure when the drivers reacted to the presence of the pedestrian, (ii) the reaction distance at the brake pedal pressure (i.e., the distance between the crosswalk and the car position when the driver reacted using the brake pedal), (iii) the mTTC, and (iv) the subjective mental workload with the NASA-TLX questionnaire.

The speed at the brake pedal pressure was significantly affected by the NDRT complexity ($p = .002$), but not by the crosswalk configuration ($p > .05$). The reaction distance (Figure 2a) was significantly affected by the crosswalk configuration ($p = .012$) and by the complexity of NDRT ($p = .027$). The mTTC between vehicle and pedestrian (Figure 2b) was significantly influenced by the crosswalk configuration ($p < .001$), but not by the different complexity of the NDRT ($p > .05$).

The results demonstrate that smart crosswalks led to faster driver reaction, i.e., longer reaction distances. This finding highlights the safety benefits associated with smart crosswalks. The increase in reaction distance was observed for both low and high complexity tasks. It is worth noting that the high complexity NDRT had a detrimental effect on drivers' perception and reaction time.



(a)



(b)

Figure 2. (a) Reaction distance at brake pedal pressure, and (b) mTTC. The dots represent the average value, the lines represent the SEM.

Furthermore, we obtained promising results from the minimum Time-to-Collision (mTTC). If with the conventional crosswalks almost all mTTC values were lower than 3 s, i.e., the threshold that separate unsafe (mTTC < 3 s) from safe (mTTC > 3s) conflicts, with smart crosswalks all mTTC values exceeded 3 s. This is a relevant achievement indicating that this technology is effective in improving safety when a driver must give priority to a pedestrian. Even though the high complexity task had a negative influence with conventional crosswalks, with smart crosswalks slightly higher mTTC values were recorded for the high complexity task with respect to the low complexity one. This outcome has a remarkable impact on pedestrian safety.
Finally, the NASA-TLX questionnaire, revealed that the manipulation of task complexity was effective in influencing drivers' mental workload ($p < .001$). Participants reported a higher mental workload when engaged in the high complexity task compared to the low complexity task.

CONCLUSIONS

The introduction of red LED strips at midblock crosswalks promotes better driver reaction times to the presence of pedestrians, ensures undisturbed vehicle-pedestrian interactions, and mitigates the effects of highly complex distracting cognitive tasks on drivers, thereby improving overall pedestrian safety.

SHORT REFERENCE LIST

[1] European Commission (2021) Facts and Figures Pedestrians. European Road Safety Observatory. Brussels, European Commission, Directorate General for Transport. *https://road-safety.transport.ec.europa.eu/system/files/2023-02/ff_pedestrians_20230213.pdf*
[2] Angioi, F., Portera, A., Bassani, M., De Oña, J., Di Stasi, L.L. (2023). Smart on-Road Technologies and Road Safety: A short overview. *In XV Conference on Transport Engineering, CIT2023.*
[3] Angioi, F., & Bassani, M. (2022). The implications of situation and route familiarity for driver-pedestrian interaction at uncontrolled mid-block crosswalks. *Transportation research part F: traffic psychology and behaviour, 90, 287-299.*
[4] Harbluk, J. L., Noy, Y. I., Trbovich, P. L., & Eizenman, M. (2007). An on-road assessment of cognitive distraction: Impacts on drivers' visual behavior and braking performance. *Accident Analysis & Prevention, 39(2), 372-379.*

Dynamic modulus and phase angle predictions of asphalt mixtures: a comparative analysis of single and ensemble ML algorithms

Fabio Rondinella[1], Nicola Baldo[1] and Bernhard Hofko[2]

[1]*Polytechnic Department of Engineering and Architecture (DPIA), University of Udine, Udine, Italy,*
fabio.rondinella@uniud.it, nicola.baldo@uniud.it
[2]*TU Wien, Institute of Transportation, Vienna, Austria* *bernhard.hofko@tuwien.ac.at*

ABSTRACT: Over the past few years, novel soft-computing techniques based on data-driven approaches are gaining growing acceptance in the field of pavement engineering. The goal of the present study is to develop single and ensemble machine learning algorithms for the simultaneous prediction of dynamic modulus and phase angle of several asphalt mixtures (AMs), thus characterizing their mechanical behavior. The encouraging results obtained could become part of pavement design procedures in order to improve the sustainability of transport infrastructures by optimizing the contents of AM components.

KEYWORDS: Dynamic modulus, Phase angle, Machine learning, Artificial neural networks, Decision trees, Support vector machines.

INTRODUCTION

Road pavements are crucial in the realization of road networks, and asphalt mixtures (AMs) represent the leading technological solution for their construction. In their conventional composition, these mixtures are mainly composed of aggregate, filler and bitumen and, as a result, they exhibit a traditional viscoelastic behavior. One of the best parameters to summarize such a mechanical response is the complex modulus E*, defined by a dynamic modulus |E*| and a phase angle φ. Since these parameters are extremely important to design asphalt pavements and evaluate their performance [1], many empirical equations have been developed over the years to predict them. The objective of this study is to design several machine learning (ML) procedures for the simultaneous prediction of both parameters and to compare their performance with the more established empirical equations. Single (state-of-art artificial neural network - SoA ANN, support vector machines - SVMs) and ensemble (decision tree-based categorical boosting - CatBoost) algorithms are investigated to develop the most reliable methodology in terms of prediction accuracy. The extensive dataset used to train the models resulted from an experimental campaign carried out on nine mixtures prepared with two different aggregates (diabase and limestone) and both with unmodified and polymer-modified binders. A number of 1680 four-point bending test (4PBT) observations were recorded under several temperature and frequency conditions. SoA ANN and CatBoost achieved very encouraging results and outperformed both empirical equations and their SVM competitors. Their simultaneous and reliable prediction of |E*| and φ could be implemented in the well-established design procedures, thus enhancing them with these promising ML approaches.

EXPERIMENTAL PROGRAM

Surface layer mixtures (AC11 and SMA11) were prepared using diabase aggregate, whereas binder and base mixtures (AC22 and AC32) were prepared using limestone aggregate. Both unmodified and polymer-modified binders were used to prepare the mixtures and, with respect to the filler, powdered limestone was always the choice. All the mixtures were prepared with the optimal binder content, determined according to the Marshall procedure. A displacement controlled 4PBT analysis was carried out in accordance with EN 12697-33. Temperatures ranged from −15°C to +45°C, whereas frequency ranged from 0.1 Hz to 40 Hz for each temperature. At the beam-bottom, the amplitude of the horizontal strain was set equal to 35 μm/m. Based on time-temperature superposition principle, the resulting master curves are represented in Figure 1.

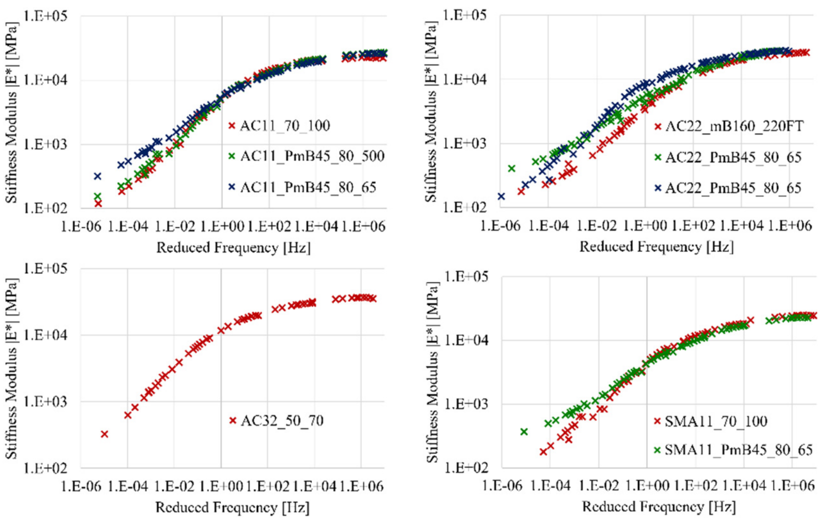


Figure 1. Master curves of the analyzed asphalt mixtures.

RESULTS

The empirical equations implemented in this methodology are Witczak-Fonseca and Witczak 1-37A [2], currently used in US M-EPDG. To fairly compare both the performance achieved by the developed and optimized machine learning models and the implemented empirical equations, input features were kept fixed as those used in empirical equations, namely $\rho_{3/4}$ [%], $\rho_{3/8}$ [%], $\rho_{No.4}$ [%], $\rho_{No.200}$ [%], AV [%], V_{beff} [%], f_l [Hz], T [°C], η_b [10^6 Poise], A, VTS, plus a categorical variable to identify the mixtures. With respect to the output features, Witczak-Fonseca and Witczak 1-37A equations could only predict |E*| [MPa], while all the ML algorithms were able to predict both |E*| and φ [°]. To determine the reliability of each predictive model, mean absolute error (MAE), root mean squared error (RMSE), and R^2 metrics have been reported in Figure 2 with respect to |E*| predictions [3] by way of example.

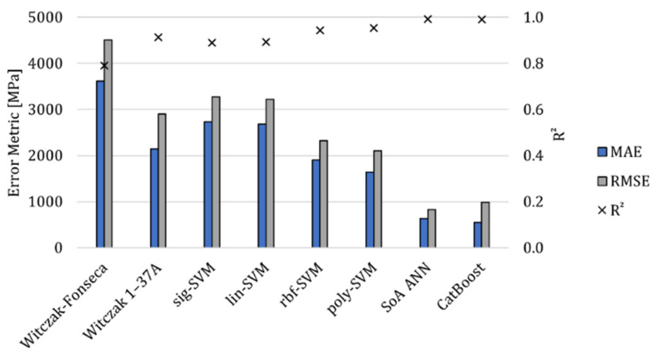


Figure 2. Predictive performance comparison between the models.

CONCLUSIONS

- Variables required as input can be easily determined during a preliminary mix design, minimizing laboratory efforts;
- ML algorithms were capable of simultaneously predict both |E*| and φ, reducing the need for additional expensive lab tests;
- SoA ANN and CatBoost showed remarkable performance allowing predicted parameters to be easily implemented in the most common asphalt pavement design procedures.

REFERENCES

[1] H. Ding, M. Yuan, H. Hu. Establishing prediction master curve of dynamic modulus of asphalt mixture considering randomness of aggregate morphology. Constr. Build. Mater. 294 (2021) 123575.

[2] M. J. Bari, M. W. Witczak, Development of a new revised version of the Witczak |E∗|: Predictive model for hot mix asphalt mixtures. J. Assoc. Asph. Paving Technol. 75 (2006) 381–423.

[3] F. Rondinella, F. Daneluz, B. Hofko, N. Baldo, A Machine Learning Approach for the Simultaneous Prediction of Dynamic Modulus and Phase Angle of Asphalt Concrete Mixtures, International Conference on Advanced Research in Technologies, Information, Innovation and Sustainability (ARTIIS) 2023, Madrid, Spain.

The Dynamic Wireless Power Transfer Project: the Experimental Development of an Innovative Technology towards the Decarbonisation of Transportation Systems

Rosalba Simeone[1], Antonio Montepara[2]
[1]*University of Parma, Parma, Italy, rosalba.simeone@unipr.it*
[2]*University of Parma, Parma, Italy, antonio.montepara@unipr.it*

ABSTRACT: In the recent years, with the rapid development of electric vehicles (EVs), the design and evaluation of different solutions for recharging these vehicles have been the subject of numerous studies. In particular, dynamic inductive charging appears as a promising charging solution, offering several advantages: no physical connection with the vehicle, no manipulation by the user during charging, and reduced risk of damage and vandalism of the system, which is integrated in the road. Several partners from industry and academia, automotive and industrial fields are participating in the following project to conduct a comprehensive analysis of the infrastructural, energy and environmental aspects of this innovative system. The research path followed two lines of experimentation. One on a large scale which consists of construction of a test track called "Arena del Futuro", equipped with the Dynamic Wireless power Transfer technology; the track is designed to test new materials and power system solutions aimed at research and system optimization. The other, on a small scale, sees the reproduction of the same technology used in the real circuit, but in the controlled laboratory environment where each variable that makes up the complex system can be modified.
KEYWORDS: Decarbonisation, Electric Roads, DWPT (Dynamic Wireless Power Transfer) system, Electromagnetic Flux

INTRODUCTION

In this short article it will be reported the main points concerning the field experimentation, on a real scale, and the reproduction of the system on a small laboratory scale in order to manipulate the organization of the variables and investigate as many possible operating scenarios.

Each test environment has been indispensable for the conduct analysis and the development of results necessary for the resolution of problems and the improvement of the complex system of electric roads and functioning with the DWPT technology. From the on-site experimentation it was possible to obtain the efficiency of the electrical system in terms of energy transmitted to the vehicle and the quality parameters of the materials used for the construction of the circuit. Instead, in the experimentation reproduced in the laboratory, it was possible to test several types of materials at the same time and to investigate at every single moment which were the best options for the materials used by studying the progress of the aging of the single materials used on the track. This has a double advantage: the first is the timely and economical understanding, resolution and management of problems generated by the operation of a completely new system on site, the second is the possibility of testing as many alternatives as possible at the same time allowing to speed up the times of research and development. Obviously, the main goal of the experimentation aims to identify how to improve or change the system components in order to obtain maximum efficiency in terms of recharging of electric vehicles and durability of the road pavement [1].

EXPERIMENTAL PROGRAM

The large-scale experimentation involved the construction of 1 km long track, with a ring-like plan shape, powered by 1 MW and to allows vehicles to sustain speeds up to 100 km/h. In order to test as many possible applications, the circuit is composed along its length by 8 types of road cross sections differing in the thickness of the layers, granulometric curves used for the mix designs and types of innovative additives used to increase the performance of the bituminous conglomerate. The tests are carried out with all-electric vehicles New Fiat 500 and an Iveco Intercity bus. Power transfer occurs between transmitting coils located under the road surface, specifically in a protective grout box located below the road paving package made up of the binder and wearing layer, and receiving coils installed onboard the vehicles. Each coil can transmit a power up to 40 kW, so the total power received by the vehicle depend on the number of receiving coils with which it is equipped. The transmitting coils are powered only when a vehicle passes above through Management Units (MUs) placed beside the road. Every MU contains inverters for converting DC into high-frequency current needed to ensure a good coupling and high-power transmission efficiency. Therefore, since to the test ring circuit has been completed both from the point of view of civil infrastructure and electric power system works and it is ready to face the testing phase, the installation of measuring systems for the detection of electrical quantities (voltage, power, current, etc.) are measured with appositive devices. The measurements and analyses are performed both on the plant and infrastructural side, as well as in terms of overall system efficiency with devices positioned on the prototype vehicles circulating during the tests on the track (Figure 1).

Figure 1. Measurement of magnetic field on board of the vehicle (left) and measurement system of electric quantities in the correspondence of MU and in AC/DC substation (right)

Other mechanical characterization tests are carried out to evaluate the performance of the road infrastructure. Tests of a destructive nature such as Ultimate Tensile Strength, Resilient Modulus and Complex Modulus of the bituminous conglomerate are carried out on the extraction of cores from the pavement of the circuit on a quarterly basis.

Non-destructive tests such as the Following Weight Deflectometer are performed to obtain rapid measurements about the evolution of the physical and chemical characteristics and mechanical performance of the 8 cross sections making up the circuit. In the laboratory, the line of work followed for the experimentation was different and focused on the research of materials and the evolution of their chemical, physical and mechanical properties following the time of exposure to the electromagnetic flux. To achieve this, a special experimental protocol was designed. It starts from the calibration of the same wave frequency of the electromagnetic field that is generated by the coils in the real circuit up to the elaboration and construction of an apparatus for measuring the fundamental variables which discriminate the quality and the efficiency of the system operation. An identical coil, to the one placed on site, is put into operation thanks to instrumentations capable of reproducing the same working pattern as a MU. First of all, a working direct current power supply with requirements of 50 V and 50 A feeds a wave generator which drives the wave frequency at which the coil must work. Subsequently, a second minor power supply, called coil controller, was connected directly to the coil and governs the correct functioning and the exact wave frequency generated. Therefore, the task of the coil controller is to modular the power of the electromagnetic flux to perfectly reproduce the conditions generated on site, in a stable manner and without loss of efficiency. To check that the assumption actually occurs, sensors have been positioned. Magnetic field sensors capture the trend of the electromagnetic flux in the space and temperature sensors detect the overheating of the system due to the operation of the coil components. A structure in non-magnetic material, to avoid the creation of disturbance effects or interference with the electromagnetic field, was then mounted above the coil. Samples of bitumen and bituminous conglomerate are then positioned on the non-magnetic structure to study the evolution of the aging of the materials due to the effect of the magnetic field. The aging that is reproduced in the laboratory is clearly of the accelerated type as the coil is kept active 24h/7days; while, on site the coils work only when it happens the recognition of the metal mass of the vehicle and takes place the communication between the source device, the coil, and the receiving device, the vehicle battery (Figure 2).

Figure 2. Preparation of one of the floors of the non-magnetic structure to support the specimens with its sensors (left) and framing of the coil with all the necessary instrumentation for its operation (right)

EXPECTED OUTCOMES RESULTS AND CONCLUSION

The project is currently under patent and many of the most interesting results obtained cannot be published yet. Despite this, on site, thanks to the simultaneous experimentation carried out in the laboratory, it has already been possible to reach 92% of the efficiency of the system by making the utility car and the Intercity bus travel at an average speed of 80 km/h and 60 km/h respectively. One of the next research objectives will be to try to develop a functional calculation model to derive the aging due to the inductive load of the electromagnetic flux on road materials by setting the main variables: the frequency of the electromagnetic wave and the temperature generated by the functioning of the system [2].

REFERENCES

[1] S. Laporte et al. (2019) ”Dynamic Wireless power transfer Charging Infrastructure for Future EVs”, World Electric Vehicle Journal

[2] J. Linden et al. (2017) “Method for Calculating Coefficients in Dynamic Energy Transfer for Electric Vehicles”, Electric Vehicles International Conference.