

30th  INTERNATIONAL
**BALTIC
ROAD**
CONFERENCE

30th International **Baltic Road** Conference



August 23–24, 2021

Abstracts

DEAR COLLEAGUES!

Desperate times require bold solutions.

Therefore, for the first time in the history of the Baltic Road Conferences we have decided to hold the 30th International Baltic Road Conference as a fully virtual event.

With this approach we hope not only to facilitate the participation of delegates who traditionally take part in our events and would not be able to travel this time, but we also strive for extended participation of any interested individual or organisation around the world.

Dedicated keynote sessions and 60 reports presented in 4 parallel technical sessions of the 30th International Baltic Road Conference provide the quintessence of technical expertise of the Baltic States, as well as, Eastern and Western Europe.

IBRC team

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This collection contains abstracts of the reports to be presented at the 30th International Baltic Road Conference, August 23–24, 2021.

The abstracts are grouped in accordance with seven main themes of the Conference and sorted by submission date.

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01

FUTURE MOBILITY, STRATEGIC PLANNING & ROAD FINANCING

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European ITS platform – rethinking ITS

Orestis Giamarelos (Federal Highway Research Institute) and
Tobias Reiff (Federal Highway Research Institute)

The expectations placed on the existing European transport infrastructure are increasing due to the growing mobility needs of the population on the one hand, and the rising volume of freight traffic on the other. At the same time, we intend to improve the quality of life of the European citizens by reducing emissions. We have agreed to make Europe climate-neutral by the year 2050 and to further reduce the number of road fatalities and injuries. In order to ensure security of supply by maintaining supply chains, individual freedom of travel together with climate goals and traffic safety in the future, an efficient use of the existing road infrastructure through the use of new and innovative technologies is indispensable.

The aim of the European Platform for ITS (EU EIP) is to increase the efficiency of the TEN-T core network through a better use of the existing infrastructure by implementing Intelligent Transport Systems (ITS). The EU EIP fosters interoperability and the development of uniform technical standards by monitoring and disseminating the results delivered by the CEF ITS Road Corridor Projects.

One major outcome is the drafting of the "Reference Handbook for Harmonized ITS Core Service Deployment in Europe". This digital freely available handbook supports the European Road Operators and Road Authorities by including the following important features:

- deployment Guidance for 14 different ITS Services, including DATEX reference profiles;
- guidance on the provision and use of traffic information provided under the European Directive (2010/40/EU);
- C-ITS developments;
- 100 Best Practices.

CoDEC: connected data for road infrastructure asset management

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Road infrastructure asset management is rapidly transforming into a digital environment where data accessibility, effective integration and collaboration and accessibility from different sources and assets are key. However, current asset management processes are not yet fully integrated or linked, and there are incompatibilities between various systems and platforms that limit the ability to integrate asset management with BIM. The CoDEC project has sought to understand the current status of information management for assets, including inventory, condition and new data sources such as sensors and scanning systems, to identify the challenges and needs for linking and integrating different data sets to support effective asset management. As a result, CoDEC has developed a data dictionary framework to help link / integrate static and dynamic data for the 'key' infrastructure assets (road pavements, bridges, tunnels). This will enable BIM and Asset Management Systems (AMS) to exchange data and help optimise and integrate data management across systems and throughout the different asset lifecycle phases, from build to operation. This work will be followed up with three pilot projects to demonstrate the feasibility of integrating asset data from various sources through linked data / semantic web technology to build the connection between AMS and BIM platforms.

Implementation of road asset management in Poland

Adam Zofka (Road and Bridge Research Institute (IBDiM)) and
Andrzej Maciejewski (General Directorate for National Roads
and Motorways (GDDKiA))

Road asset management (RAM) is a crucial aspect in the development of transportation network. RAM framework should be understood as a rational approach to business model for road authority, which dictates its business processes in a systematic and objective-based manner to ensure that strategic goals of an agency are reached. In the case of road network, such objectives are typically related to travel safety, time and comfort that should be maintained throughout the life cycle of the road assets at optimal costs. As such RAM enables road agencies to meet expectations of its customers to provide safe and reliable road network in effective and efficient way. Nowadays it becomes even more important to adopt performance-based and data-driven approach for road agencies considering current trends in transportation like connected, cooperative and automated mobility.

There are many aspects of RAM including legal, economic, technical and managing aspects. These aspects are inter-connected, and nowadays agencies build and incorporate RAM system to establish a common denominator for all agency activities at all organizational levels. This paper discusses selected aspects of RAM in Poland. Since national road network in Poland is relatively new, it is particularly important to go over well designed and detailed implementation process. It should comprise numerous items, including self-assessment and gap analysis, change strategy and transportation asset management plan (TAMP). This paper presents an update on these activities as well as future plans in order to establish modern, effective and sustainable RAM framework in Poland.

Construction of express roads in Latvian state main road network

Dace Bērziņa (Latvian State Roads)

Latvian State Road Development Strategy for 2020–2040 was approved in the year 2020. It is a vision that includes long-term perspectives, strategic goals, tasks and priorities for road network development, and it is created for more efficient planning of state road network development as well as for attracting additional funding for state owned roads.

The aim of the Strategy 2040 is to create an efficient road network ensuring that the bypass of the Riga City is accessible within two hours from every national and regional development centre in Latvia. Development centres would be accessible within 45 minutes from every Latvian urban settlement along state regional and local roads.

The strategic task is to create sections of express roads in the total length of 1000 kilometres, thus improving traffic safety and reducing the emissions of greenhouse gases.

When creating the Strategy 2040, both the changes in traffic and road use and the changes in the location of population were studied. The Strategy foresees that high-speed express road sections would connect the Riga City with the biggest cities. The proposed plan of road network development is created with the aim to cover as large a population as possible.

Special attention is paid to the Riga City, as it serves as the central hub for Latvian and Baltic transportation. After the implementation of Strategy 2040, the Riga City would be reached within 30 minutes from the nearest development centres.

The first highway infrastructure PPP project in the Baltic States according to DBFM model – challenges and opportunities

Ilze Kristīne Apsalone (Latvian State Roads), **Verners Akimovs** (Latvian State Roads), **Indra Muižniece** (Latvian State Roads), **Liesma Grīnberga** (Latvian State Roads)

Ķekava Bypass public private partnership (PPP) project is the first highway infrastructure PPP project in the Baltic States to be implemented according to the Design-Build-Finance-Maintain (DBFM) model. Its objective is to solve the 'bottleneck' of the TEN-T network road section entering Riga City with only one lane in each direction. The duration of the project is 23 years, including 3 years for design and construction of the infrastructure and 20 years for its maintenance. Ķekava Bypass consists of the main road – 17.22 km, auxiliary roads – 20.66 km, 2 tunnels, 5 two-level road junctions, 1 bridge (all in all more than 100 lane km), 2 pedestrian bridges / tunnels, etc.

The Latvian government required that the assets of the Ķekava Bypass project are classified off government balance sheet during the whole duration of the PPP contract. Thus, the Ķekava Bypass PPP tender documentation was elaborated strictly observing this off-balance sheet treatment frame. Eurostat assessed the project documentation and issued its opinion that the project corresponds to the off-balance sheet criteria.

Latvian State Roads on behalf of the Ministry of Transportation launched the Ķekava Bypass tender in December 2018. The tender was implemented in four sequent phases, namely, the qualification phase, the submission of initial offers, negotiations with the selected bidders about the initial offers, the submission of the best and final offers. On August 13, 2020, Latvian State Roads announced the winner, and the financial due diligence phase to be performed by financial institutions started.

Planning of state road renewal in the context of territorial reform

Salvis Skabs (Latvian State Roads)

In 2021, a new territorial reform will be carried out in Latvia, and the number of existing 110 local governments will be reduced to 42 regions (previous territorial reform in 2009 resulted in the decrease of the number of local governments from 486 parishes down to 110 municipalities).

Each territorial reform has always regarded the importance of the network of state owned roads in ensuring successful operation of local governments, management of their territories and provision of municipal services to local inhabitants.

After the previous territorial reform carried out in 2009, there were 104 centres of local governments that were not connected with paved roads. At present, only 59 such centres without paved road connections have remained, and improvements on roads serving these local governments are continued in the scope of annual improvement programmes financed from the state budget.

The Ministry of Environment and Regional Development within the scope of the new territorial reform in 2021 is preparing a new Investment Programme for Road Development in the Context of Territorial Reform. Respective road sections are identified by the administrations of planning regions in co-operation with local governments, the programme itself is compiled by the Ministry of Environment and Regional Development, but State Joint Stock Company "Latvian State Roads" is providing consulting on the choice of most efficient rehabilitation methods, preparation of technical documentation and potential construction costs.

Development of Via Baltica in Lithuania

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and **Jolanta Nemaniūtė-Gužienė** (State Enterprise Lithuanian Road Administration)

The total length of Via Baltica corridor, which consists of five roads (A5 Kaunas–Marijampolė–Suwałki, A1 Vilnius–Kaunas–Klaipėda, A8 Panevėžys–Aristava–Sitkūnai, A17 Panevėžys bypass, and A10 Panevėžys–Pasvalys–Riga) makes up 268 km on the Lithuanian territory. In 2019, the highest traffic volume in this corridor was 55,942 veh/day.

It is the highest-volume heavy vehicle road carrying the greatest loads. Via Baltica is a transit road; therefore, it shall comply with the requirements set to high quality roads. In 2020–2030, it is planned to implement 9 projects, the total value of which is ca EUR 704 million (194.18 km to be reconstructed). Until 2018, having implemented EUR 156 million projects, Via Baltica road A5 Kaunas–Marijampolė–Suwałki 17.24–56.83 km section (from Kaunas to Marijampolė) was reconstructed into a motorway by the end of 2018. Currently, preparations are made for Via Baltica reconstruction from Marijampolė to the Lithuanian-Polish border (A5 road from 56.83 km to 97.06 km). Strategic Environmental Assessment has already been completed, and a special territorial planning document has been approved by the Lithuanian Government. According to this document, the road section shall be widened up to four traffic lanes by constructing two safe grade-separated intersections (viaducts) and roundabouts, connecting roads, a new heavy vehicle parking lot by widening the existing bridges, by building new bridges and by implementing various environmental protection measures. At present, design works of the above-mentioned 40.23 km-long-road section are underway. The works are due to be completed by the end of 2025.

Transformation of Lithuanian road charging

Darius Ražinskas (State Enterprise Lithuanian Road Administration)
and **Aidas Saladžius** (State Enterprise Lithuanian Road Administration)

The current road user charge in Lithuania is based on a temporary system and is not connected to the actually covered mileage. The time-based charge is not considered to be socially fair; therefore, the principle 'user pays' and 'polluter pays' shall be employed. The charge to be introduced will take into account the interests of local road infrastructure users who are currently paying unreasonably high charge for a short distance covered.

If the current system is retained and e-tolling system is not established, heavy vehicle drivers would continue paying road user charge by purchasing e-vignette. It would mean that the road users charges paid by vehicle owners / holders would not cover the damages directly made by the user and the current road charging system would not guarantee sufficient financing for the maintenance and development of the road infrastructure.

Legal decisions on electronic road charging system have not been taken yet; however, the project implementation preparation is underway. The latest Parliamentary approvals were received in September 2020, and it is believed that all necessary legal acts will be amended by the end of 2020.

The road charging technology has not been selected yet. However, the conducted project's implementation analysis, the assessment of necessary investments and road charging system maintenance costs revealed that a GPS-based technology would be the most economically feasible one.

It is planned to implement electronic road charging system by the beginning of 2023. Upon the project's implementation, additional financing to ensure high quality and safe main roads should be allocated.

Pavement roughness deterioration dependency on the initial pavement roughness

Paulius Paplauskas (Vilnius Gediminas Technical University),
Audrius Vaitkus (Vilnius Gediminas Technical University),
Andrius Baltrušaitis (Vilnius Gediminas Technical University)

Managing the condition of the road network is essential to ensure sustainable and efficient road maintenance and development. Using asset management systems (pavement management systems) is a modern way to achieve minimized budget costs while maximizing the pavement service life. The term 'asset management' is broad; it describes the actions of infrastructure management – the activities of structure maintenance and operation, asset improvement, and development. Road roughness is one of the commonly used pavement performance indicators of the PMS process at the network level. This study analyzes the impact of road works on the reduction of international roughness index (IRI) depending on the road type and the type of repair. The annual change in IRI is also estimated taking into account certain conditions – road construction class, road type, heavy traffic flow, repair type. The research analyzes the data of control assurance protocols of the road sections repaired in the period of 2008–2016 and the data of routine pavement performance surveys of the Lithuanian road network performed in 2019. The results of the research are meaningful, and it is recommended to include them in the repair selection module used by the Lithuanian pavement management system.

Utilizing effective technology in high-standard road defects inventory system in Estonia

Marek Truu (Teede Tehnokeskus AS) and Romet Raun (Teede Tehnokeskus AS)

Road pavement is expected to withstand enormous traffic loads for long time, but sooner or later the deterioration reaches levels when it is optimal to apply treatment. While easy to measure roughness or rutting in normal traffic speed, defects are in most countries still collected by means of time-consuming visual inspection in low traffic speeds or expensive and difficult-to-use equipment. Also, most visual inspection systems only operate with aggregated inspection data. That makes data-collection expensive and defects-based decision-making inefficient.

In Estonia, defects inventory system utilizes high quality panoramic and orthogonal images to enable data collection in traffic speeds and detailed mapping of pavement defects in 10 classes. Defects mapped in full detail means that location, shape and size of each defect is known and classified data can be effectively used twice in pavement maintenance planning: for section selection planning in road network level when aggregated and for work method selection in design process when analyzed in detail. Combined with measured lidar-based point-cloud data, detailed 3d-basemap saves both road-owner's and road designer's valuable time in design phase.

In the period of 2016–2020, around 35000 km of state roads were analyzed with one of the most efficient road defects inventory systems in the world. Also, around 25000 km of municipal and forest roads have been captured with the same technology covering several pavement types, from bicycle paths to multilane streets and motorways.

The current presentation discusses the outcomes of Estonian defects inventory study in recent years and benefits of the system and the way there.

02

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Roller compacted concrete – best practice of Lithuania

Audrius Vaitkus (Vilnius Gediminas Technical University),

Rafal Mickevič (Vilnius Gediminas Technical University),

Ovidijus Šernas (Vilnius Gediminas Technical University)

In these days, solutions are constantly sought for reducing construction costs, the amount of materials used and the negative impact on the environment. The pavement structures designed with the top layer of traditional concrete become very massive. An alternative to traditional concrete is roller-compacted concrete, the concrete with significantly larger fine aggregates which lead the concrete mix to be non-slip. The roller-compacted mix can also achieve high concrete density and consolidation by rolling. Roller-compacted concrete is also an economical and fast-construction alternative for many pavement applications. In Lithuania, roller-compacted concrete as the top layer is an innovation and first application of it was a few years ago. However, in recent years, application of roller-compacted concrete increased in industrial areas and low-volume rural roads. The best practice of application of roller-compacted concrete was in Klaipeda Free Economic Zone, where roller-compacted concrete was used as the top layer of industrial area for heavy load traffic. Fresh roller-compacted concrete workability decreases with time. To reduce transportation time and avoid excessive moisture loss, which can cause problems in placement of roller-compacted concrete, a mobile concrete batching plant is used. The mobile concrete batching plant was located near the construction site.

Advantages of filler and surfactant additive to improve moisture sensitivity of hot mix asphalt mixtures

Asres S. Alamrew (Kassel University) and **Konrad Mollenhauer** (Kassel University)

Chemical and physical bonding between the aggregate and bitumen binder are the main factors that affect the adhesions and cohesion properties in bituminous mixtures. Moisture damage is the common problem in bituminous mixtures that results in either loss of the adhesion between asphalt-aggregate interface, which is called adhesive failure, or by reducing the cohesive strength of asphalt mastic called cohesive failure.

The objective of this research is to investigate the effect of mineral composition of aggregate on moisture sensitivity of bituminous mixtures and to explore the advantages of filler and surfactant additives to improve the durability of the mix against moisture sensitivity. Three aggregates with different mineral compositions and two bitumen binders with different penetration grade are selected for the study.

The results from the shaking abrasion test show the effects of moisture in mastic asphalt, since the loss of cohesion occurs in the asphalt mastic due to saturation and void swelling by water. Similarly, the rolling bottle test and pull-off strength tests are used to evaluate the adhesive bond between the aggregate and binder. Finally, the result of the indirect tensile strength test is conducted and correlated with cohesive and adhesive strength tests.

The mineral composition of aggregate has significant effects on the moisture resistance performance of bituminous mixtures. In addition, filler and surfactant additives used in this research have advantages to improve the performance of bituminous mixture against moisture sensitivity and improve the long-term performance of asphalt mix.

Asphalt pavement compaction control: relevance of laboratory and non-destructive testing methods

Andrius Baltrušaitis (Vilnius Gediminas Technical University),

Audrius Vaitkus (Vilnius Gediminas Technical University),

Paulius Paplauskas (Vilnius Gediminas Technical University)

Assurance of asphalt pavement layers' compaction, expressed by air voids ratio between field and laboratory bulk density, is one of the main criteria of the durability of asphalt pavement. Thus, destructive measures should be applied and many asphalt samples should be taken on site in order to determine the representative compaction level of the constructed pavement. With the fast development of technologies, new methods should be considered for fast, non-destructive and accurate determination of asphalt bulk density on site. As quite a few non-destructive methods related to asphalt pavements density measurement exist, there is a need for comparison of such methods.

The tests of this research were performed on asphalt base and binder layers composed of AC 22 PS and AC 16 AS. Ground Penetrating Radar (GPR) measurements were made on each completed asphalt layer. 40 test points of each layer were selected and the layer bulk density was determined using two non-destructive technologies (NDT), namely, nuclear density gauge (NDG) and electromagnetic pavement quality indicator PQI, and by drilling cores and testing them in the laboratory. To justify the reliability of the NDT methods, the results were verified by comparing them with the results obtained from the measurement directly on the cores taken from the different asphalt layers.

Evaluation of the residual load-bearing capacity of the existing road using plate loading test

Endijs Virsis (Riga Technical University), **Ainārs Paeglītis** (Riga Technical University), **Atis Zariņš** (Riga Technical University)

In the last few years, as the road construction budget has been decreasing in Latvia, the number of road construction reinforcement design and construction objects has been increasing. At the beginning of the project development, the existing road condition is assessed taking into account various pavement evaluation criteria, and it is determined on which road sections it is possible to reinforce the pavement and where full construction is required. The road pavement structure in Latvia is developed using "Recommendations for road design. Pavement", and inaccurate defining of the bearing capacity of the existing foundation can significantly affect the service life of the designed structure. During the construction of the road, establishing that the bearing capacity of the existing foundation is lower than specified in the project incurs additional costs for the customer. Project changes are made and special solutions are provided in order to achieve the bearing capacity of the mineral material layers defined in the project. One of the most accurate ways to determine the bearing capacity of the existing road structural layers is the static plate test. However, the results of this test are also not 100 % accurate, and any of them may give unreasonable results due to various influencing factors. The aim of this work is to analyze the results of static plate test by determining the most important factors that affect the obtained load-bearing capacity values, identify biased / erroneous test results and determine which results reflect the residual load-bearing capacity of the existing road structure.

Mineral resources of the Baltic countries and aggregates used in transport infrastructure extraction analysis

Mantas Makulavicius (Milsa) and Henrikas Sivilevicius
(Vilnius Gediminas Technical University)

The importance of mineral resources and aggregates used in transport infrastructure or for any other purposes is undeniable. Their usage and extraction not only benefits economics and social environment but also should be sustainable. Regarding this, mineral resources of the Baltic countries and aggregate extraction analysis was conducted. The main purpose of the article is to analyze the situation regarding mineral resources in each of the Baltic countries and provide the extraction data for aggregates used in transport infrastructure. Mining and quarrying sector is evaluated in whole economic context of the countries, and the period from 2008–2020 was analyzed by combining the data from all the Baltic countries for aggregates extraction. The article is valuable for putting all Baltic countries in one perspective and sharing the newest data. Further investigations could include the analysis of factors of aggregates demand and its forecast.

Adverse effects of flaming as a surface treatment method for stone slabs used in road pavements

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Jacek Nowak (Silesian University of Technology)

This paper presents the results of tests on a damaged pavement made of flamed granite slabs. Due to their architectural value, the use of such pavements made of stone materials is a popular trend in Europe, especially in historic city centres. Flaming is a popular method of surface treatment of stone elements, including slabs. The use of flame with a temperature around 1300 °C on granite rock leads to allotropic transformations of quartz. The accompanying volume changes lead to flaking of the surface. As a result, the flaming gives the slab a natural texture and improves its anti-slip properties. As it was assessed, most slabs used in pavements exhibited characteristic edge and corner damage. Examination of the mechanical properties of rock taken from a slab revealed different results for the samples taken from the high temperature impact zone and from other parts of the slab. The mineralogical tests carried out on samples from the high temperature impact zone showed changes in relation to the original mineralogical composition of granite, including the presence of glaze. These changes resulted in the accumulation of stresses, especially in the areas of slab edges and corners. The analysis of the test results was made in relation to the lack of uniform European standards for stone treatment by flaming and the lack of control procedures for this process. As a result of unrestricted flaming conditions, the originally homogeneous properties of the rock may vary within a single product and lead to its accelerated degradation during exploitation.

Motivational bonus-system based on pavement installation temperatures measured by thermographic system (TGS Pavement) in Estonia

Romet Raun (AS Teede Tehnokeskus) and **Marek Truu**
(AS Teede Tehnokeskus)

Paving is one of the most crucial stages in the matter of road lifespan, since it is the surface layer that has stand up to all the external factors (weather, traffic, etc.). Insufficient pavement density caused by thermal segregation during paving works can reduce the lifespan significantly, especially in Estonian climate (freeze-thaw cycles).

Modern technology offers different solutions to reduce the risk of low quality in asphalt production and road paving works. Mobile asphalt plant, feeder and thermo-isolated trailers are equipment that contractor can use to level up the minimal required quality requirements. The question is, when to use those and which to use? Moreover, is there any possibility to motivate the contractors to put in some extra effort?

In Estonia, motivational bonus-system has been established to encourage innovation and reward the extra effort that has been made for quality improvements. The methodology is based on years of experience gained in different researches and pilot-projects. There are no strict rules for the road paving equipment in the methodology – for example, a contractor can choose himself either the feeder or / and thermo-insulated trailers are used or not. The main requirement is that the temperatures of entire paving process (surface layer) have been measured and analyzed by special thermographic system.

Current presentation discusses the symbiosis of bonus-malus system and development of special thermographic system (TGS Pavement) as a multifunctional tool in asphalt paving in Estonia.

Theoretical analysis of the effect of aggregate shape and structure on the stiffness of unbound base layer

Vilius Filotenkovas (Vilnius Gediminas Technical University)
and **Audrius Vaitkus** (Vilnius Gediminas Technical University)

Due to lack of funds or cost savings, most constructive engineering solutions are not always most effective: worse quality materials are used and the physical and mechanical properties of the layers are not guaranteed. As a result, there is an increasing number of cases where the installed structures are damaged before the inter-repair period begins. In order to assess the performance of the road, it is important to evaluate the stiffness modulus of unbound base layers, as it is one of the main input data for designing road structures. The performance of unbound base layers, exclusively for the upper unbound base layers, depends not only on the compaction grade and layer thickness but also on unbound material type, shape, fines content and mechanical properties of aggregates. The aim of this research is to select, analyse and systematize the results of scientific research of determining the properties of the unbound base layer materials' shape and structure, their effect on stiffness modulus and prediction of the performance of the road structure. Based on the results of the research, conclusions and recommendations for further research of the effect of particle shape and structure on the stiffness modulus of upper unbound base layer are presented.

Field studies of MSWI bottom ash as aggregate for unbound base course mixtures

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Audrius Vaitkus (Vilnius Gediminas Technical University),
Ovidijus Šernas (Vilnius Gediminas Technical University)

In the European Union, about 30–40 million tonnes of residues known as municipal solid waste incinerator (MSWI) bottom ash is generated and landfilled annually. To address the continuous growth of landfills and to implement zero waste and circular economy policies, researchers are researching ways to turn MSWI bottom ash into a useable resource. The conducted studies show that MSWI bottom ash is suitable for civil engineering, especially for roads, however, there is a lack of field studies. As a result, MSWI bottom ash was used to construct unbound base course in heavy vehicles parking lot in 2018 and two pedestrian paths in 2018 and 2020 in Vilnius (Lithuania). This paper focuses on the composition of structure and performance of those unbound base courses in terms of stability of particle size distribution, bearing capacity and permeability. The conducted study showed promising results for MSWI bottom ash as an aggregate (mixture) to construct unbound base course.

Optimisation of nano-ZnO and nano-SiO₂ mixing time for bitumen modification

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Nanotechnologies have gradually penetrated the field of bitumen modification, especially where durable asphalt mixtures have to be designed. Longer mixing time, higher temperatures or / and higher rotation (shearing) speeds are used to increase the dispersion of nanoparticles in bitumen; however, this is not necessarily beneficial to the physical and mechanical properties of the final material. As a result, in this study nano-zinc oxide (nano-ZnO) and nano-SiO₂ mixing time for bitumen modification was optimized considering the physical and mechanical properties of the final bitumen. For this purpose, bitumen PMB 25/55-60 was modified with nanoparticles at 180 °C using a laboratory high-shear mixer at a rotation speed of 4000 rpm for different modification time selected on the basis of literature review (60 and 90 minutes). Penetration, softening point, viscosity at 135 °C, recovery and non-recoverable creep compliance (multiple stress creep and recovery test) at 60 °C were measured in order to determine the optimal mixing time. The results showed that 60 minutes ensures the dispersion of nano-ZnO and nano-SiO₂ in the bitumen PMB 25/55-60, and longer mixing time does not have a significant effect on the properties of nano-ZnO and nano-SiO₂ modified bitumen (the difference was less than 7 %).

ViaStructura – a new way of pavement structure design

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Martynas Karbočius (Vilnius Gediminas Technical University)

The catalogues of standard pavement structures are a common way to design road pavements. In 2019, new regulation for the design of standard pavement structures KPT SDK 19 was issued in Lithuania. One of the new requirements requires verification of layer thickness of high-class pavement structures. Such verification should be done by internationally approved mechanistic-empirical methods. In addition, it is recommended to use the same methods to adjust the layer thickness of the selected standard pavement structure for lower classes. These calculations are particularly applicable when the design load (ESAL) is at the lower or upper limit of the class range. Vilnius Tech Road Research Institute experts and outsource IT specialists spent two years for the design model ViaStructura development. Web software based on mechanistic-empirical approach includes the boundary conditions, based on Austria, the United States and Germany experience and the laboratory test results of construction materials. Materials can be selected from the created database which can be simply expanded with new materials by the user. Additional function allows the comparison of separate designed pavement structures. The article presents the concept of the ViaStructura model for the design of flexible pavement structures, reveals its main principles and advantages comparing to the pavement structure selection by the standard catalogue.

Geotechnical analysis of road embankment test sections over soft peat layer in Estonia

Sven Sillamäe (Tallinn University of Technology), **Artu Ellmann** (Tallinn University of Technology), **Sander Varbla** (Tallinn University of Technology)

Various road embankment reinforcements on over a 2 to 4 meter thick peat deposit have been constructed in 2015 in the area of Kose-Võõbu in the central part of Estonia. The test sections consist of five different reinforced road embankments: one and two layers of georeinforcements (woven geotextile), geocell mattress, light weight aggregate (LWA) and expanded polystyrene (EPS) light weight embankment structures with georeinforcement coupled with a section of mass replacement. All test sections were loaded with surcharge in order to accelerate consolidation. Surcharge was removed in 2018 in conjunction of constructing new 11 km of road which was completed in August 2020 followed by opening the road to daily traffic. The test section embankment was regularly monitored by high precise leveling and terrestrial laser scanning to assess the ranges of vertical motions during the entire course of the construction. This paper presents the final geotechnical analysis for the sections and geodetic monitoring results of the first year of road exploitation. The results are used for elaborating geotechnical recommendations for future road constructions over the peat deposits.

Assessment of surface characteristics for coarse aggregates by flowing coefficient method

Arturs Riekstiņš (Latvian State Roads), **Jānis Baumanis** (Latvian State Roads), **Kristaps Krastiņš** (Latvian State Roads), **Kristaps Kalinka** (Latvian State Roads)

In this study, for assessment of surface characteristics, the flow coefficient of coarse aggregates was evaluated as an alternative to the widely used crushed and broken surfaces test. It has been proved that visual assessment is not only time consuming but also inaccurate. The European standard EN 933-5 allows to use a flow coefficient method according to EN 933-6 as an alternative for the assessment of coarse aggregates, but it does not specify any requirements. Therefore, this study aimed to assess the flow coefficient test and if it could replace the tradition visual assessment. In total, 28 gravel samples were tested. The following properties and their influence on the flow coefficient were evaluated – flakiness, particle size distribution and the amount of crushed and rounded surfaces. The results show that the flow coefficient test could be used as an alternative if the boundaries of the granulometric curves are set.

Road design and construction on low bearing capacity soils using piling method: experience of SLLC “Latvian State Roads”.

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(Latvian State Roads), **Mārtiņš Ābols** (Latvian State Roads)

The road system in Latvia has evolved over time to a complex network of physical structures that include roads, bridges and overpasses; however, in large, it consists of narrow roads of local significance that follow the existing topography and consist of thin foundation and pavement layers. In-depth geotechnical research of road sections before construction has only been carried out in recent decades, thereby with a certain regularity SLLC “Latvian State Roads” has to deal with low bearing capacity soils under the road foundation. As the recent experience shows, there are sections of roads that in the past were constructed on peat. In 2018, during the reconstruction works of the regional road P32 Augšlīgatne–Skrīveri a low bearing capacity soil under the road foundation was determined. An additional in-depth geotechnical research showed a bog section with a peat layer at a depth of 10 m in a 320 metres long section. Although at that point it was possible to continue the work using simple soil stabilization methods, there were concerns about the longevity of the investment. To stabilize the road foundation, a combination of gravel columns and unreinforced concrete pile columns was used. A total of 952 columns were constructed. The aim of this paper is to share technical information and our good practice of road design and construction on low bearing capacity soils using piling method, and it gives a summary of field observations, geotechnical research, design considerations and risk management assessments that were carried out in this specific case. The positive outcome of this case led to a number of future projects where similar methods for load bearing capacity improvement were planned and used.

Falling weight deflectometre and plate load test: Direct and indirect comparative testing

Andrejs Taranovs (Latvian State Roads)

Plate load test is a widely used method in Latvia both in quality control and road design processes. This test is performed according to the DIN 18134 standard. Such test usually takes at least 30 minutes and requires a certain load weight. Considering the relatively long time needed for this test, alternatives were sought and a potential alternative was defined to perform testing with Falling Weight Deflectometre (FWD). In order to check this assumption, both direct and indirect testing was performed and correlation between the results of both tests was defined.

In the first case, the test was performed in the same location with both pieces of equipment on a surface of unbound pavement. In the second case, the test with Falling Weight Deflectometre was performed on the surface of bituminous pavement, but the plate load test was performed in the same location on the surface of base course with prior demolition of bituminous layers. In order to compare the results of indirect comparative testing, the backcalculation for the data acquired with the Falling Weight Deflectometre was performed according to the German calculation method.

The results acquired with direct testing showed that the testing with Falling Weight Deflectometre and the plate load test are interchangeable if no characterization of the layer compaction is required. The German method of backcalculation is very simple. Despite positive references from other specialists this method in comparative testing did not show sufficiently good correlation with the results acquired in the plate load test.

Investigation of comparability of TSRST and SCB cracking tests for evaluation of low-temperature properties in asphalt mixtures and use in quality control

Jānis Baumanis (Latvian State Roads), **Arturs Riekstiņš** (Latvian State Roads), **Andris Balodis** (Latvian State Roads)

The mix design procedure for asphalt mixtures in the Baltic region requires ensuring resistance to low temperatures due to the climatic conditions. The Thermal Stress Restrained Specimen Test (TSRST) has been considered as the most precise direct test method to determine the thermal behaviour of asphalt mixtures. As the TSRST test is time-consuming and the equipment is much more expensive, the possibility to use Semi-Circular Bending (SCB) as a preliminary test was evaluated and the potential threshold was recommended. This study presents the evaluation of low-temperature properties with SCB and TSRST methods and the tests suitability assessment for use in quality control. The supplementary rating was made by analysing the results of Fraass breaking point test of asphalt binders. In total 36 different asphalt samples were tested to investigate the fracture test methods and to assess the influence of bitumen type and composition on the resistance to low-temperature cracking. The results displayed an acceptable correlation between both test methods that allow using SCB for pre-screening purposes. At the same time, the results indicated that the type of used bitumen has a crucial influence on asphalt mixtures resistance to low-temperature cracking.

Asphalt concrete frost resistance according to fatigue resistance and stiffness criteria

Nauris Paulovskis (Latvian State Roads)

The formation of snow cover has been unsustainable in recent decades, which means that freezing and thawing are becoming more frequent in Latvia, and that is one of the reasons why asphalt concrete frost resistance matters. Asphalt concrete beams were exposed to multiple freeze-thaw cycles and afterwards tested on a 4-point bending test for stiffness and fatigue resistance. Frost resistance testing for aggregates and concrete is a popular and widely described and used test method worldwide, but there is no such testing standard for asphalt concrete. This study aims to develop a methodology for determining the frost resistance of asphalt concrete by adapting the requirements of cement concrete standart AASHTO C666, as well as to experimentally evaluate the effect of frost resistance on the fatigue strenght and stiffness of asphalt concrete. The results show significant correlation between the asphalt concrete void content and fatigue life after multiple freeze-thaw cycles and correlation between the amount of freeze-thaw cycles and asphalt concrete fatigue life.

Pavement optimisation with aggregate base or asphalt layers stabilised with hexagonal geogrids

Michal Golos (Tensar International) and Piotr Mazurowski (Tensar International)

The use of hexagonal geogrids in pavement structures results in the increase of the life of designed structure. This offers the possibility to reduce the thickness of layers without reduction of pavement life or to increase the traffic capacity of a pavement without the need to increase its thickness. This way of using geogrids in pavements design was introduced to the pavement industry by a producer of hexagonal geogrids as a Pavement Optimisation (PO) concept. It can be transformed into both economic and environmental benefits, and, obviously, results in savings of natural resources and reduction of carbon footprint of a project.

PO with geogrids can be used both in the newly designed pavement structures and in the asphalt overlays of the existing old pavements. Asphalt overlays enhancement with a geogrid either increases the fatigue life of overlays or allows the reduction of overlays thickness to achieve the same pavement life. In new pavements, the stabilisation of aggregate base with geogrids increases the stiffness of aggregate, which increases the performance of a whole pavement.

This paper presents the results of several tests which confirm beneficial effects of using hexagonal geogrids in asphalt overlays and aggregate base layers, from laboratory to full scale accelerated pavement tests. Also modifications of mechanistic-empirical pavement design method, which allow to implement the geogrid benefits into the design process, are discussed. Finally, the case studies of pavements – newly designed and reconstructed – optimised with hexagonal geogrids are presented.

Dynatest LWD in quality control

Ain Kendra (T-Konsult OÜ) and Riho Eichfuss (T-Konsult OÜ)

Since 2017, we have used Dynatest LWD in research and everyday works on construction QC. There are three different generations of LWD devices in the market – Finnish fixed load high stress, German fixed load low stress, and Danish variable stress devices. Measured bearing capacity depends on the stress level used. Actual level in pavement depends on the depth of layer, thus measurements have to be done at the level close to real life if we wish to compare the results with the values.

To compare different devices, Germans have begun with plate load test and Zorn, the US studies compared Dynatest with Zorn and on that base PLT was linked to Dynatest. Tallinn Standard Pavements were prepared in 2015 and improved in 2019, based on Finnish InfraRYL approach, with an option to use LWD for QC. We use it also in civil works for foundation bearing capacity control.

Laboratory tests have shown that the use of geosynthetics within the field of impact of LWD reduces significantly the measurement result – up to one third. Based on the Italian ANAS Technical Specification, LWD can be used for QC of cold stabilized layers. Instead of waiting for a week for the hardening of cement, LWD measurements at 4 hr and 24 hr after compaction can be the proof of acceptance before laying next layers. In Pärnu, replacing of pavement with a cement stabilized base and three-layer asphalt was provided within a weekend, actually the conditions for asphalt were fulfilled at 5.5 hours after the compaction of factory-mixed cement-stabilized layer.

A critical review on mixing parameters for high content reclaimed asphalt mixtures

Mukul Rathore (Ceļu Eksperts Ltd), **Viktors Haritonovs** (Riga Technical University), **Mārtiņš Zaumanis** (EMPA, Swiss Federal Laboratories for Materials Science and Technology)

High content reclaimed asphalt (RA) mixtures have been identified as one of the options to reduce the environmental and economic impacts of pavements construction. However, the process of designing and producing high content RA mixtures is challenging, and the asphalt industry have serious concerns towards the quality and long-term performance of these mixtures. In laboratory, several parameters affect the mixture characteristic, and if not controlled, may result into inaccurate estimation of performance. This state-of-the-art study aims to identify critical parameters for high content RA mixture production and highlight the effects of these parameters on the mixture performance. The mixing parameters adopted in several laboratory studies have been highlighted and compared. The best practices to mix the recycled asphalt in laboratory are reviewed in order to optimize the laboratory mixing. Based on the review, important considerations for evaluating the laboratory performance have been discussed.

Surface texture and layer permeability of aquaplaning resistant asphalt pavements

Audrius Vaitkus (Vilnius Gediminas Technical University),
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Tire / pavement noise is one of the biggest environmental problems caused by the contact between the car tire and the pavement surface. It is known that porous asphalt (PA) pavements have good properties in noise absorption, however, these mixtures could also solve another important problem which appears on roads – aquaplaning. This phenomenon reduces traffic safety and driving comfort. Aquaplaning appears when tires become separated from the pavement surface by a thin water film and the ability to increase braking force or control the vehicle motion is almost entirely lost. However, PA pavements have relatively low durability properties. This research aims to analyse the surface texture and permeability characteristics of aquaplaning resistant asphalt pavements. Four different mixtures with different largest particle size (AT 5, AT 8, AT 11 and AT 16) were tested. Large-scale laboratory testing was performed to evaluate their surface texture and permeability properties. The research revealed that mixtures with 8 % activated mineral limestone powder (AMLPL) showed better mechanical and physical properties than other mixtures with 4 % AMLP and 4 % granite screenings or just 4 % AMLP.

03

BRIDGES

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Adaptation and resilience from a maintenance perspective for swing bridge: Lessons learned in recent retrofitting project experiences

Felipe Collazos-Arias (Unican) and David Garcia-Sanchez (TECNALIA RESEARCH & INNOVATION)

This paper reviews all the existing swing bridges around the world to emphasize the high-level technology performed in early 20th century and analyzes the recent experience in the rehabilitation and retrofitting of a singular swing steel bridge. The bridge over the Asón estuary at Treto, in the North of Spain, showed significant problems, and the structural condition level was critical previously to its intervention in 2015. The rehabilitation project, including the restoration of the structural and functional safety level of the structure, was dealt with after material studies and tests were performed. The new updated structure from the old one of the nineteenth century to the new standard codes was also performed.

Apart from the historical value of the bridge and the 'green' and safe-security aspects, the intervention took into account all the social requirements of the population in the area who recovered the pride in this emblematic and centenarian infrastructure, and it is, itself, a successful intervention from the resilient point of view.

Analysis of quality control plans for the bridge over river Mazā Jugla according to COST TU 1406 methodology

Roberts Auziņš (Latvian State Roads) and **Ainars Paeglītis** (Riga Technical University)

Bridges are one of the most expensive parts of the road network, and therefore in the bridge management process, it is very important to make the most technically and cost-effective decisions on planned actions (such as maintenance, renovation and reconstruction works). The decisions must be based both on the current situation and possible future options and alternatives.

The European Cooperation in Science and Technology (COST) during action TU 1406 "Quality specifications for roadway bridges, standardization at a European level (BridgeSpecs)" in the period from 2014 to 2019 has organized the framework for the development of bridge Quality Control Plans (QCP) including the system of data collection, data processing and outcomes.

This article analyses and compares different Quality Control Plans developed according to COST TU 1406 methodology for the existing bridge over the Mazā Jugla river, located on local road V169 km 3.90 in Latvia.

Viaduct over the Lorupe ravine

Indra Dziedātāja (Latvian State Roads) and Mārtiņš Dambergs (Latvian State Roads)

More than fifty years ago, on 20 July 1968, a viaduct over the Lorupe ravine was opened. It is one of the greatest structures of Latvian bridge builders. In many aspects the structure of the viaduct and its construction technology has been mentioned internationally. It has also started a new stage in the bridge construction in the former superpower – the Soviet Union.

The Lorupe ravine is 30 m deep and 200 m wide with very steep banks. A road was crossing the ravine already in the time of the Russian Tsar in the middle of the 19th century. When automobilization developed, driving on this road was connected with numerous road traffic accidents, especially in winter.

The design work on the new road began in the early 1960s.

The overpass, 200 m long, was designed as two continuous girders of reinforced concrete with a box cross-section. It was a novelty to slide this structure from one side onto the bridge piers. It required additional bearings on which to slide the enormous concrete mass. A solution was found – plates of a super slippery material, fluoroplastic. However, this required a structure never seen before – a structure of flexible piers that would react flexibly to vibrations during the assembly and use. In that time, the structure assembled with this method was the first engineering work of this kind in the former Soviet Union and the second one in the world (Venezuela had the first).

Flexible piers, stressing, assembly, scenic research, methods of ecological approach and the construction process itself involving many road construction companies was a great learning experience for the bridge builders of that time.

The viaduct was reconstructed in 2000.

Methodology for calculation of bridge safety factor in Lithuania

Saulius Zadlauskas (State Enterprise Lithuanian Road Administration) and **Mindaugas Augonis** (Kaunas University of Technology)

The paper reviews calculation methodologies of safety factor of the United States and Slovenia and proposes a method for more accurate estimation of residual strength of bridges designed and built in Lithuania. For more detailed analysis, the main parameters and defects directly affecting the strength of bridges were analysed in detail. In addition, the flows of heavy vehicles, which have significantly increased for previously designed bridges, were assessed.

This article proposes to calculate the dynamic factor of bridges not according to the empirical formulas used in the United States and Slovenian safety factor calculation methodologies. The findings of the bridge dynamic tests conducted in Lithuania showed that the parameter strongly depends on the smoothness and damage of carriageway wearing surface. In order to evaluate the suitability of the Lithuanian bridge safety factor calculation methodology proposed in this article, a real bridge was selected. Its safety factors were calculated according to the above-mentioned and proposed methodology and the obtained results were compared.

04

TRAFFIC SAFETY

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Implementation and efficiency of average speed enforcement systems on Lithuanian roads

Laura Gavėnienė (Vilnius Gediminas Technical University),
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Donatas Čygas (Vilnius Gediminas Technical University)

Average speed enforcement systems have been used on the roads of foreign countries for many years already and give a positive effect on reducing accident number. The scientific paper presents good practices in the use of average speed enforcement systems in various countries and their impact on the improvement of traffic safety. The paper analyses the experience of system installation on the roads of Lithuania and the first results. The paper also proposes methodologies for the selection of road sections to be enforced, the equipment used, and the distribution of road sections in the road network of Lithuania. A detailed analysis is given of the effect of average speed enforcement systems after their installation in three different periods on 25 road sections. The analysed data is differentiated between the main and national roads. Conclusions and recommendations are given at the end of the paper for further development of average speed enforcement systems.

Improving traffic safety by using Waze user reports

Raitis Šteinbergs (SJSC “Latvijas autoceļu uzturētājs”) and **Māris Kligis** (SJSC “Latvijas autoceļu uzturētājs”)

Inspection regularity of the road maintenance crew and the existing types of inspection have not been good enough to reveal what is really happening on the roads. So, the road users' contribution to road traffic safety is very important to ensure fast reaction to different road hazards (for example, pothole, obstacle (tree) or dead animal).

The most common way to report hazards on state roads has been by phone, by email and on social media (Twitter and Facebook). In Latvia, both Latvian State Roads and Latvian road maintaining company ensured these communication channels. Meanwhile, the Waze navigation application already had a functionality to report road hazards – to warn other Waze users. But these road hazards were not solved until someone reported them through the existing channels to Latvian State Roads or Latvian road maintaining company.

To ensure better road traffic safety and faster reaction, the Latvian road maintaining company gained access to the Waze hazards feed and in collaboration with Riga Technical University developed a system for analyzing and processing the Waze data. As a result – the Latvian road maintaining company is able to improve road safety by reacting faster to road hazards reported by Waze users.

Today, the Latvian road maintaining company gets more than 200 reports from road users per month, and up to 70 % of total reports are generated by Waze. The advantages of the Waze data analyzing and processing system are as follows:

- exact hazard location;
- built-in report validation tool;
- Waze is a highly popular report channel in local community (there are no costs of report service providing).

Effect of the tangent element of horizontal alignment on driving speed on two-lane rural roads

Mindaugas Šeporaitis (Vilnius Gediminas Technical University),
Viktoras Vorobjovas (Vilnius Gediminas Technical University),
Audrius Vaitkus (Vilnius Gediminas Technical University)

The lack of coordination between adjacent geometric elements of horizontal alignment can lead to unsafe speed. This paper presents a study on driving speed at tangents on the regional roads. This study evaluated the effect of tangent and adjacent elements of horizontal alignment on driving speed distribution for two-lane rural roads and developed prediction models for operating speed. Spot speed data of vehicles were analysed at 500 road sections. Statistical analysis of the speed data of 300 sites revealed a critical vehicle category. The effect of preceding elements and tangent length on driving speed were analysed, and the critical length of tangent was identified as the most influencing parameter. An operating speed prediction model (OSPM) for tangent was developed using regression analysis. The proposed OSPM was compared to the models developed by various authors; and the related design consistency and traffic safety issues were discussed. The results are expected to benefit both other researchers and the organisations responsible for the development and implementation of normative technical documents for road design.

Identification and analysis of potential risk factors influencing the road safety level at designated pedestrian crossings

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Zsolt Hamza (KTI Institute for Transport Sciences Non-profit Ltd.)

According to the data of the European Road Safety Observatory, around 21 % of all road fatalities in the EU are suffered by pedestrians. In 2019, in Hungary, the road accidents of pedestrians have had a share of 14.6 % in all road accidents with personal injuries, which meant 2535 accidents in which one or more pedestrians were injured. A significant proportion of the accidents occurred at designated pedestrian crossings (43.1 % of pedestrian accidents in 2019), and this trend increased over the last 5 years. To account for the problem, the Institute for Transport Sciences Non-profit Ltd. conducted a research focusing on the identification of potential risk factors which may have a negative impact on the level of traffic safety of designated pedestrian crossings in urban areas. The analysis and ranking of the risk factors have been carried out based on experts' evaluation and scoring with the use of statistical methods. The results of the work explore the risks that need to be paid special attention to when reviewing the existing and establishing new pedestrian crossings.

Traffic management solutions on non-signalised crosswalks in Latvia and their effect on traffic safety

Māris Šeflers (3M)

According to the road traffic accident (RTA) statistics, the vulnerable road users are majority of road fatalities and most of them are pedestrians in Latvia. This study was done with the aim to investigate and analyse the technical solutions of traffic organization that are used on the non-signalised crosswalks in Latvia. Their technical condition and compliance with national regulatory standards were evaluated. The Ministry of Interior data base on the RTA category of collision with pedestrians was filtered and later 32 crosswalks were observed on the spot during the daylight and nighttime in several cities of Latvia; most of them were located in Riga city. The main emphasis was on how pedestrian crossings look from a car driver's seat position, whether they are well enough visible for drivers during the day and nighttime. The type of traffic management solution installed on those pedestrian crossings was recorded, and the technical condition of traffic signs and 'zebra' road marking was analysed. The photographs of drivers' view were analysed by using visual attention software, and it was detected whether there are any obstacles in the infrastructure environment which could influence drivers' visibility when approaching the pedestrian crossing. It was concluded that the condition and performance of traffic organization equipment are not maintained on regular basis by the road authorities and road owners. The lighting of pedestrian crossings is not effectively designed. It is recommended to improve the visibility of pedestrian crossings from the drivers' perspective in the urban areas by increasing the performance parameters of traffic management equipment, especially in the nighttime.

High performance pavement markings enhancing the camera and LiDAR detection.

Gernot Sauter (3M), Marcel Doering (3M), Rik Nuyttens (3M)

It is well known that camera and video sensors have limitations in detecting pavement markings under certain conditions, e.g. glare from sunlight or other vehicles, rain, fog, etc.

First generations of lane keeping systems depend on visual light. Erroneous detection is also resulting from irregular road surfaces such as glossy bitumen sealing strips, rain puddles or simply worn asphalt. The role of higher performing markings and better visual camera detection has been studied with Vedecom France.

LiDAR (light detection and ranging) technology could help to fill the remaining gaps, as it actively sends out IR (infrared) light that returns reliable images of the road scenario and pavement markings both day and night. In order to evaluate the opportunities of LiDAR technology for the detection of road markings, 3M Company and the University of Applied Sciences in Dresden decided to work together in a joint research project.

All-Weather Elements AWE, are the latest development of high-performance optics, using high index beads to provide reflectivity both in dry and wet conditions.

It could be determined that high performance markings help to increase the level of detection by both camera and LiDAR sensors. The AWE marking was detected from significantly longer distances, especially in wet and rainy conditions. In combination with common camera based LKA and LDW systems, the LiDAR sensors can increase the overall detection rate of pavement markings. This is especially important for vehicles with higher SAE levels of automated driving and can support the overall safety of vehicles.

The research also evaluated existing test methods for wet and rain reflectivity in EN 1436 and ASTM E 2832 and how measured performance correlates with LiDAR detection.

Road traffic safety analysis of different junction types on the state roads

Valentīna Āmare (Latvian State Roads) and **Juris Smirnovs** (Riga Technical University)

The highest number of road accidents occurs at junctions. One of the aims of traffic organisation is to improve traffic safety in these areas. Based on a variety of indices – road capacity, points of conflict, number and severity of road traffic accidents – different alternatives for junctions are evaluated. However, the road network has many junctions, and roads serve as a means to travel from point 'A' to point 'B' at a given time. Therefore, one of the most important tasks when addressing the issue of road safety is to find a rational way of improving the safety without losing the importance of the road. The aim of this paper is to analyse the impact of different junctions on the road network and on the basis of actual data develop a method for the evaluation of different types of junctions with respect to the road class.

The development of brightness evaluation method for digital billboards and light objects

Gunta Krūmiņa (University of Latvia), **Līva Volberga** (University of Latvia), **Gatis Ikaunieks** (University of Latvia), **Lauris Naumovs** (Latvian State Roads)

Bright LED lighting elements are already common in urban areas. Their location on streets and roads is attractive due to the active flow of people moving along them. The Ministry of Transport and Latvian State Roads have received complaints from the Riga City Council Construction Board and drivers that certain billboards and decorative lighting objects are too bright and make road visibility difficult especially at night when the risk to the safety of vulnerable road users is the greatest. Latvian State Roads has commissioned the University of Latvia to conduct a study to develop the brightness evaluation method which could be used by infrastructure managers, controlling institutions and installers of lighting objects and could be used during the billboard active operation. We tested the recommended method of OAAA (USA) and concluded that it is not applied for large billboards (over 25 square meter) due to calculated far distance and low sensitivity of lux meter. We have developed a new method based on the display / background illuminance ratio and Unified Glare Rating. The rating helps to determine how likely a display is to cause discomfort to those around it. The lower the value, the less discomfort the driver will experience from the billboard. The new method is applied for the active and different size billboards and using lux meter that is not an expensive device, and that is applied on the road and in the city. Moreover, we take into account the glare effect of advertising on drivers' vision.

The effect of display brightness on visual function of young and old drivers

Gatis Ikaunieks (University of Latvia), **Gunta Krūmiņa** (University of Latvia), **Līva Volberga** (University of Latvia), **Lauris Naumovs** (Latvian State Roads)

Nowadays outdoor advertising displays have become popular. They can affect road safety, disturb drivers' vision, and affect visual attention. The perceived brightness of display luminance usually changes with human age. Older subjects have an increased level of intraocular light scattering (retinal straylight) which causes disability glare. Another important factor is the retinal illumination which decreases with age due to opacities in the eye lens and due to a reduction in eye pupil size. The aim of the study was to assess the preferred level of display luminance for young and old subjects when looking at different contrast objects. 18 young subjects in the age of 20 to 24 years and 10 old subjects in the age of 55 to 69 years participated in the study. The task was by using the method of adjustment to find out the acceptable level of display luminance when the recognition of low (20 %) and high (>90 %) contrast objects was comfortable. The pupil size was determined in each condition. Measurements were done in a dark room. The results showed that with high contrast objects old subjects chose lower ($p < 0.05$) but with low contrast objects the same level of background luminance as the group of young subjects. There was no significant correlation between the acceptable level of display luminance and the pupil size. We can conclude that the preferred level of background luminance for older subjects depends on the objects' contrast.

05

ROAD ROUTINE MAINTENANCE

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A compact road weather station

**Taisto Haavasoja (Teconer Oy), Pauli Nylander (Teconer Oy),
Leena Puhakka (Teconer Oy)**

Road Weather Stations (RWS) have been extensively used for collecting information about slippery road conditions during the last thirty years. Recently, vehicle based mobile road condition monitors have challenged the fixed RWS. A closer study reveals that both approaches have their advantages and can complete each other. Fixed RWS can provide accurate trend data, whereas mobile condition monitors can cover the road sections between RWS. Nevertheless, a traditional RWS is a fairly expensive investment, typically about 30 000 € or much more, and often includes a number of components not essential for the purpose of measuring and predicting road conditions.

To reduce the total cost, we have developed a bare minimum of a fixed RWS including the essential sensor information like road surface state (dry, moist, wet, slush, ice or snow / frost), friction, water and frozen layer thickness, air temperature, road surface temperature, dew point temperature, atmospheric pressure, wind speed and estimated ground temperature at -6 cm. In addition to the sensors, the system includes only a small cabinet with power supply, a battery and a communication unit to transmit the data to a server. This RWS can be easily installed to an existing gantry or to a pole by the side of the highway. All software and firmware as well as sensor calibration can be updated remotely. The first test installation on an existing street light pole took 45 minutes from starting the installation to getting real time data on a road weather online service. To ease the installation, a tiltable mast is available, which can be mounted by the side of any pole so that no special tools, ladders or person lifters are needed for servicing the station. The targeted end user price of the station is one third of the traditional price level.

Why is it important to have a correct road maintenance termstock?

Kai Simson (Estonian Road Administration)

Road maintenance influences every single person, and therefore it is important that terms and concepts are clear and precise.

The terms in the regulations are not always clear and unequivocally understandable. There are also problems with synonyms: there are many terms for one concept and it is not clear which one to prefer. There are problems with the practicality and clarity of the terms, also with the fact that the well-established colloquial expressions are only understandable to people who come into contact with road maintenance on a daily basis.

Therefore, I covered this issue in my survey via reviewing the condition of the Estonian road maintenance terms, using legislation, instructions and other materials which are used to regulate the area. A survey among experts was carried out to get their evaluation of the situation.

The results of the studies show that there is a need to plan the road maintenance termstock in Estonian. Experts pointed out that there is a need for common termstock that all parties would have a common understanding of concept definitions and what terms denote them. It was also pointed out that problems with translations rise because there is no central termbase from where to verify terms and concepts.

Most frequently emerging problems are as follows:

- terms do not have clear concept definitions;
- there are many synonymous terms for one concept;
- inconsistent use of terms in legislation and in the guidelines;
- systematization of terms has not been taken fully into account;
- ambiguous terms are in use;
- there is lack of termstock that would cover the needed terms and have correct concept definitions.

Planning of road maintenance termstock is important for everybody who needs to use terms and concepts – journalists, scientists, maintenance operators, state institutions, translators, etc.

Road temperature forecasting model based on Big Data collected by public transport

Märt Puust (Teede Tehnokeskus AS), **Tanel Jairus**
(Teede Tehnokeskus AS), **Stanislav Metlitski**
(Teede Tehnokeskus AS)

Since 2016, commercial public transport vehicles are used to collect the road condition and temperature data from Estonian state roads. The initial goal was to just share operative data to the maintenance operators and traffic information centre. However, the amount of collected data has grown to a point where it can be analysed using Big Data methods, Artificial Intelligence and Machine Learning.

A unique road temperature forecasting model has been developed before the last winter season (2020/2021) and field tests were carried out on the main road E263 Tallinn–Tartu during the winter season for adjusting the model in different weather and traffic conditions. The model was based on the existing principles of road weather science but improved with the power of new tools from advances in information technology.

While this model was developed and tested mainly on road E263, the underlying principles and technology are robust enough to apply it to other roads and regions. This presentation gives a general overview of the model development and validation process, what was the main achievements and setbacks of the first testing winter, as well as what potential the model has in scaling it to the other roads and regions.

Road deformation monitoring using unmanned aerial vehicles

Sander Varbla (Tallinn University of Technology), **Artu Ellmann** (Tallinn University of Technology), **Raido Puust** (Tallinn University of Technology)

Large-scale road deformation monitoring with conventional surveying methods is a time consuming and labour-intensive task. Instead, unmanned aerial vehicles (UAV) in combination with structure-from-motion photogrammetry are now capable of high-accuracy and detailed surveys. The UAV surveys are contactless, and thus have lower risk factors to the surveyor. To reach the sub-centimetre measurement accuracy, a real-time positioning UAV was employed in a road embankment test section that is constructed over peat deposits in Võõbu, central Estonia. This study confirms that centimetre-level road deformations can be detected with integrated georeferencing that requires a reduced amount of ground control points compared to the conventional indirect georeferencing. The accuracy of the developed method was evaluated by comparing with high-precise levelling and terrestrial laser scanning results. These tests demonstrated that the proposed method can be employed for quick and contactless quantification of magnitude of road deformations.

Comparison of winter maintenance requirements (Estonia, Latvia, Lithuania)

Jānis Kastanovskis (Latvian State Roads)

Three Baltic states are located next to each other on the coast of the Baltic Sea. Similarly to Finland, density of population in these countries is low. All three countries have large amount of state roads with low traffic density.

Climatic differences are minimal. Milder climate is in coastal area but the inland weather conditions are more severe. The average air temperature in January in Estonia is from -2 to -7 degrees Celsius but in Lithuania from -1 to -5 degrees Celsius. The number of snowy days fluctuates from 50 to 120.

All three countries have common contracts for summer and winter maintenance, where the responsibility for maintenance activities lays on the contractors. Despite common history, the methods of the assignment of road maintenance contracts are different in every country.

Estonia awards contracts in open tenders and has performance-based contracts. Latvia has the contract awarded to the State Joint Stock Company "Latvijas autoceļu uzturētājs" (Latvian Road Maintainer) by law, and the contract is unit price based. Lithuania has the contract awarded to the state-owned company "AB Kelių priežiūra", and the contract is unit price based.

The requirements for road conditions are quite similar in all three countries. They have three levels of maintenance.

High service level means snow and ice-free surface of the road pavement during winter in constant weather conditions and quick response in case of worsening road conditions. Medium service level means that snow and ice is allowed on the surface, but activities have to be undertaken to improve skid resistance. The lowest service level means that snow and ice is allowed on the surface and activities to improve skid resistance (mostly only snow cleaning) may be undertaken in some spots only.

In Estonia the expenses for winter maintenance are lower than in the neighbouring countries, but it does not have impact on the traffic safety during winter.

06

SMART ROAD SOLUTIONS & ITS

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Using factory-installed sensor systems for remote on-board weighing

Tanel Jairus (Teede Tehnokeskus AS), **Märt Puust** (AS Teede Tehnokeskus), **Stanislav Metlitski** (Teede Tehnokeskus AS)

In this day and age, all new vehicles are filled to the brim with different sensors. These sensors are used to make the vehicles run smoother and sustainable. However, these devices can also be used for collecting data which would otherwise need substantial investments in infrastructure. This study was carried out to determine the possibility of using on-board-weighing (OBW) equipment to reliably and accurately monitor weights of heavy goods vehicles.

Estonia has long been the leading innovator in managing heavy vehicles via new technologies such as telematics, GIS and ITS. Previous developments such as current road networks for heavy vehicles ('green roads' for winter time and 'purple roads' for whole year) have been widely accepted by logistics companies and road administrators. These developments give strong background for new innovations with OBW equipment.

For this purpose, five trucks were selected, connected and monitored through the fleet management platform provided by FleetComplete. Necessary additional hardware and software developments were done to allow to read the weighing data by telematics devices from vehicles CAN bus using FMS interface and display the data through web interface. For verification purposes, weighing of fully loaded HGV vehicles was carried out with portable scales.

In the analysis part, telematics data was merged with the known road database information on spatial basis. Missing data was modelled using machine learning. Separate models were created for each truck axle. All models had R2 values near or exceeding 0.9 with mean square error less than one ton per axle.

Using computer vision for measuring pedestrian and bicycle traffic on level railroad crossings

Tanel Jairus (Teede Tehnokeskus AS)

There are different methods for measuring pedestrian and bicycle traffic, each has its own shortcomings. Manual counting is very labor-intensive and thus expensive. Sensor systems such as laser or infrared gates or pneumatic tubes have problems with people moving in groups. And people tend to move in groups.

In this study, an innovative approach was used on level railroad crossings using low-cost video cameras and computer vision. On each site, a camera with low power usage was installed nearby with an off-the-shelf battery providing enough power for several days of recording. The recordings were processed with scripts written in Python and employing the YOLO (you-only-look-once) machine vision framework. Both object detection and tracking were employed, and all videos were analyzed twice – firstly for people, secondly for bicycles.

This processing was done on a reasonably powerful desktop computer (AMD Ryzen Threadripper 1900X with 32GB RAM) with a high-powered consumer-grade graphics processing unit (Nvidia GTX 1080) at average on 2–3 frames per second on single thread. Further speed increase was achieved by running multiple threads simultaneously and masking the video outside the region of interest. This produced trajectories of both pedestrians and bicycles, which were compared to the position of the rails on the video in order to determine whether the subject actually crossed the railroad.

Automation of issuing process of permit to use roads by abnormal transport

Modestas Lukošius (State Enterprise Lithuanian Road Administration) and **Rolandas Mazaliauskas** (State Enterprise Lithuanian Road Administration)

Since the end of 2017 the Lithuanian Road Administration (LRA) has taken over from the former State Road Transport Inspectorate the authority to issue permits for oversized and heavy vehicles using the national significance roads. LRA has launched a pilot project for automated authorising system, in which application is submitted by filling an electronic form and providing a driving route on a map. The route in most cases is automatically approved by the system. If there are any restrictions on the route or in case of larger parameters of a vehicle, an LRA specialist shall review it. Upon coordination, the system automatically calculates a charge for the use of roads by abnormal transport and informs the applicant. The applicant pays this charge via electronic banking, and the system automatically issues a permit (such payments make up to 90 %). If the charge is paid by standard transfer, the system automatically issues a permit after the LRA employee has registered the payment details.

E-waybill using experience & development in Estonian state road building

Taavi Tõnts (Estonian Road Administration) and **Aivo Salum**
(Estonian Road Administration)

Estonian Road Administration (ERA) has since 2010 developed digital solutions for abnormal 52 t transport monitoring. In 2020, we signed the memorandum between 8 different parties for developing bulk material transport digital solutions (e-waybill system) for road building.

The aim is to make the logistic more transparent from the beginning of the loading point for the different authorities. The second aim is to make the truck movement corridor visible for the traffic control, avoiding week roads, bridges, etc. The final, and the most difficult task is to develop the mass control system, so that there is automated weight info in the e-waybill system visible for the traffic police and for building supervisors, etc.

We have met with Association of Estonian Cities and Municipalities and many others, and everyone is very interested in going from paper waybills for faster, cloud based, e-waybill systems, which is also more CO2 friendly. This digital e-waybill allows single data entry, and all the rest data with statistics is visible for the concerned people.

ERA is planning to pilot in 2021 also many road building projects with e-waybill demand, after we have drawn the conclusions from 3 ongoing projects from 2020. So far, the feedback has been mainly positive from different parties.

We have started with our Ministry also wider digitalisation projects concerning the new regulation (EU) 2020/1056 of eFTI for the cross-border transport logistics digitalisation, which must be applied in every member state by 21.08.24.

Less temptation to exceed the speed limit, or towards Vision Zero

Viktoras Lapinas (State Enterprise Lithuanian Road Administration)
and **Mantas Kišonas** (State Enterprise Lithuanian Road
Administration)

In 2020, the Lithuanian Government has approved traffic safety programme Vision Zero. One of the complex measures to improve traffic safety and to reduce the number of driving rules infringements is the development of average network of speed cameras on the roads of state significance. It is planned that the network of average speed cameras will cover more than 800 km of state significance road network in Lithuania in 2020–2021. Initially, it was planned to implement these measures only on rural roads. However, taking into consideration the principles of road eligibility for average speed camera installation, some road sections crossing the so-called linear settlements were selected to test the impact of such systems on driving habits as well. It is presumed that from the beginning of exploitation of these systems the reduction in the consequences of severe road accidents on the selected most dangerous sections of state significance roads will be observed.

The rolling out of international project SMART E263/E77 for advanced traffic management

Boriss Jelisejevs (Latvian State Roads) and **Kristijan Duubas**
(Estonian Road Administration)

Intelligent transportation systems (ITS) provide significant added value to road transportation, making the related investments distinctively effective and long-lasting. Moreover, some ITS activities may be eligible for financial support of the European union (EU). That was the way, how Estonian and Latvian national road administrations (NRA) evolutionary worked on the project proposal "Smart corridor Tallinn-Tartu-Luhamaa-Riga E263/E77" (acronym – SMART E263/E77), which was approved by EU program Interreg Central Baltics, as CB891 project. The project started on 1 June 2020 and its implementation will last till the end of 2022, according to quite challenging schedule. The project's activities primarily include numerous installations or road telemetry and telematics devices (especially, variable message signs) for advanced traffic management, to be supported by cross-border traffic plans and improvements of traffic control centres. The project's target is to provide general travel time saving at least by 0.88 % across the whole corridor, however, for the motorway-type sections it should reach more than 5.5 %. The project's awaited results will improve the following NRA functions of the E263 and E77 roads transport: adaptive (to variable road conditions) traffic management; gathering and dissemination of traffic information; decision-making support for road maintenance operations (especially in winter). The paper will summarize the project's progress information with emphasis on traffic management issues.

Benefits and performance of the electronic journal of construction works (poster presentation)

Paulius Bautrėnas (State Enterprise Lithuanian Road Administration) and **Marius Čereška** (State Enterprise Lithuanian Road Administration)

Electronic construction journal (later – e-journal) has been developed to replace the former printed construction journal. The purpose of e-journal is to ensure effective supervision of road construction and reconstruction works and to avoid potential abuse. Records made by contractors, supervisors and controlling institutions in e-journal enable to manage the work process in each road construction and reconstruction building site. All road construction process participants have access to the data, comments and findings entered into the e-journal. The e-journal accurately records all deadlines, technical supervision or control performance time. It is a significantly faster and more effective means of control and quality assurance of performed works.

Use of BIM in SLLC “Latvian State Roads” for process management

Zigmārs Krūmiņš (Latvian State Roads), **Juris Smirnovs** (Riga Technical University), **Valentīna Barkova** (Latvian State Roads), and **Roberts Auziņš** (Latvian State Roads)

BIM is an integrated set of building design, construction and management processes, technologies and regulations that allow all parties involved to jointly design, build and manage a building in a digital environment. The financial benefits from BIM are estimated in the long run, and the main factors for financial savings are productivity and quality, which can be achieved by applying the BIM technology and appropriate processes during the construction cycle (design, construction and management). Studies show that savings can reach up to 10 % of construction costs.

Currently underway is the process of implementing and configuring the Microsoft Dynamics platform for processing and using work information of SLLC “Latvian State Roads” (LSR). Microsoft Dynamics is a line of enterprise resource planning and customer relationship management software.

In general, LSR intends to use the system in the following stages of the construction cycle:

- design stage;
- construction procurement stage;
- construction stage;
- warranty period.

Microsoft Dynamics has both pros and cons for processing LSR information. Only after full implementation it will be possible to assess the effectiveness of this platform. The objective of the article is to explore how the use of BIM can improve the LSR work process.

Implementing building information management (BIM) in Estonian Transport Administration

Erko Puusaag (Estonian Road Administration) and **Anti Palmi** (Estonian Transport Administration)

Digitalisation is the key to efficiency in the road construction industry. Building Information Management (BIM), being the main development in the architecture, engineering, and construction (AEC) industry, offers a technology as well as processes to bring traditional design and construction practices to the digital era. Estonian Road Administration started the process of BIM implementation in the Estonian road industry in 2017, when the first planning of pilot projects began. Today, the utilisation of BIM is set as a strategic goal for Estonian Transport Administration (formerly Estonian Road Administration), and a structured approach has been developed in order to overcome such a complex shift in the way how road information is being managed during the whole life cycle of a road. The development of principles of data movement, setting technical guidelines and requirements, managing legal issues and communication within the organisation as well as outside, training of personnel are all aspects that need to be taken into consideration. Successful adaption also needs good communication with the industry, which is mainly done with Estonian Digital Construction Cluster – a collaboration which brings together the main stakeholders of the sector. In a few years time most of the main sections of the road life cycle will hopefully utilise BIM successfully in Estonia, but the key lies within a well developed and executed implementation. The paper describes the development of such an implementation plan and also brings out the main issues and success factors that are relevant for a successful shift towards digitalisation in the road construction industry.

Floating Car Data as input source for road maintenance

Björn Zachrisson (NIRA Dynamics AB)

The last time the winter maintenance experienced a technology disruption was with the introduction of RWIS stations during the 80s. Since then, there has been a lot of improvements and optimizations of operations but no revolutionary technological advancements. That is until 2020 when connected vehicles started measuring the road state in terms of friction, roughness, potholes, and environmental parameters. This is done at an extreme scale in cooperation with the Volkswagen group and without any added hardware, using software only, the scalability is almost infinite.

Having access to reliable real-time data changes is the way winter maintenance can be handled. Alerts are based on the real experience and finally there is a way to follow-up and evaluate the operations. On the asset management side, doing the right action at the right time is a cost saver while also increasing the overall road safety.

07

ENVIRONMENT, CLIMATE CHANGE & ENERGY EFFICIENCY

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Cement bound waste rubber for sustainable pavements

Matija Zvonarić (Faculty of Civil Engineering and Architecture Osijek),
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Cement bound courses (CBC) have many positive characteristics, but also some detrimental effects on the pavement wearing courses. Due to cement hydration, this mixture is affected by shrinkage, which induces cracks in the whole layer, allowing weather conditions to propagate through asphalt layers in a short period. Also, its stiffness negatively affects cracks propagation without providing elastic support for upper layers. As a result, roads are covered with various damages, which reduces driving comfort and safety and in turn demands new financial investments. The focus is on reducing the detrimental effect of CBC on the pavement. Nowadays, large quantities of recycled rubber can be found on the market. Wasted rubber is a large ecological problem due to its long decomposition period. On the other hand, by mechanical grinding and separation processes, suitable fractions of rubber can be obtained for use in construction. Consequently, the replacement of conventional material by crumb rubber reduces the consumption of natural material and energy for its exploitation. Appropriate amounts and fractions of recycled rubber have the potential to reduce shrinkage and increase the elasticity of CBC. This paper will research possibilities of implementation of crumb rubber in CBC and its effects on mechanical characteristics of several mixtures. By using recycled materials in the construction processes we undertake a major step in sustainable management of natural resources.

Construction of economical pavement structures with wood ash

Sanja Dimter (Josip Juraj Strossmayer University of Osijek),
Martina Zagvozda (Josip Juraj Strossmayer University of Osijek),
Tea Tonc (Josip Juraj Strossmayer University of Osijek),
Miroslav Šimun (Zagreb University of Applied Sciences)

Stabilized mixes that are used in pavement structures are composed of aggregate bound with hydraulic binders (cement, lime) or bitumen. The most commonly used for the construction of base layers are mixes stabilized with cement. A long-standing construction practice for pavement structures was based on the use of quality granular materials for the construction of base layers. However, when designing the pavement structure and selecting materials, economy, sustainability, and environmental impact, in addition to their mechanical properties, should also be considered. Clear requirements and guidelines for sustainable development have imposed the need to explore the possibility of using non-standard materials in construction. Wood ash which is formed as a residue from the combustion of biomass in the production of electricity and heat is one of the newest and, in Croatia, less researched alternative materials that can be applied in construction. The paper describes compressive strength tests of mixtures of sand from the Drava River and cyclone wood ash stabilized with various contents of cement. The obtained results showed that with wood fly ash (in a content of 30 % mass.) in the stabilization mixture of sand, values of compressive strengths can be achieved within the required limits necessary for the construction of base layers of the pavement structure stabilized by a hydraulic binder.

E-pavement development

Ain Kendra (T-Konsult OÜ)

From 2016, Estonian Road Administration initiated research in Tallinn Technical University (TalTech) to study the possibilities to integrate road pavement with photovoltaic panels. In the research on transparent pavement materials the best properties were found in crushed forged glass. In binder research the bio-asphalt was tested, but unfortunately too little light passed the binder, so finally, EPO-compound was selected. Two sample modules were prepared before the Road Conference in Tallinn in 2017. During research a small team was formed and a start-up company was established to further develop the solutions. The first winter indicated the problems on watertight electric connection with PV panels, and we redesigned the modular structure of panels. The current module is made from ca 20*20 cm bricks (the size is based on a typical PV-panel), preinstalled on a frame from recycled plastic decks. A standard size of 3*8 modules has been selected for easy installation and integration at common voltage level. Besides power generation, different colour LED strips are used to add functionality to modules, from simple illumination of pedestrian / bicycle path boundaries to integration with traffic lights at the pedestrian crossing. Tactile surfaces have been produced to help impaired pedestrians on crossings, but due to rounded turn areas, the pedestrian crossing wait area is not always rectangular. In cooperation with Tallinn City, test modules are installed in Mustamäe and soon will be installed in several places in Tallinn.

The current development has several goals – we are seeking for cheaper compound material and looking for different sizes which have to fit with standard concrete pavers blocks. However, modular approach is preferred to integrate the pavers in block, which is easier to install. We have not found ideal connector technology to provide a weatherproof connection which does not require qualified skills at installation. So far we have restricted the applications outside of car traffic areas, despite the bricks having excellent strength and also very high abrasion resistance.

Of course, for power generation there are more suitable alternatives, but it seems that intelligent illumination has wider future.



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