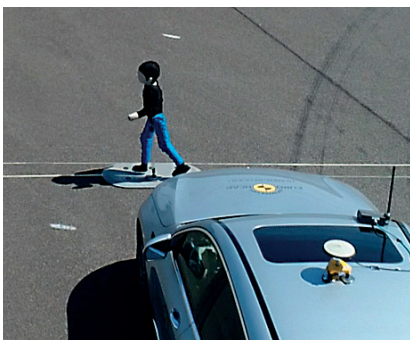
Annual Report 2019



Reports of the Federal Highway Research Institute

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Federal Highway Research Institute

The Federal Highway Research Institute (Bundesanstalt für Straßenwesen, BASt) was founded in 1951. BASt began its work with research in the field of highway construction. In 1965 BASt was commissioned, beyond the scope of highway construction tasks, to work towards enhancing highway capacity and safety. In 1970 the Federal Parliament voted to establish a central agency for road traffic accident research which was set up at BASt.

Today BASt is a practice-oriented, technical and academic research institute of the Federal Government with a focus on the road sector. It covers diverse research subjects resulting from the relationship between road, people, and the environment. Its function consists of improving the safety, environmental compatibility, economic viability, and efficiency of roads.

BASt provides scientifically based decision support to the Federal Ministry of Transport and Digital Infrastructure (Bundesministerium für Verkehr und digitale Infrastruktur, BMVI) in technical and transport policy issues. BASt is among the leading institutes in a network of centres of research excellence in the roads sector, and substantially involved in developing regulations and standards at the international level. Consultancy and expert opinions, reviewing and certifying are also among BASt‘s functions. Moreover, BASt is an assessment centre for driving licensing.

Its headquarters have been in Bergisch Gladbach since 1983 on premises covering about 20 hectares, including ten experimental halls and large-scale test facilities, some of them unique in the world. Since 2017 BASt has also been operating the Demonstration, Investigation and Reference Area (duraBASt) at the Cologne-East motorway.

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Preface

Good transport policy needs a solid, science-based basis in the decision-making process. For a state system guided by the principles of foresight and safety, it is essential to have an understanding of the application and impact of modern technologies, the changes in mobility and road safety, the environment, energy and climate action. With its research, BASt performs an important bridging function between politics on the one hand and science on the other.

In the past research year, about 200 BASt scientists completed roughly 300 projects to make scientifically sound decision support available for transport policy issues and technical issues. One third of these projects were sub-contracted to universities and other scientific institutions, sometimes with considerable supervision by BASt; two thirds were in-house projects. These projects ranged from answering ad-hoc questions from the parliamentary sphere to completing multi-year projects funded by the government.

With this annual report, we want to familiarise you with a selection of 32 projects from our cross-departmental research activities – and of course the people who were involved.

BASt's research addresses the societal, technological and economic aspects of important challenges on a yearly basis. One perennial issue: young drivers. For years, the number of fatalities has been decreasing. In young adults aged 18 to 24, the total of ca. 350 persons killed in 2019 marks the lowest rate ever achieved for this age group. But we are convinced that we must be able to top even this success. We want to lower young drivers' risk of being involved in accidents; to that end, we are willing to use unconventional means. We present these to you in our annual report.

Machines are considered the better drivers. This aspect is also comprised in our road-safety activities. In the report, you will also find a diverse selection of our on-going research activities: ranging from parking for trucks, bicycle highways to digitisation in bridge and road constructions.

As a federal research institute – together with the Federal Ministry of Transport and Digital Infrastructure, in close alliance with the federal government's Autobahn GmbH and the Federal Trunk Road Authority – we are well-prepared to tackle the challenges of the future optimistically and with motivation.

I wish you an inspiring read.

Stefan Strick, President of BASt

Content

Highlights 2019

Road Safety Day at BASt

Road Safety Day was celebrated across Germany on 15 June 2019. Initiated by the German Road Safety Council (DVR), it took place this year for the 15th time. BASt opened its doors and, together with 16 partners, presented an entertaining and informative programme to about 2,000 visitors.

Both young and old were invited to participate and try out what 50 action and information booths had to offer: laboratory experiments, simulators, personal light electric vehicles, virtual realities, bridges to build, and walk-in tunnels. These were demonstrations of how digitised traffic, automated driving and driver assistance systems will change the transport sector in the future.

Furthermore, there was a multitude of practical information, covering driving licences, road signage, cycling and first aid, peeks into BASt's test halls with tests of road markings and visibility in the dark. Current research results, inspections as part of road and bridge construction, innovative measurement systems and vehicles rounded out the programme.

In a roll-over simulator, guests were able to try out what happens in an accident without endangering themselves, experiencing a two-vehicle crash at close range. Dummies were used for these crashes, of course. BASt also showed the dummies in a unique exhibition. Current and historical model were presented, the oldest dating from 1970.

The new Internet portal on the psychological effects of accidents went live that day too. Victims of traffic accidents, their families, witnesses and first responders will find extensive information there (see page 66).

Open House event in Berlin

BASt presented a small selection of its diverse research areas at the Open House event of the Federal Government at the Federal Ministry of Transport and Digital Infrastructure (BMVI) in August.

More than 7,000 citizens familiarised themselves here with current challenges and innovations in the transport sector and the future of mobility in Germany.

26th World Road Congress 2019 in Abu Dhabi

More than 6,000 participants from 144 nations came to Abu Dhabi in the United Arab Emirates for the 26th World Road Congress (WRC). The World Road Association (PIARC) offered its visitors an extensive programme from 6 to 10 October. There were 48 meetings on five conference days, 15 workshops, 6 poster sessions and 42 technical visits, as well as a large exhibition with 26 national pavilions and 151 exhibitors. BASt represented Germany at a joint booth together with the BMVI and the Road and Transport Research Association (FGSV). Transport ministers from more than 40 countries and their deputies attended the opening ceremony

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and the high-level meeting. Germany – as an active PIARC member state – was represented by a 50-member delegation. BASt scientists has successfully submitted their papers to the WRCs call for papers and presented their topics in various technical and poster sessions. They were also available for questions from trade visitors in Q & A sessions.

BASt motorway art competition

Lukas Süß' "The Wheel" is the winner entry in BASt's motorway air competition at the Niederrhein University of Applied Sciences. On 13 February 2019, Lukas Süß, Lauritz Paul Löder and Timo Elmpt-Habel received the awards for their projects in the scope of the 3rd research colloquium on the construction of concrete roads at the University of Stuttgart.

One of the oldest motorways in Germany dating from 1937 – A11 from Berlin towards Szczecin – was extended and renewed this spring. BASt came up with the idea of preserving parts of it and exhibiting them as a memorial. The design faculty of the Niederrhein University of Applied Sciences announced the competition project under the auspices of Prof. Thomas Klegin. It is planned to install "The Wheel" in a publicly accessible area on BASt's premises in front of its headquarters in Bergisch Gladbach.

The projects were assessed at a jury meeting at BASt on 21 January 2019; from left: Lauritz Paul Löder, BASt president Stefan Strick, Lukas Süß, Prof. Thomas Klegin and Timo Elmpt-Habel


GL BA 1093


MESSFAHRZEUG
ABSTAND HALTEN
GL BA 1044

Highway Construction

Putting MESAS into service

Climate change impacts analysis for the network of federal trunk roads

Reference sections on duraBASt

duraBASt – recent investigations

HESTER – systematic road maintenance

Accelerated pavement testing

Hand-held WLP measuring instrument

Initial experience with nation-wide round robin tests

Putting MESAS into service

Dr Dirk Jansen, civil engineer, head of section, Mehdi Kalantari, civil engineer and
Dr Claudia Podolski, geophysicist, „Deign and Structure of Pavements“ section

The road network is of great macroeconomic significance as major shares of both goods and passenger transport are handled using the roads. Data on the condition of the road network, which can in turn be used for optimised, resource-saving maintenance planning, is thus highly valuable. Previously, data on surface conditions in particular was primarily collected across the network, evaluated and used for maintenance planning. In recent years, technologies were further developed with which also to collect data on the inner condition of pavements, driving at high speeds of up to 80 kilometres per hour. BASt's task consists of providing an unbiased assessment of these technologies and, where applicable, developing strategies to incorporate them into regular maintenance planning activities at the network level.

Technologies

Ground penetrating radar is one of the main technologies used in surveying a road's structural condition, i.e., describing the condition below the road surface. Measuring load-carrying capacity by applying loads is another. For the latter, a range of measurement systems have been available for decades which, however, can only collect data when stationary or driving slowly over the road. These measurement systems are only suitable for use at the network level, especially in the network of federal trunk roads, to a very limited extent, both for commercial reasons and because of their adverse effects on traffic flow. Therefore, they are hardly used in Germany. The development of a fast-moving measurement system, the Traffic Speed Deflectometer (TSD), has now enabled surveying load-carrying capacities across the network. BASt has accompanied the TSD development. The development process included comparative measurements as well as sensitivity tests, using a prototype and the first production models. Results and recommendations from these projects were implemented by the Danish manufacturer and incorporated into the construction of BASt's own TSD.

from left: Dr Dirk Jansen, Dr Claudia Podolski and Mehdi Kalantari

BASt's TSD was produced in 2017 and delivered at the beginning of 2018. It carries the serial number 14.

The MESAS vehicle

The condition of a road – to estimate its commercial and technical service life – cannot be described on the basis of only one measured variable. In analogy to human medicine, several parameters are imperative before diagnoses or projections can be made. The first question to arise is what parameters or measured variables will be necessary in the future when integrating the road's inner condition into maintenance planning. These different parameters and measured variables are sometimes identified using measurement systems that differ greatly and thus possibly at different times (of the year) and with varying localisation accuracy. These influences need to be excluded for a uniform evaluation of all parameters. BASt's TSD was therefore configured as a „Multifunctional assessment tool for the structural evaluation and the design of pavements“ (MESAS). The instrument to measure load-carrying capacity, the ground penetrating radar system, the surface scanner and laser to record evenness and images, front cameras and positioning systems were combined in a way that is thus far unique around the world.

Two people operate MESAS when conducting measurements: besides the driver, there is an operator who controls all the measurement systems and documents supplementary data about the road environment. Technical staff then process and organise the measured data which is

also analysed and evaluated by scientific staff. MESAS was a challenge for everyone involved and for the IT structure, and not only because of the high density of data and information, but this challenge was successfully mastered in the course of taking it into service.

The MESAS project

MESAS is not only the name of the measurement system, but also the umbrella term for an extensive scientific project aiming to utilise the inner structural condition of pavements for the purposes of maintenance management.

A suitable data basis needs to be generated first, particularly because structural condition data is not yet available to the extent needed. After the initial entry into service – which, besides extensive instruction for the operator and setting up processes, also included tests to determine the stability and reproducibility of the measuring procedure – in 2019 the vehicle was already able to measure more than 11,000 kilometres to collect data, mainly in the motorway network.

While data was collected, this unprecedented, unique data base was also used for initial findings and evaluation tests; these will have an impact on future operating strategies. Geographic information systems (GIS) were instrumental in this process, as they were able to show with visualisation and categorisation that MESAS is capable of forming section and identifying so-called “hot spots” in the roads network. The data needs to be cross-referenced and it is essential that additional data sources – such as parameters for materials, pavement structural details and traffic load data – be taken into account to produce reliable evaluation. This has been included accordingly in planning projects for subsequent years.

MESAS measurement vehicle and the operator’s work station inside the driver’s cabin

Furthermore, separate measurements were taken to clarify fundamental issues on the impact of asphalt temperature and speed on the measurement results in order to develop standardisation methods. This included the “Königsforst circle” – a test track around the Cologne Königsforst area, not far from BASt, comprising motorways, rural roads, federal trunk roads and roads in built-up areas – which was repeatedly driven over throughout the year, including in extreme temperature conditions. Test measurements were taken on the oval proving grounds of an automotive test centre at varying speeds, ranging from 20 to 90 kilometres per hour. This data base will also be used for quality assurance and to derive temperature standardisation functions.

International and topic-based networking

The questions that MESAS is working on and the evaluation of the structural pavement conditions at the network level are of interest around the world. BASt is therefore a member of numerous committees and working groups. A case in point is the collaborative assessment of methods for structural substance evaluations together with the Danish Road Directorate. These efforts are based, for example, on the analysis and further development of existing projection functions which establish how the load-carrying parameters relate to the level of expansion on the bottom side of the asphalt packet to identify and forecast additional action needed.

MESAS is collecting data at a big data level. At the latest, when additional parameters become involved, it may make sense to apply modern big data methods to create value-driven results – in other words smart data. For this purpose, BASt initiated the BD-Pave project where it has taken the lead and undertaken initial steps. ■

Climate change impacts analysis for the network of federal trunk roads

Dr Martin Klose, geographer, Anne-Farina Lohrengel, geoscientist and Lennart Meine, geographer,
"Adaptation to Climate Change" section

Analysing the impacts of climate change on the federal transport infrastructure is an essential focal area in the research activities and the user dialogue under topic 1 of the Knowledge – Ability – Action Expert Network of the Federal Transport Ministry (BMVI) [1]. The analysis can be used by experts in the future as a valuable tool to identify and prioritise the transport infrastructure's needs in adapting to climate change.

Background

Climate change is a challenge for planning and managing the federal transport infrastructure. Climate-related influences and natural phenomena such as floods can lead to restrictions in the availability of route sections and necessitate unplanned construction and maintenance measures. Besides additional costs for owners, operators and users of transport infrastructure, these events can also incur macro-economic costs.

An essential aim should be to ensure that the transport infrastructure is available, even under the impact of climate change and extreme weather conditions. The climate change impacts analysis provides important information in this context. Using different sub-analyses, the potential impact of climate change is estimated for the near future (2031 to 2060) and the distant future (2071 to 2100).

The climate change impacts analysis is conducted for the road, rail and waterways transport modes deploying a uniform methodology.

Methodology

The climate change impacts analysis consists of three essential investigation steps: an exposure analysis, vulnerability analysis and a criticality analysis. The exposure analysis aims to identify route sections where climate-related events or natural phenomena can occur at present and in the future. The vulnerability analysis, on the other hand, is conducted to identify route sections that are sensitive to potential impact because of their structural properties.

from left: Dr Martin Klose, Anna-Farina Lohrengel and Lennart Meine

BMVI Network of Experts
Knowledge Ability Action

Additionally, criticality is assessed. The term criticality refers primarily to the significance of a route section for overall transport. The criticality analysis aims to assess the transport-related consequences of potential restrictions of availability using indicators such as the average daily weekday traffic (ADTw).

Floods as an example

For the exposure analysis, the flood hazard maps of the Länder are imposed on a federal transport infrastructure map. In the example, the map shows the result of identifying potential risk areas for river and coastal floods. The potential flood hazard areas marked red on the map refer to a medium flooding scenario which, statistically speaking, occurs once about every 100 years (HQ100). In such a medium flooding and flash flood scenario, about 2 per cent of the network of federal trunk roads is affected across Germany (roughly 1,100 kilometres). The results of the research activities under topic 1 also show that a 100-year flood at the Rhine river today may in the future occur every 20 to 50 years, assuming a "business-as-usual" emission scenario (RCP8.5 climate model; with a climate forcing of 8.5 W/m^2 in 2100 in accordance with IPCC's Fifth Assessment Report).

Middle Rhine stress tests

The Middle Rhine stress tests [2] constitute a special case in the cli-

mate change impacts analysis. Transport-related consequences and costs of closed sections and restricted traffic were analysed in constructed extreme scenarios. One scenario studied referred to a hypothetical, extreme flood in 2030, for which an usually long duration of 21 days and a related closure of any Rhine shipping, of federal highway 9 and rail section 2630 were assumed. The individual stress tests were conducted on the basis of existing data and projections in federal transport infrastructure planning. For this exemplary 2030 flood scenario, the overall estimate of additional transport costs amounted to a figure in the mid-double-digit millions of euros range. Macroeconomic costs were not taken into account in the scope of the Middle Rhine stress tests.

Conclusion

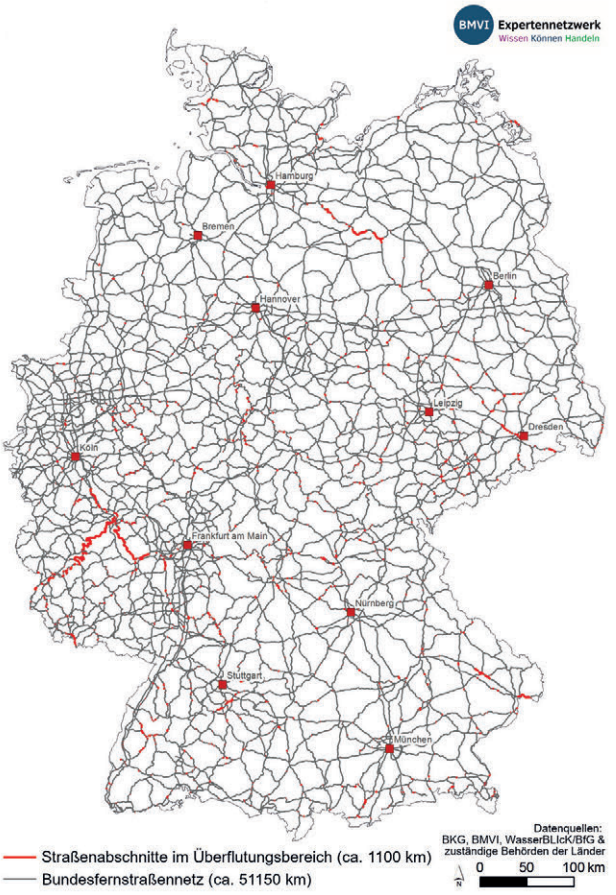
The German Adaptation Strategy (DAS) sets the political framework for climate change adaptation in Germany. “The German Adaptation Strategy aims to reduce the vulnerability to unavoidable climate change impacts, sustaining and enhancing the adaptive capacity of natural, societal and economic systems.” [3]

The climate change impacts analysis for the federal transport infrastructure was developed based on the cross-sectoral climate changes impact and vulnerability analysis in the scope of the German Adaptation Strategy (DAS). It creates the necessary basis to ensure the availability of the transport system.

Specifically, the climate change impacts analysis provides:

- insights into potential climate change impacts on the federal transport infrastructure
- an information and planning basis for adaptations to climate change
- contributions to identify and prioritise the adaptation needed for climate change

Developing the climate change impacts analysis aims to support specialists. A knowledge transfer into practice is to be ensured by establishing regulations. Regulations are an important instrument in implementing adaptations to climate change, because findings concerning future climate-related influences can be fed into maintenance and planning projects through such regulations. ■



Sections of the network of federal trunk roads located in the area of potential floods (highlighted red) of a “medium” flood (HQ_{100}) (Source: 2019 final report of the BMVI Expert Network on topic 1)

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[2] KOTZAGIORGIS, S., ROTHSTEIN, B., SCHOLTEN, A.: Influences of extreme weather and climate conditions on cross-regional traffic flows – Middle Rhine stress test scenario, final report on research project 69.0001, commissioned by BASt 2019, unpublished
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www.bmvi-expertennetzwerk.de

Reference sections on duraBASt

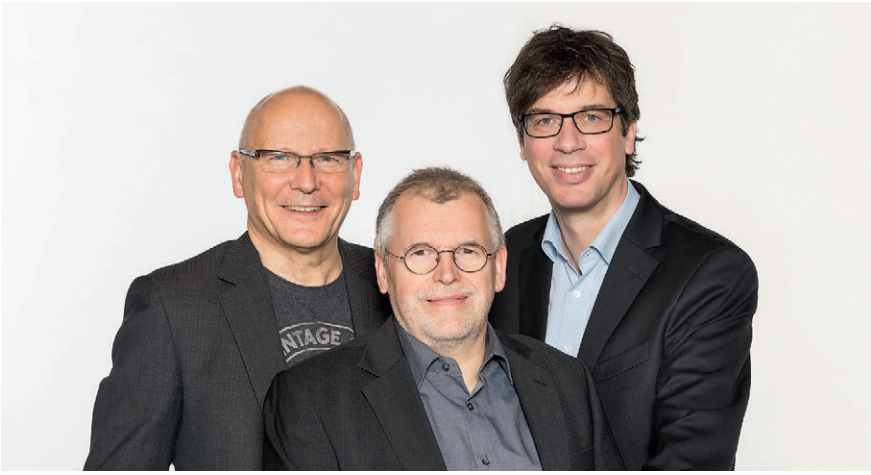
Winfried Glattki, electrical engineer, Christian Gottaut, civil engineer and Andreas Wolf, civil engineer and tropics technologist, deputy head of "Surface Characteristics, Evaluation and Maintenance of Roads" section

With roughly 13,000 kilometres of federal motorways and about 38,000 kilometres of federal highways, Germany has one of the densest road infrastructure networks in Europe. It is the task of the respective authority responsible for construction and maintenance to provide an efficient and safe road infrastructure to road users with a a uniformly good level of quality. Maintaining federal trunk roads is thus a priority task for both the present and the future.

Road surfaces need to be skid-resistant, even, silent and durable to continue in the long term meeting the requirements for road infrastructure as regards road safety and efficiency. In this context, the road monitoring and assessment (ZEB) plays a crucial role. In the scope of the ZEB, road conditions (evenness in longitudinal and transverse profile, skid resistance and substance characteristics (surface)) on federal trunk roads have been systematically surveyed and subsequently evaluated in regular 4-year cycles using a fast-moving measurement vehicle in moving traffic. ZEB results provide an essential basis for national maintenance planning.

Quality assurance

The quality assurance for measurement vehicles deployed in ZEBs includes tests on various referencing sections of BASt's Demonstration, Investigation and Reference Area (duraBASt). Besides sections with longitudinal evenness, the area also offer a section for transverse evenness, a section with structural substance characteristics such as cracks and patched areas, a section for skid resistance and one for texture. With their surfaces offering a range of defined and permanent properties, the sections are setting new benchmarks in BASt's approval of these measurement vehicles, contributing to improved surveys of road damages in the scope of ZEBs. The sections are not part of a public road network and are thereby not subjected to the continuous changes that are caused in particular by traffic loads.



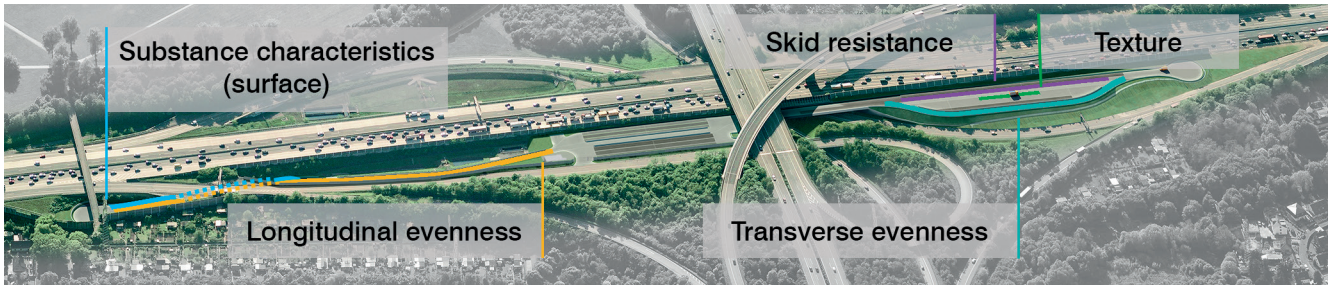
from left: Andreas Wolf, Winfried Glattki and Christian Gottaut

The reference sections are also used to further develop measurement systems for road condition survey, to scientifically research new parameters to describe the condition of road surfaces and to update corresponding regulations.

Temporary operating license

A road surface's longitudinal and transverse evenness are important quality attributes for driving comfort and safety, and they have a major influence on road and vehicle wear. Incorporating the reference sections into the licensing process for temporary licenses (ZbBz) for measurement systems surveying longitudinal and transverse evenness is an important quality component in the ZEB process.

Pursuant to the "Technical test requirements for measurements of longitudinal and transverse evenness of road surfaces, Section: Contactless measurements, 2009 edition", measurement systems conducting longitudinal and transverse evenness measurements in the scope of ZEBs must have a temporary operating license from BASt. The license, which needs to be renewed each year, ensures that the licensed measurement systems comply with the requirements applicable in Germany and are suitable for measurements with the accuracy required. The temporary operating license is thus an important quality assurance component in surveying road conditions with fast-moving measurement systems. Testing the measurement systems is divided into a static and a dy-



Reference sections on duraBASt

namic part. The static tests are conducted at BASt, while the reference sections on duraBASt are used for the dynamic tests.

Section for longitudinal evenness

The reference section that can be used to test measurement systems surveying longitudinal evenness is located in the southern part of the duraBASt area. The section is about 220 metres long and has an embossed, defined unevenness profile that corresponds to a road in situ in bad condition. Additionally, a heavily varying longitudinal gradient, slight curve radii and several horizontal flat planes are also integrated into the section. The unevenness is imprinted uniformly across the width of the pavement which makes it possible to have the same pavement geometry to test the measurement systems regardless of the vehicle's trajectory.

BASt's MEFA measurement vehicle in action on the duraBASt reference section for longitudinal evenness

Section for transverse evenness

The section at a length of about 210 metres to dynamically test measurements systems for transverse unevenness is located in the northern part of the area. It offers a fast-changing series of transverse tilts and radii, which enables dynamic measurement conditions – such as rolling motions of the measurement vehicle – for a profile-related survey of the surface using pertinent measurement systems. To ensure that transverse evenness can be analysed separately, the section does not have a longitudinal gradient.

Complex scenarios can be implemented with the special pavement geometries present here. These can even include defining new parameters for a more extensive description of the pavement's unevenness (3D evenness analysis).

Incorporating the two referencing areas into the processes of issuing temporary operating license and of the self-monitoring of BASt's own reference measurement systems already began in the mid-2018. After concluding the comprehensive tests for this incorporation, the effective operation for on-road measurements in the scope of temporary operating licenses began in early March 2019. In total, more than 100 on-road measurements were conducted on the two reference sections with all measurement vehicles used for ZEBs.

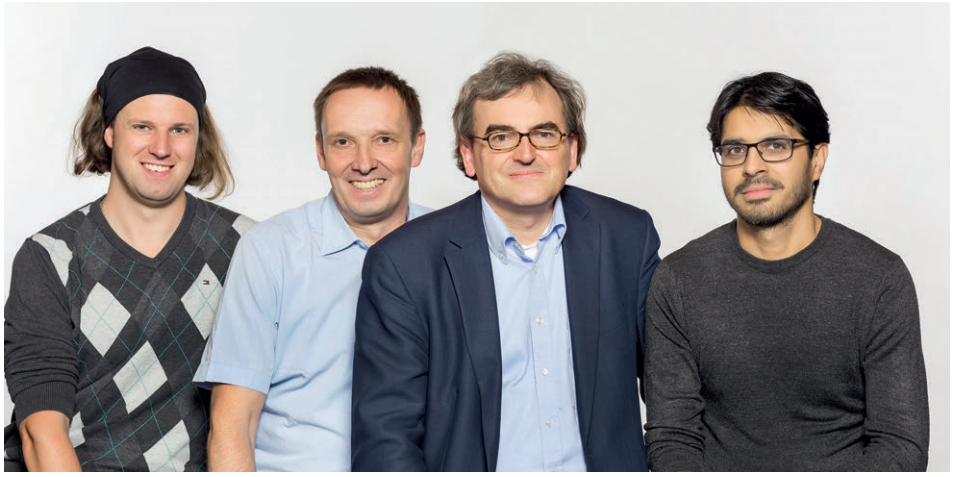
Research

In early September 2019, comprehensive skid resistance and texture measurements were conducted on the corresponding reference sections in the scope of research projects on contact-less surveys of the skid resistance of road surfaces and road markings. A separate research project included tests of new survey technologies with respect to their suitability and comparability to the evenness measurement systems used in ZEBs. A measurement programme using various novel measurement systems was implemented in November 2019 on the reference sections for longitudinal and transverse evenness. There is also research on updating the quality standards for licensing evenness measurement systems for ZEB measurements and acceptance measurements. ■

www.durabast.de

duraBASt – recent investigations

Stefan Höller, civil engineer, "International Road Construction Research Tasks" section, Oliver Ripke, civil engineer, deputy head of "Asphalt Pavements" section, Mehdi Kalantari, civil engineer and Dr Bastian Wacker, civil engineer, deputy head of the "Design and Structure of Pavements" section



from left: Dr Bastian Wacker, Stefan Höller, Oliver Ripke and Mehdi Kalantari

The road infrastructure is already now confronted with a series of future challenges: technology and energy transitions, the impacts of projected climate change, the demographic shift and an aging infrastructure will change the boundary conditions for mobility in a more pronounced manner and more quickly than this was the case in the past decades. Innovation cycles of about 20 years will not keep up.

Since late 2017, BASt has been operating its Demonstration, Investigation and Reference Area (duraBASt) at the Cologne-East motorway interchange to accelerate the process of ongoing technological developments. The demonstration and investigation sections are used to implement, analyse and evaluate innovations under close to real conditions. By using accelerated pavement testing (APT, see page 20), the innovation cycles can be considerably reduced, and new developments can be introduced more swiftly into construction practice.

The following projects have thus far been implemented together with universities and technical colleges, construction and construction machinery industries, engineering consultancies and road construction authorities: SEDa – road construction for energy production, concrete core sealing, HEALROAD – self-healing road, HESTER (see page 18) – precast concrete slabs for road maintenance and new roads, OBAS – process optimisation in road construction and open porous asphalt and concrete. The legal framework conditions vary greatly from project to project. They range from being initiated completely by BASt, to funding programmes of the Federal Ministry of Transport and Digital Infrastructure (BMVI), the Federal Ministry of Education and Research (BMBF), the Federal Ministry for Economic Affairs and Energy (BMWi), the Road and Transport Research Association (FGSV) and the European Union, to studies fully or partially initiated by the industrial sector.

The subject areas maintenance, recycling and alternative bonding agents are some of the current focal areas of ongoing studies. The research projects include: Inno-Pave, Relaxed Hybrid and Cold Recycling.

Inno-Pave

Today's manufacturing of asphalt roads is subject to considerable environmental influences that can cause major fluctuations in quality. This has a decisive impact on a road's service life and utilisation properties. In the "Fundamental research on polymer materials and innovative manufacturing and installation technologies for pavement top course systems (Inno-Pave)" project, a multi-layer top course to be manufactured under stable conditions was developed using polymer-based and textile materials. Inno-Pave was funded by the BMBF in the scope of its "HighTechMatBau" funding initiative. Public and private-sector research institutions as well as businesses worked together on the research approach of utilising polymer-based materials in connection with textile reinforcement in a multi-layer top course. An upper texture layer reduces the generation of noise while the absorption layer beneath it additionally lowers noise emissions. The aim was to create a top course that reduces noise on a lasting basis but has a significantly longer lifespan compared to conventional noise-reducing pavements. Installing it on a large area on the duraBASt premises gave an impression of the versatility of the installation methods developed in the scope of the research project, and helped gain experiences in handling the construc-

tion materials, which are unusual in road construction.

Relaxed Hybrid

In the scope of maintenance measures for old concrete pavements, it can be economically viable to integrate the existing reinforcement into the new design and overlay it with asphalt. An artificially pre-damaged concrete pavement was installed in the scope of a cooperation project between TPA GmbH and BASt, and about two months later an impactor was used to relieve the pressure on the concrete. Afterwards, an asphalt base course and an asphalt top course were constructed.

Besides BASt's APT programme, not only a number of sensors were deployed to measure the acceleration but also additional systems to measure skid resistance and texture. The aim is to provide values as guidance for calculating the design in cases where the old concrete pavement is intended to be used as a base course in maintenance measures to overlay concrete pavement with concrete pavement in a method that saves resources and energy, and is cost-efficient.

Cold Recycling

Due to an increase in maintenance measures, there is an excess of asphalt extracted from top and binder courses, as the use of identical layers is regulated in pertinent regulations. Different cold recycling methods are seen as promising to successfully recycle them. There are possibilities to use up to 100 per cent extracted asphalt.

One cold recycling method is based on the use of foam bitumen. By injecting small amounts of water into hot bitumen within an expansion chamber, a foam-like material can be produced. This foam remains stable for a few seconds, can mix with granulated asphalt during this time and enables the material to be well-compacted at low temperatures. Usually, small amounts of cement will be added as a second bonding agent to increase rigidity and absorb humidity. The resulting material can be deployed as a base course after compaction and a short rest period.

In 2019, a cooperation project between Wirtgen GmbH and BASt began, aiming to gain experience with a cold recycled layer made of foam bitumen and cement. Based on the results from laboratory tests, a formulation for representative granulated asphalt (2.2 per cent foam bitumen and one per cent cement) was identified and installed on the duraBASt premises. Accelerated pavement stress tests and other tests have been scheduled for 2020.

Outlook

The research projects "polyurethane-bound top courses", "inductive dynamic loads", "optimising texture grinding" and "high-polymer modified asphalt" are planned on the duraBASt premises. There is a range of additional requests for projects in the demonstration and testing part of the premises as well as for using the reference tracks. A great number of visitors from Germany and abroad visit regularly to learn about new developments, thereby contributing to spreading the information about innovations and increasing their acceptance. ■

Production of Inno-Pave surface

Relaxed Hybrid: impactor in action

Installation process of a Cold Recycling layer on duraBASt

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HESTER – systematic road maintenance

Christiane Fischer, civil engineer, “Concrete Pavements“ section

Hybrid strengthening system for road maintenance deploying novel materials

Traffic areas made of concrete for both federal trunk roads and the network of minor roads with a heavy traffic load – such as intersections or bus lanes in urban areas – are currently manufactured in Germany exclusively monolithically and in situ. This inevitably necessitates longer periods of road closures for repair and maintenance measures. However, when rehabilitating such road sections and traffic nodes, it is important to implement high-quality and durable road construction measures in a short period of time. This can be achieved, for example, by deploying modular prefabricated concrete systems that can be installed, for the most part, independently of weather conditions.

Demonstrator in the space of a bus stop

Together with six collaboration partners from the domains of research and road construction practice, a hybrid system of prefabricated elements was developed in the scope of the multi-player “HESTER” project, completed in late 2018, as part of the “Material innovations for industry and society – WING” research programme funded by the Federal Ministry of Education and Research (BMBF). This system has been successfully implemented numerous times in practical trials in municipal street networks at bus stops and bus stopping areas. Besides installation and application technologies, including height adjustments, all other construction processes such as setting up and securing the construction site, transporting the prefabricated elements, defining the work cycles and executing subsequent activities were tested and continuously improved.

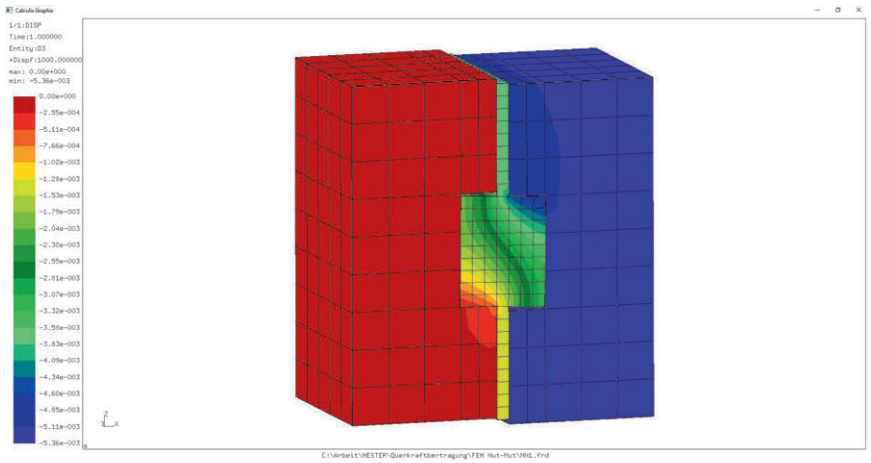
Developing a modular system of prefabricated elements

The theoretical basis for designing and constructing such a system was developed prior to tests of substances and construction materials in order to be able to systematically describe the requirements for innovative materials and to implement them in the system. A semi-automatic planning and designing system was also developed to ensure high-quality implementation. Modern finite-element models with 3D volume elements were used with which tension and deformation conditions can be determined for both individual components and the overall system.

Simultaneous to testing fresh and hardened concrete, the coupling of prefabricated elements and their alignment to the appropriate height and position were studied. A silicate resin, especially adapted for project purposes, was used as a bed plate which also served the function of the filling material in the bolt anchor chambers, and of transferring the shear force in the preferred groove/groove coupling system. In previous projects, the slabs were always positioned by means of cross beams placed on the contiguous pavement structure. In the course of the research project, the “HESTER-Kombi®” height adjustment system was developed which for the first time enables aligning the slabs independently of the existing pavement. Furthermore, the elements are equipped with a thread for transport anchors, and at the same time support silicate resin injection.

Tests in situ

Based on theoretical studies and laboratory tests, BASt together with its partners conducted a large-scale test on the duraBASt premises in July 2017. In a second step, two demonstrators were set up under real conditions in situ with the help of the Berlin Office for Public Roads and Parks in Marzahn-Hellersdorf. A bus stop in disrepair was first re-



3D FE model of the "coupling variant groove/groove"

paired using the system developed, whereby a manhole located in the space needed to be considered in planning the prefabricated elements.

A total of 13 prefabricated elements were installed, aligned in height and position, injected with silicate resin and prepared for the sealing of joints.

A second demonstrator was then built within a bus stopping area in June 2018, also in Berlin. The prefabricated elements were manufactured with a bent joint bow and a washed concrete surface with the aim of improving the acoustic properties.

BASt has been monitoring the demonstrators since then, beyond the end of the project. CPX measurements were taken at the two demonstrators and three other bus stopping areas were repaired with prefabricated elements from the HESTER project to identify tyre-road surface noise, and a falling weight deflectometer was used to measure load-carrying capacity. Furthermore, deformation analyses were conducted at the first demonstrator with the help of stationary and mobile laser scans.

Conclusion

On the basis of the results from the initial observation period of the two demonstrators (up to 600 days), no anomalies were detected which could indicate an early failure of individual slab parts or of the overall system. The joints necessitated by the construction did not show any particularities either joint movement (horizontal/vertical) or the joint sealing systems employed.

It was observed that the "slab chain" system's efficiency (load-carrying capacity, effectiveness index) responds to the heterogeneity of the substructure as regards load-carrying capacity and evenness or roughness. This means that in the future such criteria and their homogeneity need to be taken into account in producing the substructure. In summary, since the project was completed, a modular prefabricated concrete slab system has been made available, with which to implement repair measures fast, at a high quality and, for the most part, independently of weather conditions. A final durability assessment can only be made in the scope of continued monitoring of the demonstrators. ■

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Prefabricated element with recess around manhole structure after installation and height adjustment

Accelerated pavement testing

Dr Bastian Wacker, civil engineer, deputy head and Dr Dirk Jansen, civil engineer, head of the „Design and Structure of Pavements" section

Accelerated pavement testing (APT) on the duraBASt Demonstration, Investigation and Reference Area enables faster results compared to long-term observations in the public road environment.

Basic principle

Accelerated pavement testing simulates a high number of roll-overs under realistic truck tyre pressure conditions. BASt's Mobile Load Simulator MLS30 is used for this purpose. With four tyres and a tyre load of five tonnes, it exerts pressure on the test track at a maximum of 6,000 times per hour. The road surface's reaction is measured by means of various measurement systems and built-in sensors and ultimately in material tests.

Load tests

Load tests conducted in 2018 were subjected to a concluding evaluation in 2019 in the scope of a research project on professionally sealing drill holes from core extractions. There was a total of 1.6 million roll-overs, and extensive measurements were taken. The tests enabled a comparison between the different variants of sealing drill holes, as a supplement to preceding laboratory tests. An initial draft recommendation for action has been prepared. The project has shown, in particular, that construction-related issues can be tackled in various scaled tests in the scope of research projects.

Besides conducting APT on existing structures – prefabricated concrete elements and Inno-Pave – a new project was prepared in cooperation with TPA GmbH: pressure-relief hybrid. A concrete pavement was installed in two construction phases, then pre-damaged and after about two months an impactor was used to relieve pressure: finally, an asphalt base course and an asphalt top course were built on top of it. The load tests under the MLS30 took place between July and November 2019.

Thanks to the support from many parties involved and continuous process optimisation, more than 7 million loads were applied with the MLS30 during 75 per cent of the workdays available (160 load days) in 2018 during duraBASt's first season. In 2019, the previous year's utilisation rate was not quite achieved because of a multitude of ongoing construction measures, but about six million roll-overs nonetheless took place. Besides adaptations to be made in the sensor installations and the analysis of measured values, the system will also be retrofitted to enable further automation of MLS30 to increase efficiency. ■

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Installing a concrete carriageway on duraBASt (left) – on the right the Mobile Load Simulator MLS30

Hand-held WLP measuring instrument

Andreas Buslaps, electrical engineer, Winfried Glattki, electrical engineer and Christian Gottaut, civil engineer,
“Surface Characteristics, Evaluation and Maintenance of Roads“ section

from left: Andreas Buslaps, Christian Gottaut and Winfried Glattki

Pursuant to road construction contracts, road evenness is measured in Germany using contact tools such as the 4-metre aiming post or the planograph. When these methods are employed, unevenness is determined only up to a wave length of a maximum of four metres. A road’s excitation range that is relevant for humans, cargo and the carriageway lies between 0.2 and 50 metres, however, meaning that the measurement systems referred to above cannot always fully describe road evenness. This sometimes has the effect that unevenness that is seen as a disturbance by users, occurs even on newly-built roads. It is therefore necessary to identify evenness in an extended wave length range such as the one enabled by the WLP (Weighted Longitudinal Profile) method.

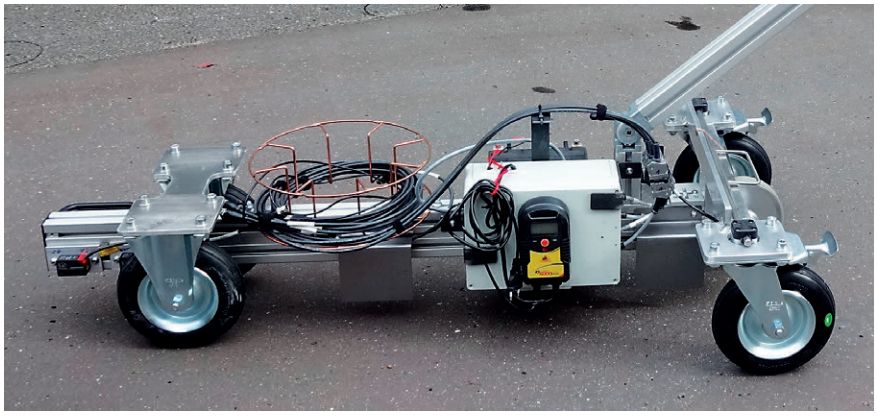
A road’s evenness can be depicted as an endless profile using the principle of multiple scanning processes with several laser sensors suspended from a rigid beam. With this method, unevenness at wave lengths of up to 50 metres can be depicted in a longitudinal profile. Fast-moving measurement systems providing this capability, have already been successfully used in structural condition surveys and assessments of road surfaces (ZEB) for years already. Easy-to-use, hand-held systems are needed, however, for self-monitoring purposes during construction processes. Internationally, quite a high number of hand-held measurement procedures, which can also measure longer wave lengths and periodic unevenness, are already in use. They function according to varying operating principles but mostly use inclinometers. The way they work is different from the principle of multiple scanning, and thus only to a limited extent comparable to fast-moving measurement systems.

Based on these deliberations, BASt started its own development of a hand-held measurements system in late 2018 to determine WLP by means of multiple scanning. The aim was to be able to swiftly implement a test set-up for mobile, hand-held evenness measurements while at the same time keeping the implementation costs as low as possible at the same time.

Prototype

Four laser sensors on a rigid beam are the core piece of the prototype developed. In contrast to fast-moving systems deployed to date, the measuring base has, however, been substantially shortened in order to gain mobility.

The first testing phase took place on duraBASt. Highly reproducible measurements were taken here on real road surfaces, which were consistent with the results of conventional, fast-moving measurement systems. ■



Prototype of a hand-held measuring instrument

Initial experience with nation-wide round robin tests

Franz Bommert, civil engineer, “Asphalt Pavements“ section, Ute Marx, civil engineer, “Earthworks, Mineral Aggregates” section and Wolfgang Roßbach, civil engineer, “Asphalt Pavements“ section

Large volumes of construction material and material mixes are processed in new road constructions, extensions and maintenance. Inspections in accordance with construction contracts aim to ensure that these construction materials comply with the technical regulations in place, and that roads built using them are safe and durable. In the field of road construction, certified testing centres are preferred sub-contractors to conduct these contractual tests in accordance with the “Guidelines for the certification of test centres for construction material and material mixes used in road construction” (RAP Stra). The testing centres are certified by expertise and inspection type.

Qualified testing centres as defined by RAP Stra

A RAP Stra certified testing centre is characterised by technical expertise, independence, reliability, due diligence and neutrality. Additionally, the testing centre must be available at short notice. These preconditions are checked during the certification process. A certified testing centre has the obligation to continuously train its staff in new developments in the subject areas it has been certified for, and to maintain, renew and supplement their technical equipment. The procedures for certification and continued obligations for the certified testing centres are intended to ensure that the construction performance can be assessed unequivocally on the basis of their inspection results. The RAP Stra version currently applicable (2015 edition) is the completely revised fourth edition of the guidelines. One significant change in comparison to previous editions is that the certification issued by one certifying state authority is valid at the national level. To maintain and improve the level of high quality of the inspection services in all the Länder, it was agreed to conduct round robin tests across Germany to review of the testing centres’ work methods. Participation in the round robin tests is mandatory for RAP Stra certified testing centres.

from left: Franz Bommert, Ute Marx and Wolfgang Roßbach

Implementation of round robin tests

In 2017, BASt was assigned the task of implementing nation-wide round robin tests applying uniform quality criteria. One principle of the nation-wide round robin tests stipulates that each RAP Stra certified testing centre has to participate in a round robin test once every 5 years in each subject area for which they have been certified. All participants conduct the round robin test by subject area at the same time.

BASt started organising the round robin tests in 2018 and plans to complete the first round of all subject areas under review by mid-2020. The organisational preconditions to conduct the round robin tests needed to be established first. This included describing and documenting processes, defining general implementation provisions, determining costs and drafting documents to establish the contractual relationship between the test centres and BASt. The general implementation provisions ensure that all participating testing centres receive the same information about their tasks and the method employed. The documents are available on BASt’s website.

Depending on the subject area, 40 to 160 RAP Stra testing centres were named by the certifying state authorities for participation in the tests. The testing centres are noti-

fied about an imminent round robin test about four weeks before the samples are sent out. The general implementation provisions, a formatted result sheet and a round robin test questionnaire are transmitted together with the notification letter. The questionnaire aims to assess the routine and experience the testing centres have with the specific inspection method, as well as the status of inspection tools monitoring. The round robin tests also include the task of drafting a review report.

Special attention should be paid to ensuring that all testing centres receive the same sample material, because it is otherwise impossible to compare their work methods. While for some construction materials a sufficiently homogeneous composition is complied with due to their production process, there are others – for example material mixes for layers without bonding agents – which need to be mixed specifically from aggregates. A concrete plate was manufactured especially for the round robin test on concrete pavements to extract the cores necessary.

Initial findings

The first round robin test was completed in May 2019 with the publication of the report for subject area F "Surface treatment methods, thin asphalt pavements in cold and hot application on sealing". It became apparent here that despite prior notification of both the round robin test and the implementation provisions, not every testing centre was capable of fully performing the tasks requested. Not every testing centre participating in the round robin test submitted a report about the tests they performed, or their reports were incomplete.

The findings were rated with a Z score. About 25 per cent of the testing centres achieved a questionable or a non-satisfactory result or one that could not be taken into account in at least one of the inspection procedures. It also became apparent that a comparison of the testing centres' results frequently showed overly large deviations. This means that the work methods in about 50 per cent of the testing centres need to be improved with respect to at least individual aspects.

Round robin tests are therefore a necessary tool to assess the quality of the inspection services from the RPA Stra certified testing centres. The report concerning this round robin test has been sent to all testing centres involved. It can be assumed that the testing centres will deliberate on their results and, where necessary, take measures to improve the quality of their work methods.

In the meantime, BASt has received the results from the testing centres for the round robin tests in all other subject areas, except subject area A "soils and soil improvements". The evaluations and reports concerning these round robin tests are scheduled to be completed in spring 2020.

The plans for the next 5-year period (2020 to 2024) will be coordinated with the Federal Transport Ministry and the certifying state authorities at the beginning of 2020. ■

Bridges and Structural Technology

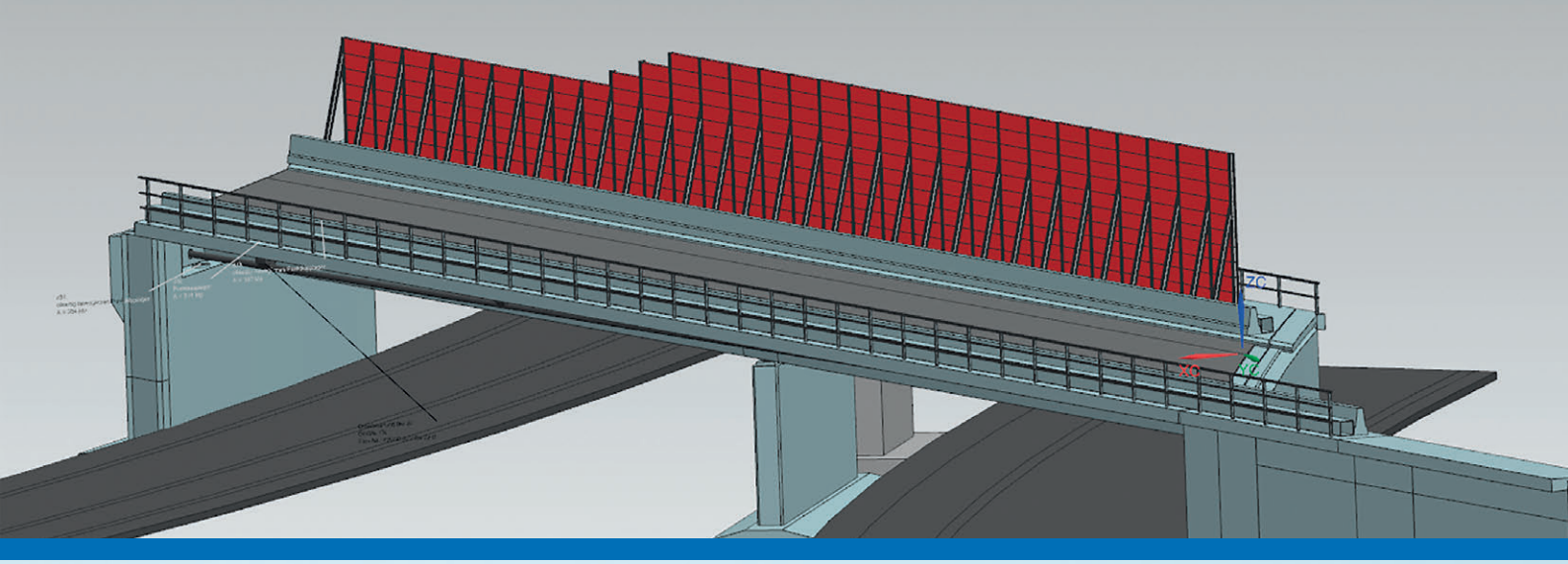
Inspection of engineering structures and digital technologies to detect and analyse damages

Digitising existing structures in bridge construction

Bridge durability assessments

Steel bridges: thermal stress as a result of installing mastic asphalt

Gabions in stress tests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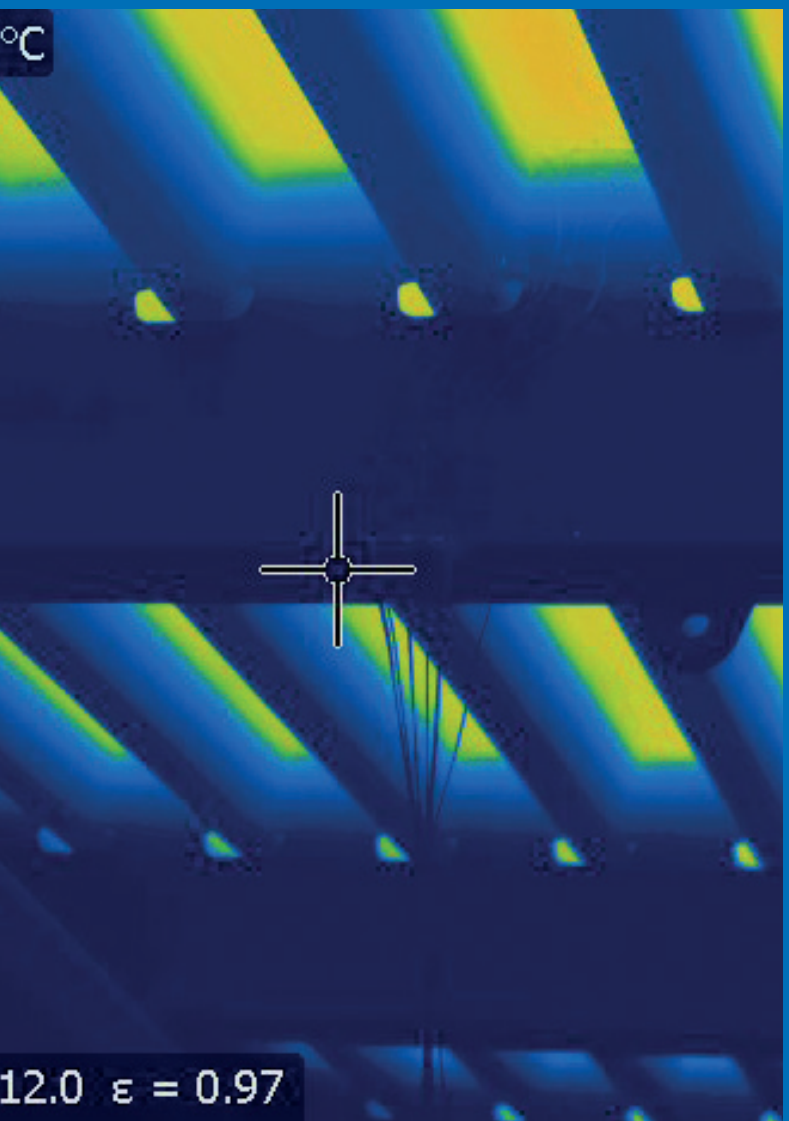
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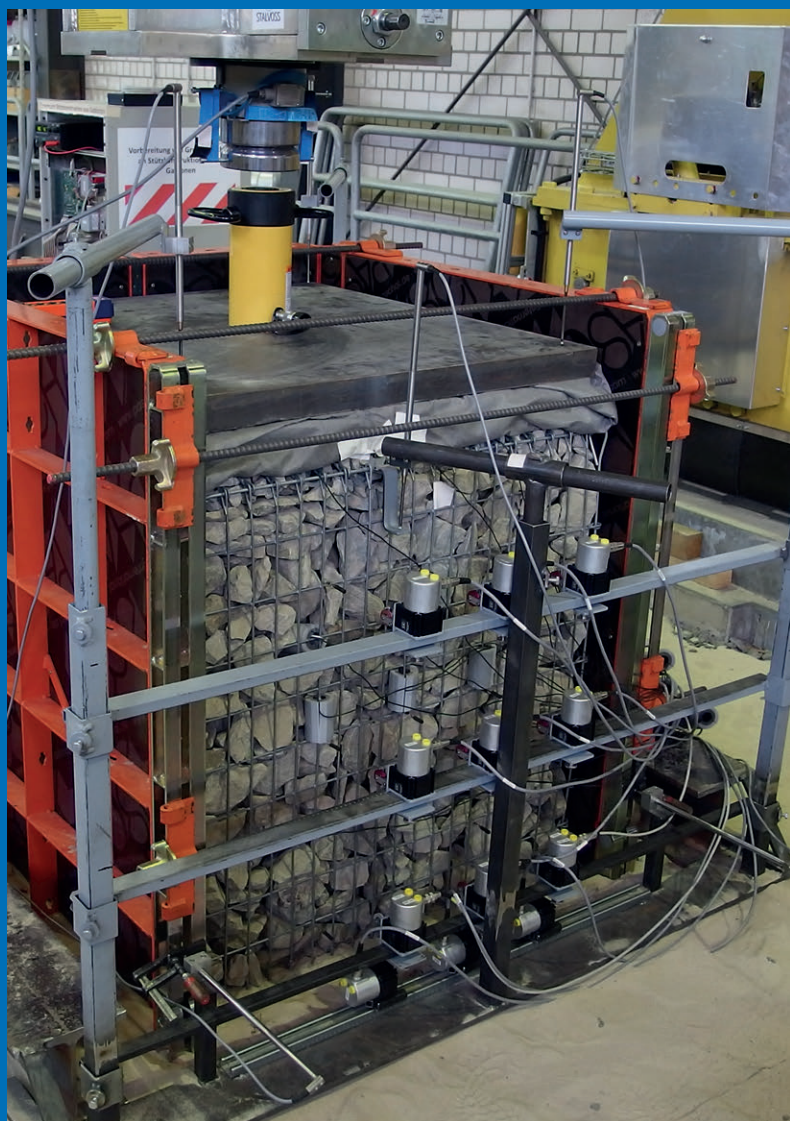


Inspection of engineering structures and digital technologies to detect and analyse damages

Dr Martin Friese, civil engineer and Ralph Holst, civil engineer, deputy head of the "Maintenance of Engineering Structures" section

Engineering structures that are part of transport infrastructure need to be inspected in accordance with DIN 1076 in a close, arms-length inspection to ensure they are stable, serviceable and safe for traffic – and in order to detect potential damages at an early stage. The inspections can incur major expenses for human resources and tools, and there are significant risks for the inspection personnel.

The aim is thus to design the inspection of engineering structures more efficiently by using unmanned aircraft systems (UAS) in connection with artificial intelligence/ pattern detection, focusing arms-length inspections on damaged/ critical sections. One of BASt's research projects focused on image analysis to detect typical damages, for example, cracks in the concrete surface.

Flight route planning and generation of image data

Reference engineering structures were selected for an automatic image analysis to test automated image data recording and to detect existing cracks. Using a great number of photos and supplementary terrestrial images, almost all the structures were depicted. On this basis, a georeferenced 3D-model was calculated and used to determine the optimal flight paths for a UAS. The UAS flew automatically around the structures along preplanned routes. The flights were georeferenced using natural, distinctive control points in the vicinity of the engineering structures, which were integrated in a conventional method using a GNSS receiver (global navigation satellite system).

In a preliminary processing step, the image data recorded was subjected to a geometric and radiometric correction/improvement, before a 3D model was reconstructed to ensure that, for example, the images had, to the extent possible, the same exposure level.

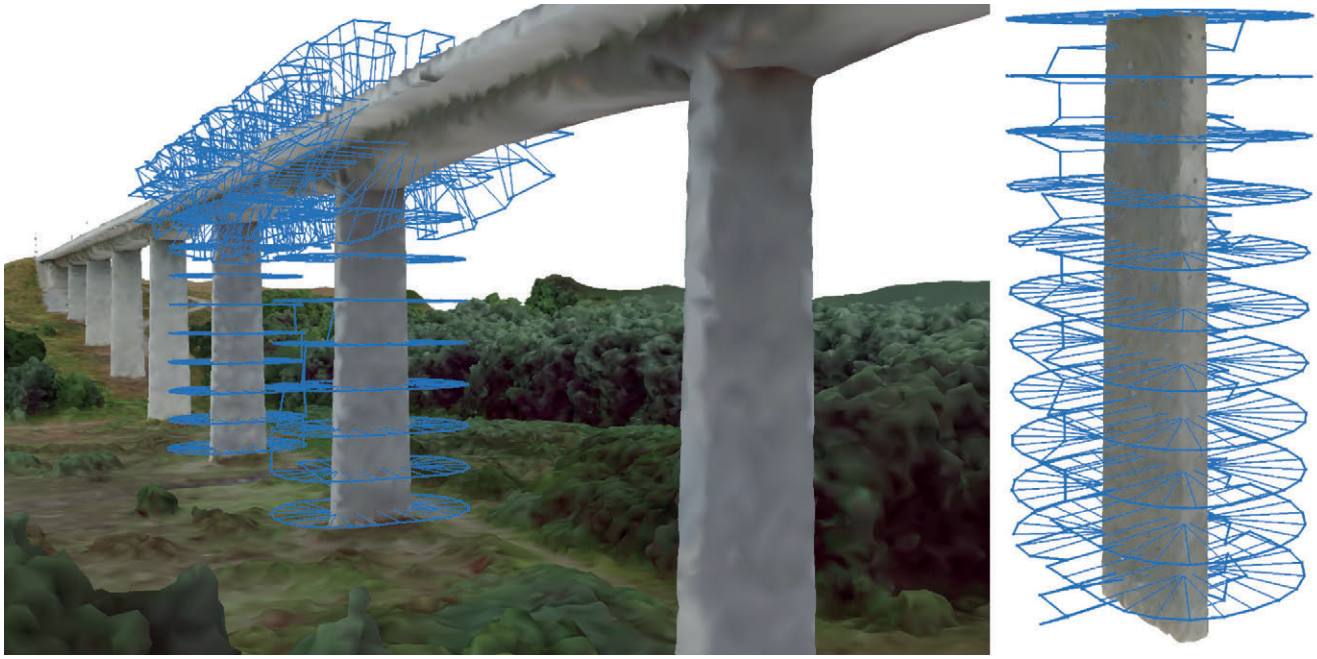
Automatic image analysis and localisation of damages

In the pattern recognition method, using a variety of images an algorithm detects changes (for example, concrete cracks) on the basis of characteristic properties, and thereby assigns them to the "cracks" category. As cracks can have varying characteristics, a great number of images is required to train the algorithm. In this way, the results are continuously improved and thus, in turn, the detection rates. It is important to have independent, new images to review the quality of the findings in a testing phase after the training phase.

Different types of neural networks can be employed for this task. Various methods were researched and tested in the scope of the project.

Artificial neural networks (ANN) in the form of CNN (convolution neural network) proved to be especially suited for the question researched, learning adequate properties and features to differentiate the content of the images. By connecting sev-

UAS at a bridge structure (photo: gmtib)



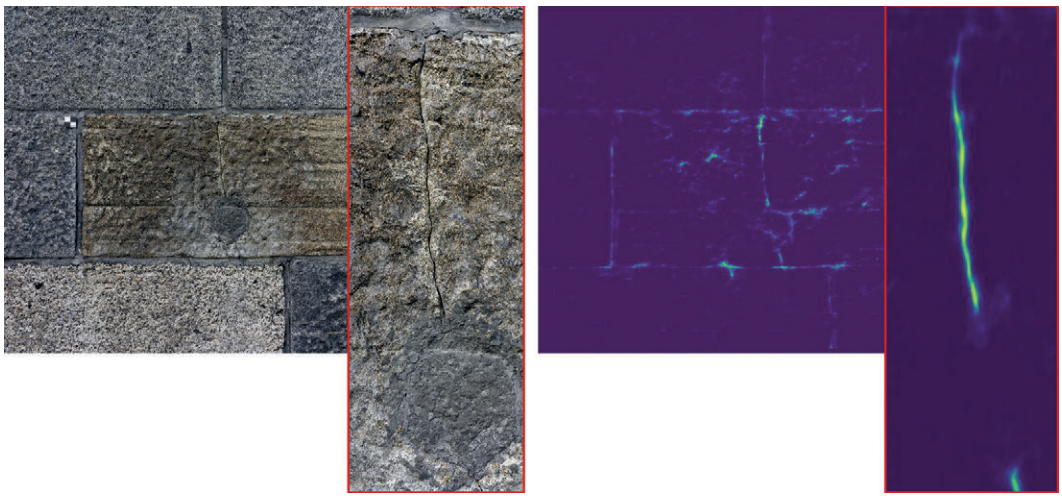
Georeferenced 3D model with automatically generated flight path (photo: gmtib)

eral convolutional layers, even complex features composed of several individual features can be learnt.

Besides the detection of damages in the image data generated, their localisation within the engineering structure is of particular interest. Damages can be viewed directly in their context, easily found again on site, and monitored over the course of several subsequent inspections. The changes enable better projections about the engineering structure's condition.

Outlook

This project created the foundations to support inspections of engineering structures in future. Nonetheless, additional intensive research and development activities are required in view of developing a reliable image-based support system for inspections of engineering structures. Additional technological engineering activities are necessary with regard to an automated and UAS-based recording of image data about engineering structures, such as 3D navigation, robust distance control, integration of even more efficient camera technology. In this context, it would make sense to prepare a catalogue of technical requirements for UAS that are designed to be deployed specifically in inspections of engineering structures. ■



Result of crack detection at a bridge structure (photo: gmtib)

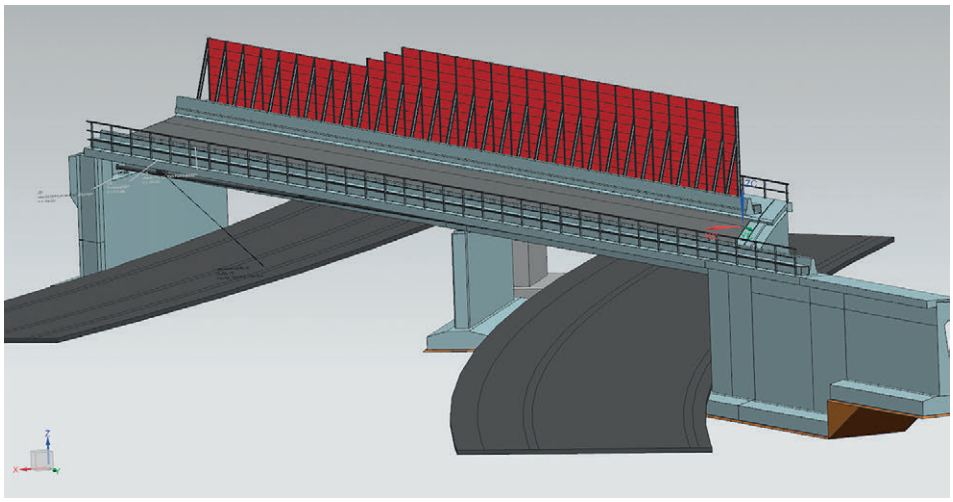
Digitising existing structures in bridge construction

Jennifer Bednorz, civil engineer, “Steel Structures, Corrosion Protection, Bridge Equipment“ section and Dr Iris Hindersmann, geographer, “Concrete Structures” section

With the introduction of the Digital Planning and Building implementation plan by the Federal Transport Ministry, it is required to apply the Building Information Modeling (BIM) method in infrastructure projects starting in 2020. Approaches and strategies for deploying BIM in operating and maintaining bridge structures currently exist only to a limited extent.

Methodology

Possibilities to develop BIM-compatible as-built models for existing bridges were analysed, practically applied and recommendations were made on their use in the operating phase. Structural models were developed for the duraBASt bridge, using the point cloud of a laser scan, including the box girder and also using conventional modelling on the basis of as-built documentation. The two models were compared geometrically to show and evaluate the difference between the planned and actual condition of the existing bridge.



BIM model of the duraBASt bridge derived from as-built documentation enriched by semantic data

Point cloud from the laser scan in the box girder

Result

As-built models can be drafted using the two variants: laser scan and subsequent modelling from as-built documentation. The studies illustrate possibilities to use the models and provide a cost estimate for drafting the model. The result of a laser scan is an exact as-built model which enables, for example, an analysis of the minimum concrete surfacing by surveying the bridge’s box girder. The accuracy of parametric and associative BIM models on the basis of as-built documentation depends on the quality of this documentation. The BIM model enables the operator to access information on the geometry, measurements and relevant structural information. Construction projects can be planned faster and more easily on the basis of the structured data. Updates for repair and maintenance purposes, for example, can be implemented in the model, and necessary plans can be derived from the model. Photos of damages taken during structural inspections of the engineering structure can be supplemented and linked to the accurate coordinates of the structural component. ■

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Bridge durability assessments

Dr Maria Teresa Alonso Junghanns, civil engineer, “Concrete Structures“ section

Pursuant to applicable regulations, bridge structures made of concrete need to be structurally safe, serviceable and durable throughout their lifespan. Ambient impact – such as CO2 in the air, chlorides from de-icing salt, frosts and temperature – can cause a loss of compressive resistance in the concrete and lead, for example, to reinforcement corrosion which in steel-reinforced bridges has a significant impact on their load-carrying capacity and serviceability.

Durability assessments are currently done in a descriptive manner across the globe on the basis of information about exposure: there are legal requirements for the composition of concrete, for example, depending on environmental conditions. The consequences of damaging mechanisms – for example, cracks – are evaluated and documented in the scope of the regular inspections of engineering structures. This procedure does not enable a lifespan prediction and is contrary to the procedures employed in measuring superstructures for static and dynamic strain. Model-based types of durability assessments are currently being tested for federal trunk roads.

Calculating durability

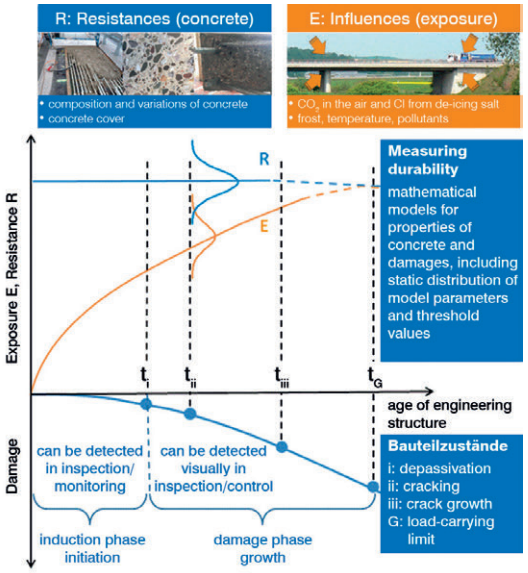
Durability is calculated based on models enabling a static quantification of the exposure and resistance of structural elements. The model starts from the assumption that a damage is first induced and can then progress during the growth period until it causes structural failure.

Applying the descriptive rules for concrete bridge structures pursuant to the Additional Technical Terms of Contract and Guidelines for Civil Engineering Works (ZTV-ING), the Technical University Munich used calculations to review a projection for concrete bridges concerning carbonated and chloride-induced corrosion. For the assessment situation, the effects of high exposure and low material resistance were juxtaposed against that of high material resistance and low exposure. Real climate data from different locations in Germany was taken into account [1].

The results show that probabilistic calculations can constitute a basis for lifespan projections of bridge structures, and that they can enable a transition from the assessment procedures currently deployed to a reliability-based procedure. Additional analyses of engineering structures from all exposure categories are needed, however, for a safe, practical application [2].

Outlook

In BASt research projects, model parameters and calculations are currently being reviewed for possible simplifications, taking the results from laboratory tests and inspections of engineering structures into account. The research activities aim to develop a strategy to efficiently conduct laboratory tests and inspections of engineering structures in conjunction with the approaches necessary to enable a lifespan evaluation in terms of durability, taking current and future procedures into account as regards sustainability. ■



Principles of durability assessment and possible damage-progression phases in engineering structures

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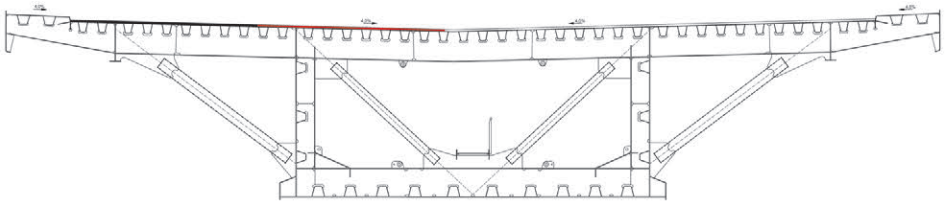
Steel bridges: thermal stress as a result of installing mastic asphalt

Heinz Friedrich, civil engineer, deputy head of the „Steel Structures, Corrosion Protection, Bridge Equipment“ section

Installing a protective mastic asphalt layer on 28 June 2019

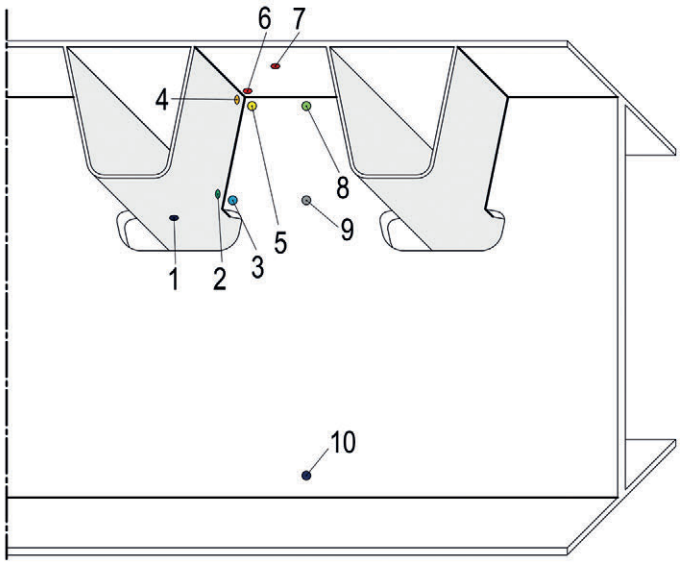


Cross section of the Upper Moselle Bridge

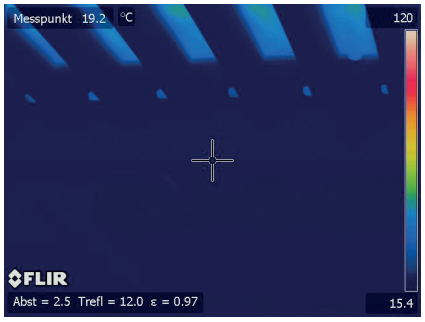
In the first structural inspection after replacing a bridge’s deck surfacing, a disproportionately high number of cracked weld seams are observed in the pavement plates of steel bridges made of orthotropic materials. The obvious assumption would be that the damages are connected to the stress caused by replacing the bridge’s deck surfacing.

Relevant stress can occur when the old deck surfacing is being removed due, for example, to the dynamic stress from the processes of milling, when installing the new deck surfacing, including thermal stress, when installing the mastic asphalt or possibly during rolling, due, for example, to the dynamic stress from compacting top courses made of roll asphalt. The problems are further aggravated as increasingly more efficient machines are developed, such as high-performance mills or asphalt pavers with ever broader paving screeds.

Positioning of temperature sensors inside the bridge at cross beam No. 6



Positioning of temperature sensors



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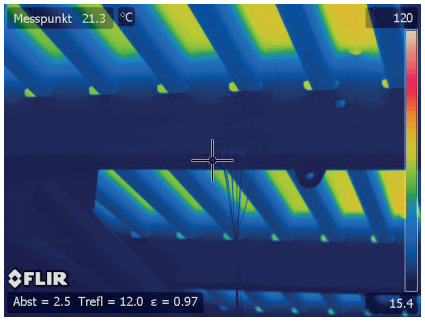

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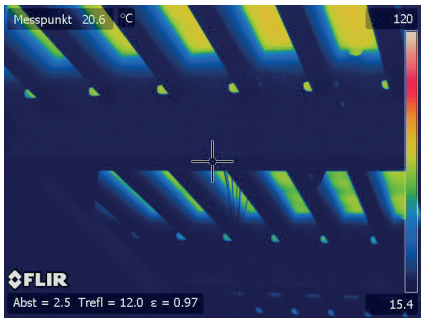

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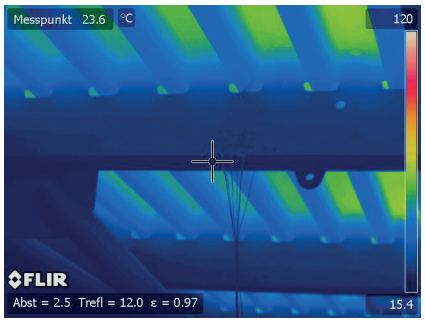

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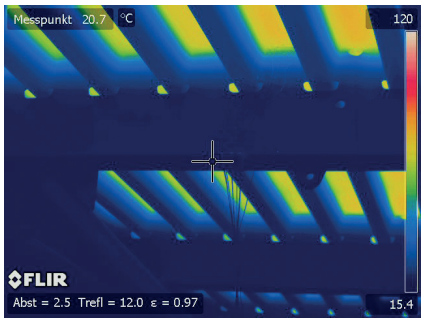

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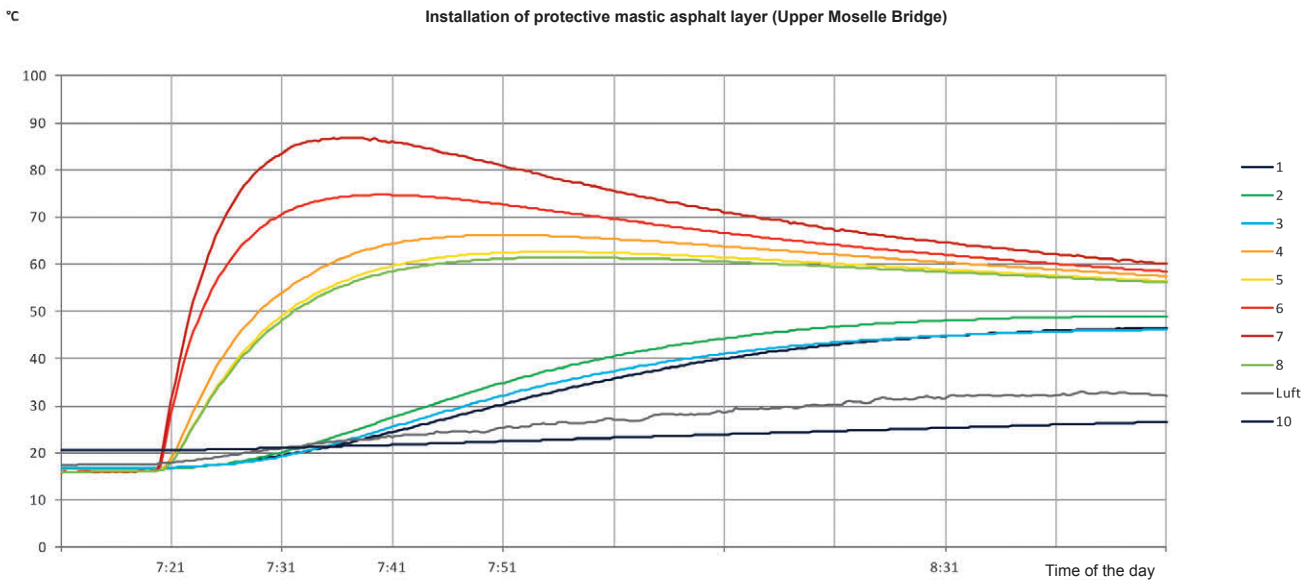
IR images of observation area during the installation of a protective mastic asphalt layer at different times of the day

The basis for further analyses concerning the "Stress on steel bridges from replacing deck surfaces" topic is currently being developed and described in the scope of a research project. Its focus is the thermal stress on the steel construction as a result of installing a new bridge deck surfacing. For this purpose, various renewal measures have been accompanied by technical experts to document the process steps and to identify temperature distribution patterns in orthotopic deck plates during asphalt installations. The structures studied are the Rhine Bridge Leverkusen, the Wiehltal Bridge, the Rhine Bridge in Duisburg Neuenkamp and the Upper Mosselle Bridge.

The photos here document the exemplary installation of protective deck surfacing at the Upper Moselle Bridge and related measurement results. ■



Temperatures measured with the sensors at cross beam No. 6

Gabions in stress tests

Wilhelm Decker, technical specialist, Esther Schreck, geologist and Felix Wawrzyniak, physics laboratory technician,
"Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section

Retaining wall made of gabions

Gabions have come to be deployed frequently in roadside and landscape scenery along federal trunk roads. The welded mash cages filled with rocks are a popular and cost-efficient type of construction method. Besides being used as decorative elements and in lieu of fences in horticulture and landscaping, they are also deployed as quick and cost-efficient structures in civil engineering. Gabions fulfil a variety of functions here as well – as retaining walls, wall facings and also as noise barriers. They are available in various models and sizes. Gabions can be purchased as factory-filled baskets which require nothing more than installation, but they are also available as individually variable systems that can be filled with local stones. Retaining walls several metres in height can be seen along federal highways and federal motorways for the purpose of securing slopes. Retaining walls made of gabions are a type of civil engineering structures.

from left: Felix Wawrzyniak, Esther Schreck and Wilhelm Decker

Regulations

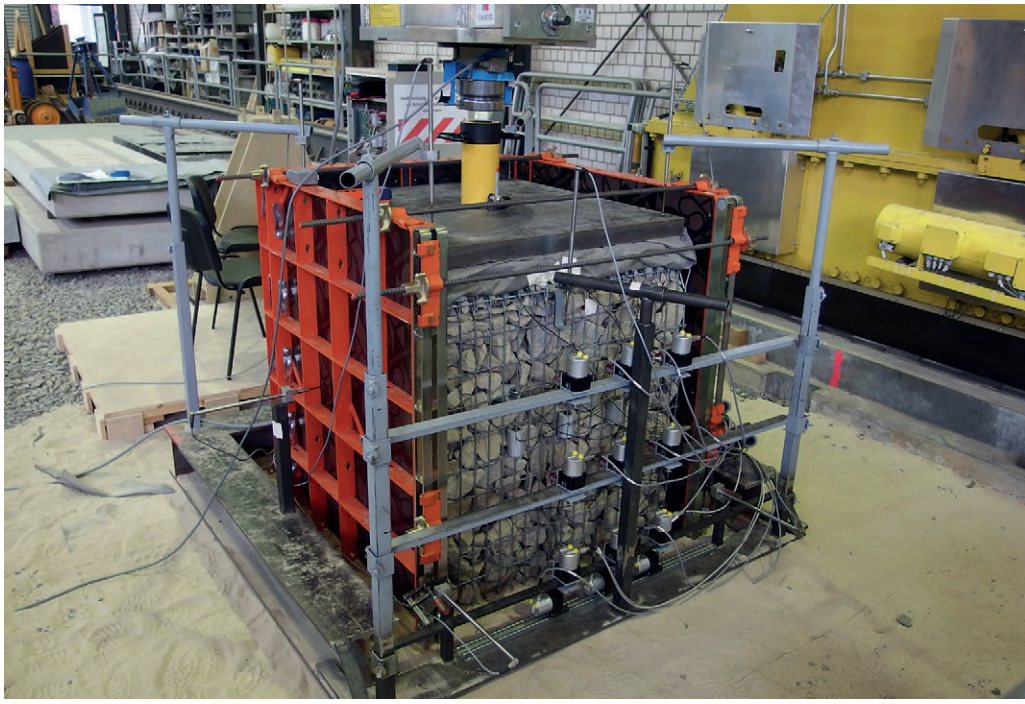
The requirements for civil engineering structures are defined in a number of different regulations in order to ensure the structures' quality and durability. As simple as gabions may appear in their design, they are complex from the static stability perspective. Because of their composition, the filled welded mesh cages constitute a special case as they are not homogeneous structures. Thus there is so far no specific verification to be found in the regulations for the internal structural stability of an individual element. Additionally, the height of gabion installations is restricted to six metres. It is intended to close this gap in the regulations by including a corresponding verification procedure. BASt's tasks include adapting the relevant regulations and updating them to the state of the art.

Stress tests for individual baskets

Stress tests are one possibility to identify the deformation properties of a material or component and the stresses it can withstand. In these tests, for example, a concrete specimen is stressed to the point of material failure. Usually, these tests are conducted in the laboratory using

small samples. A large-scale test facility is needed to test gabions of 1x1x1 metres in dimension. BASt has had a modern stress frame since 2015, with which a test load of up to 200 tonnes can be applied on a component. The first step was to develop a concept for the test set-up and measurement technology, as neither experience nor publicly accessible research results were available.

There are many different types of gabions: they differ in size, stiffening elements, mesh width and locking mechanisms. An exemplary model made of welded mesh panels approved for civil engineering purposes was selected.



Stress test on an individual gabion

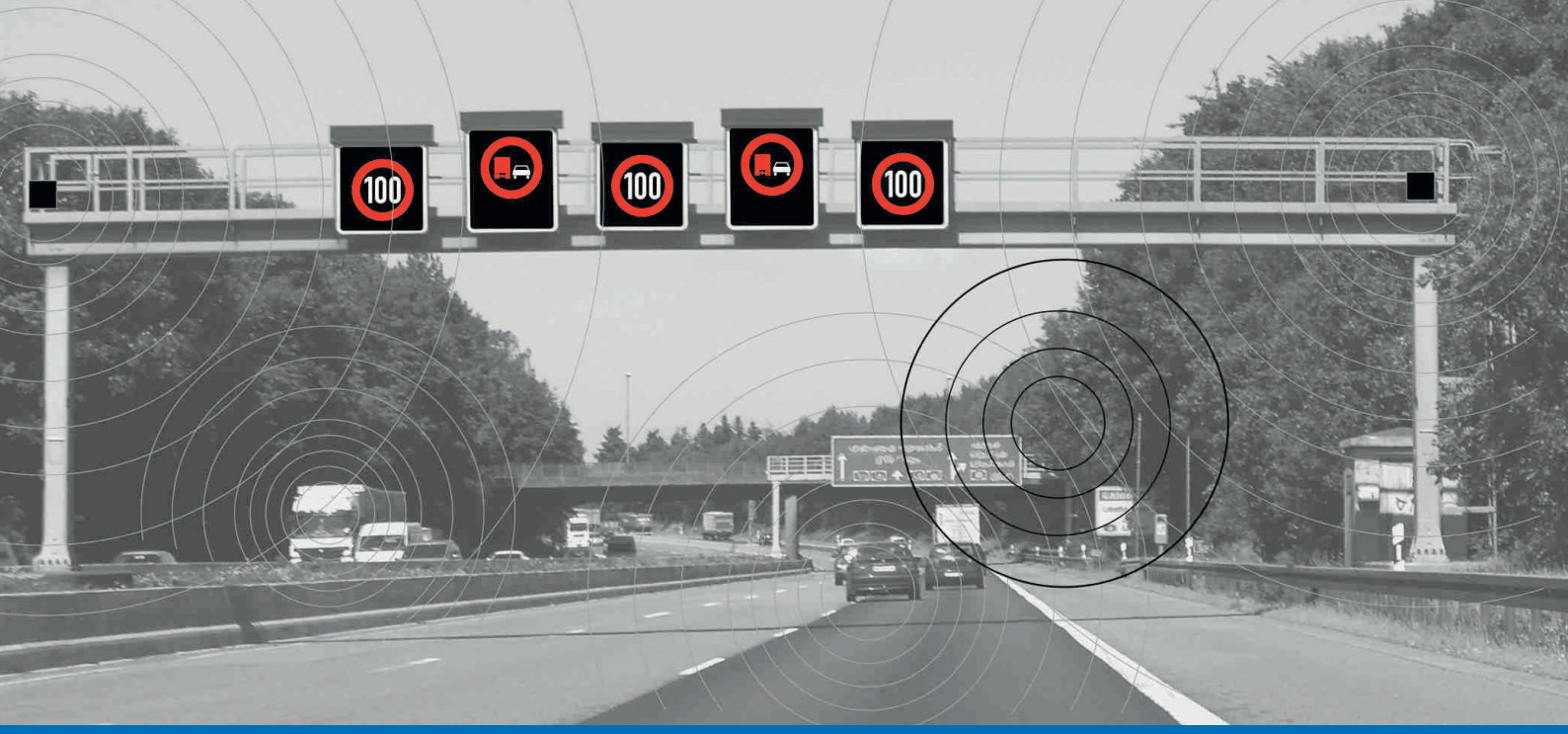
In the past, gabion tests were conducted with a sand filling and others filled with loose greywacke stones. As can be seen in the image, the mesh cages were enclosed by steel frames on three sides. This simulates an individual element within a retaining wall. Deformations on a retaining wall are only visible on its open front side. Additionally, sensors were placed on the inside and outside of the gabions. On the inside, force sensors were welded into the stiffening elements to measure the tensile forces on the spacers as the load increased. On the outside, measurements were taken of the test force induced, the front panel's horizontal expansion and the vertical compression of the basket. The load on the gabions was increased in uniform steps. The increased load force was selected in such a way as to correspond to the weight force of a filled gabion.

Additional tests were conducted in the course of the project which used a more compact granite filling. After completing the trial phase of the individual tests, the next step is to compare and evaluate different verification procedure options.

The tests so far have shown that a gabion's stability results from the interaction between the mesh cage and its filling material. With increased loads, the loose stone filling led to material shifts and higher deformation rates at the front panel. The mesh panels, spacers and connectors did not show any material failure even at high loads.

Outlook

Once the stress tests of the individual gabions are completed, the load-bearing behaviour of a large retaining wall will be tested. BASt has the technical possibility and space also to conduct stress tests on large retaining structures. Studies on the deformation behaviour of a wall several metres high are intended to provide an understanding of the behaviour of gabions when they make up part of a connected structure. The results will be used to develop a calculation procedure to verify the inner structural stability of gabion structures and incorporated into existing regulations. ■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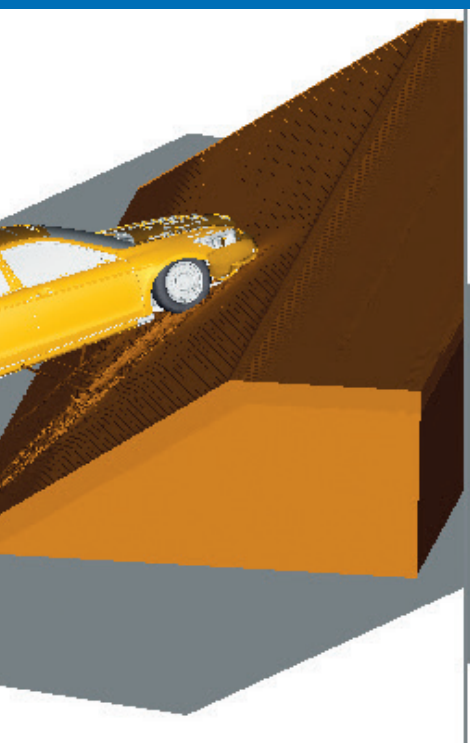

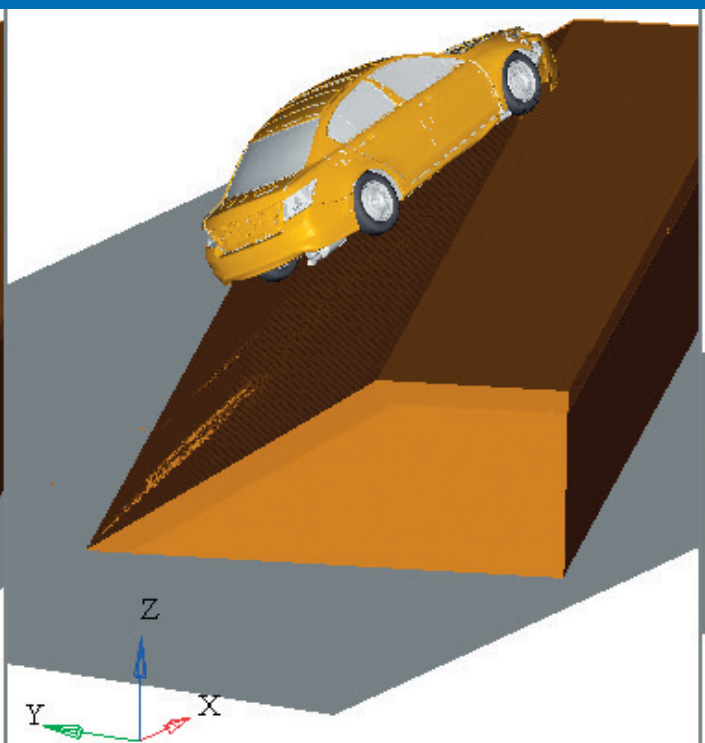
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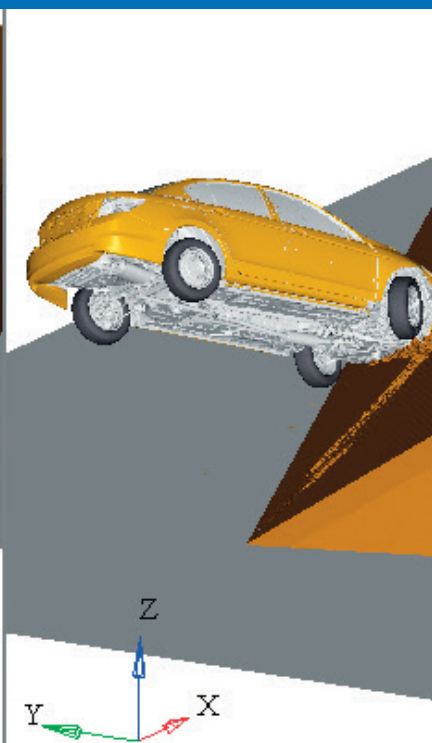
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Traffic Engineering

Infrastructure requirements for automated driving on motorways

High-speed cycling links: tools for practical implication

Innovative noise mitigation

Truck parking along federal motorways

Light emissions

Removing oil spills on traffic spaces

BaustellenCheck

Digital crash tests – crash simulation

Infrastructure requirements for automated driving on motorways

Tom M. Gasser, lawyer, head of "Automated Driving" section, Bernhard Kollmus, traffic engineer, "Highway Design, Traffic Flow, Traffic Control" section, Dr Jan Ritter, civil engineer, "Highway Equipment" section, Dr Lutz Rittershaus, physicist and engineer, head of "Connected Mobility" section and Karen Scharnigg, civil engineer, „Traffic Management and Road Maintenance Services" section

Motorways offer particularly good preconditions for automated driving because their infrastructure is standardised. A traffic congestion pilot will be the first implementation of automated driving in this environment. A driving function which is about to be launched will completely take over the task of driving on motorways. The Road Traffic Act was adapted already in June 2017 to enable drivers to leave the steering of the vehicle to a suitably capable driving system while pursuing a non-driving activity themselves.

BASt's findings show that automated driving functions offer considerable benefits in terms of road safety: the vehicle's comprehensive sensory equipment significantly improves environment recognition. This improves the efficiency of emergency braking and collision-avoiding functions, and driving becomes safer as these systems intervene to prevent imminent accidents or minimise damages. Road safety is likely to be improved in self-driving modes too: weaknesses of human drivers such as distraction, drowsiness etc. and the driving mistakes that result as a consequence no longer occur. Self-driving vehicles also have high potential at high speeds on motorways and in complex situations that can occur in inner-city traffic. However, in these conditions, the vehicle's built-in sensors are not capable of scanning the environment to a sufficiently reliable extent.

The perspectives and issues of players from the infrastructure sector and the automotive industry were brought together in order to develop possible approaches to a solution. The study focused on the infrastructure needs of automated driving on both motorways and rural roads with structurally separated carriageways. Steering a vehicle in situations critical for road safety was the base assumption for the results derived.

The outcome is that road markings proved to be of great relevance in conventional road infrastructure because of their significance in positioning the vehicle in the traffic lane.

from left: Tom M. Gasser, Bernhard Kollmus, Karen Scharnigg, Dr Lutz Rittershaus and Dr Jan Ritter

In this context, it will be necessary to know the criteria for road markings to be machine-readable in order to take the parameters relevant for automation into consideration in future legislation. That has now become the subject of follow-up research activities.

Additionally, setting up a digital infrastructure has been identified as a promising solution for most of the driving situations where road safety is a critical concern. This greatly reduces the necessity to take other, similarly effective individual measures (for example, structural ones).

Digital twin

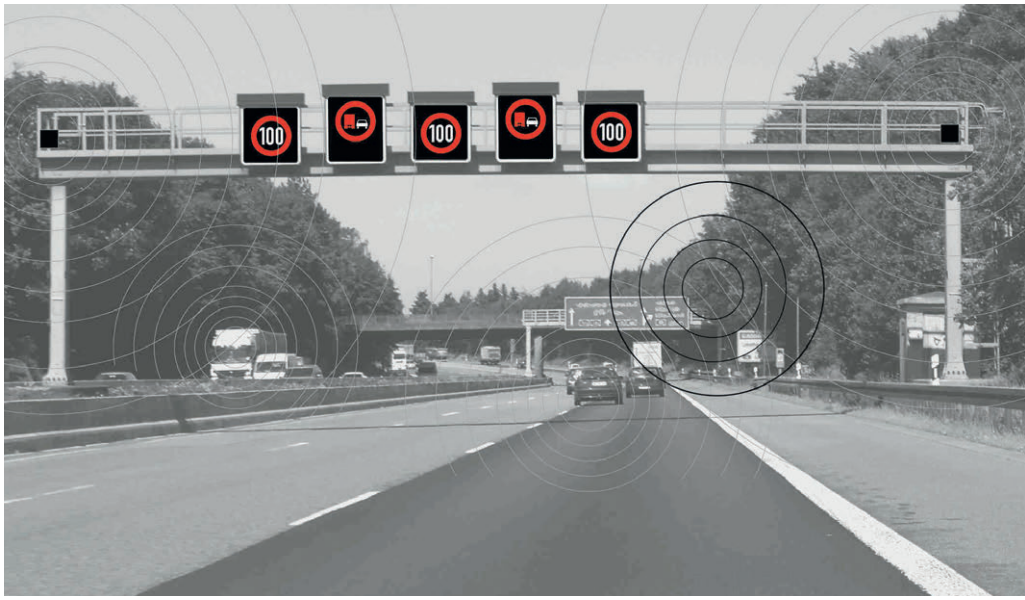
Data from authorities for road construction and operation as well as road traffic authorities would be fed into such a digital representation, as well as data generated by the self-driving vehicles themselves. This solution, also called digital twin, provides a comprehensive depiction of known conditions and requirements on and along the road driven, while taking strict requirements for data quality and real time availability into account. This twin would also offer a potential benefit for the authorities involved for their duties. At the same time, this data base can be used as input for driver information systems, and thus enhance road safety for all drivers as an assistance system. It is an element of vehicle networks which is centralised, cost-efficient and can be extended flexibly. Private companies could be contracted, for example, to set up and operate a digital twin.

It is important to differentiate between foreseeable and unforeseeable events that can occur while driving to illustrate both the effect and residual restrictions of a digital infrastructure. These events have in common that they pose a challenge for vehicle sensor systems and steering processes in recognising the situation at hand: only if they are known, can a safe steering strategy be initiated early enough.

Foreseeable events

Foreseeable events can be solved in each case if the information is available. Roadworks that are not suitable for automated driving and need to be passed manually are foreseeable events that can be addressed by imposing a safe steering strategy for self-driving vehicles. The temporary use of the hard shoulder as a traffic lane is another relevant condition. Information about such an event poses additional challenges for halting the vehicle with low risk in the case of a technical defect in the automated driving function. Road section-specific instructions and restrictions can also be planned ahead in terms of steering-relevant regulations along roads. A (digital) forecast increases the reliability of environment perception at the same time. Events occurring beyond sensor range can also thus be included in automated steering. This is just as necessary at high speeds as it is in complex situations, for example, when relevant objects are blocked from view. Only a digital infrastructure will make it possible to avoid drastic steering manoeuvres which in themselves may become a hazard for other road users.

Also the condition of road markings and vertical traffic signs can be documented for automated steering purposes, because a deviation – continuous wear, for example – can, for the most part, be planned for. If the deviation is a result of a specific incident, for example, an accident, this is a condition at the transition from a foreseeable towards an unforeseeable event.



Vision of future connected digital infrastructures

Unforeseeable events

Any event that occurs at short notice – particularly accidents, obstacles in the middle of traffic lanes from fallen cargo, etc. – is not foreseeable when it first occurs and, if at all detectable, will be available via the digital infrastructure only to subsequent vehicles as information to enhance road safety.

Signs and instructions for police officers are a significant challenge for vehicle sensor systems, as they have priority over other traffic regulations and their occurrence is not foreseeable. This includes the challenge to adequately steer the vehicle in the presence of vehicles with special rights and right of way (blue emergency lights and sirens). Vehicle-to-vehicle communication appears to be the most viable option in this situation, as it could also be adapted to police signalling disks to make them machine-readable. This results is a need for further research.

The present studies have shown BASt that comprehensive digitisation is necessary that will also include the field of infrastructure. ■

High-speed cycling links: tools for practical application

Dr Jan-André Bühne, economist, "Coordination Office Requirements Management", Caroline Rose, civil engineer, Highway Design, Traffic Flow, Traffic Control" section and Benjamin Schreck-von Below, traffic engineer, head of "Safety Concepts, Safety Communication" section

The German government is supporting the use of environmentally friendly modes of transport by funding bicycle highways as part of high-speed cycling links (RSV). RSVs are intended to connect important areas that thus have high potential, enabling safe and attractive cycling at high speeds over greater distances. They are thus designed primarily for every-day bicycle traffic and commuters. RSVs are an important element in planning cycle path networks to connect urban and rural areas and close gaps.

Procedures for potential and cost-benefit analyses are necessary for planning purposes for those areas for which no adequate or uniform data was available previously. On the basis of a BASt study, these new tools have thus been developed to provide guidance for planners.

from left: Benjamin Schreck-von Below, Caroline Rose and André Bühne

Potential analysis procedure

A potential analysis for RSV routing purposes aims to assess traffic volumes to be expected on a potential link. It is intended to verify that a sufficiently high number of people can be expected to use the (new) traffic link. This includes estimating whether a shift towards a different mode of transport – from car to bicycle in particular – can be expected as a consequence of this RSV.

Depending on data availability, for such a potential analysis a detailed procedure can be used based on macroscopic traffic models or an approximation can be made. An approximation assesses traffic volumes on the basis of less basic data. The result of either procedure comprises all information necessary to form the basis for a subsequent cost-benefit analysis.

Cost-benefit analysis

A macroeconomic assessment consists of various components concerning benefits and cost, including changes in travelling time, health effects due to increased exercise, vehicle operation costs and planning costs. This procedure also contains descriptive components for which no monetary value was assigned, such as improvements in the quality of life and recreational landscape.

Conclusions and recommendations

In addition to potential and cost-benefit analyses, the study also addressed aspects of routing cycle paths and designing interconnection points.

In view of drafting elements, a minimum width of 4 metres is required for independently managed RSVs

to ensure that cyclists can cross and overtake each other safely. A marked line in the middle of the path has a positive effect. A separate footway should be available for pedestrians, segregated by a delineation strip or a wide grass or gravel strip. In built-up areas, the high-speed cycling link can be given priority over other lanes provided that the maximum speed of 30 kilometres per hour and a traffic volume of 2,000 motorised vehicles per day are not exceeded in this location.

With these calculation tools for potential and cost-benefit analyses, appropriate procedures based on robust findings were developed for direct use by planners and authorities responsible for construction and maintenance.

The "High-speed cycle links – Guidelines for potential analysis and cost-benefit analysis" guidelines that were developed provide important information and calculation data for planners of high-speed cycle links.

The study's results will also be used in the ongoing revision of regulations concerning the design of urban streets and cycling facilities. ■

www.bast.de/schnellverbindungen

Innovative noise mitigation

Dr Fabio Strigari, physicist and Dr Wolfram Bartolomaeus, physicist,
„Environmental Protection“ section

Steadily increasing mobility is accompanied by increasing traffic-related noise emissions – and the health effects of people‘s exposure to noise can no longer be disregarded. In its “Innovative noise mitigation” focal area, BASt is researching novel technologies to satisfy increased noise mitigation requirements and identifying new potential to reduce traffic-related noise pollution.

Extensions for noise barrier walls

Modular wall extension systems offer a simple possibility to improve the acoustic effectiveness of existing noise barriers. On the one hand, higher walls enhance the reduction of noise levels. On the other, additional noise mitigation can be achieved by using particular geometries and absorbent materials. Using a wall extension made of sound absorbing foam as an example, a multi-part study reviewed the noise reduction effect of this type of extension. For this purpose, the propagation of sound was simulated numerically and numerous measurements were made, both in the laboratory and under real life conditions.

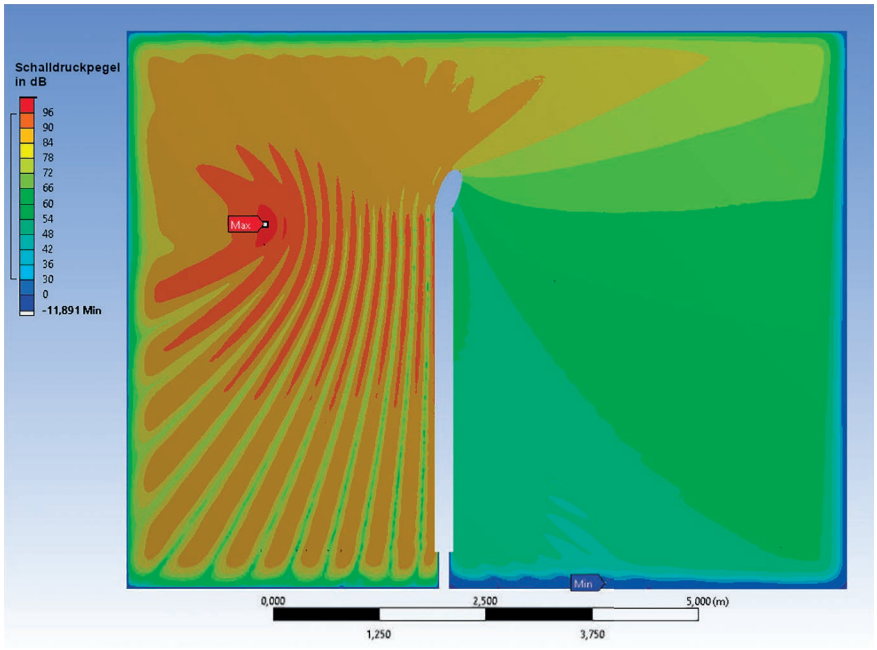
All the measurements indicate that the noise reduction achievable is about 3 dB to 4 dB compared to a barrier without extensions. Surprisingly, the acoustic effectiveness is thus the same as achieved when raising a noise barrier by the height of the extension elements.

Analysing the numerical simulations results in even more detailed findings about how sound propagates through and over the extension elements. It will be possible to derive an understanding about how noise reduction depends on the frequency of the incident sound wave. At the same time, it can be used to quantify the effectiveness of the extension material more precisely and to separate it from the impact of the elements’ geometry. While the absorption material itself has a positive effect on acoustic effective-

Noise-reducing extension made of whisper foam on top of a noise barrier (photo: Andre Jaborek, Hessen Mobil)

ness, the shape of the extension elements reduces the noise reduction that can be achieved.

From an acoustic perspective, these types of noise barrier extensions thus do not have a significant advantage over raising wall height. However, if a decision is made to enhance the noise mitigation effect of an existing noise barrier, other criteria – such as costs and ambient conditions – will also have an influence on the decision-making process. In some cases, the simple installation of the elements can be an argument in favour of using them. The method used in this study will be applied to future research on other types of wall extension systems. Numerical simulations, in particular, can be an effective tool to optimise such systems and practically support their implementation.

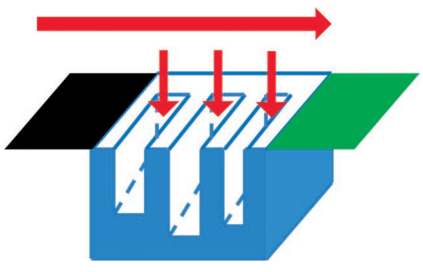


Simulation of sound propagation in front of and behind a noise barrier with wall extensions, cross-section, colour coding illustrates the acoustic pressure level in dB

Noise reduction using diffractors

The acoustic effect of barriers with low diffractive edges directly next to roads were examined in studies in the scope of the EU's HOSSANA project. A grid made of 9 low brick rows led to a noise reduction of 7 dB. A Dutch company has taken up this concept and developed corresponding diffractors for installation in lateral roadside areas.

Slits in concrete blocks of various depths and widths that are buried next to roads function as Helmholtz resonators. The incident sound wave coming from the road is thus reduced at a broad frequency spectrum by its interaction with the reflective wave from the slits. This development will be tested soon in a field test. ■



Schematic diagram of a diffractor

Truck parking along federal motorways

Dr Marco Irzik, civil engineer, deputy head of section and Dominik Schmitt, traffic engineer, "Highway Design, Traffic Flow, Traffic Control" section

Identifying the demand

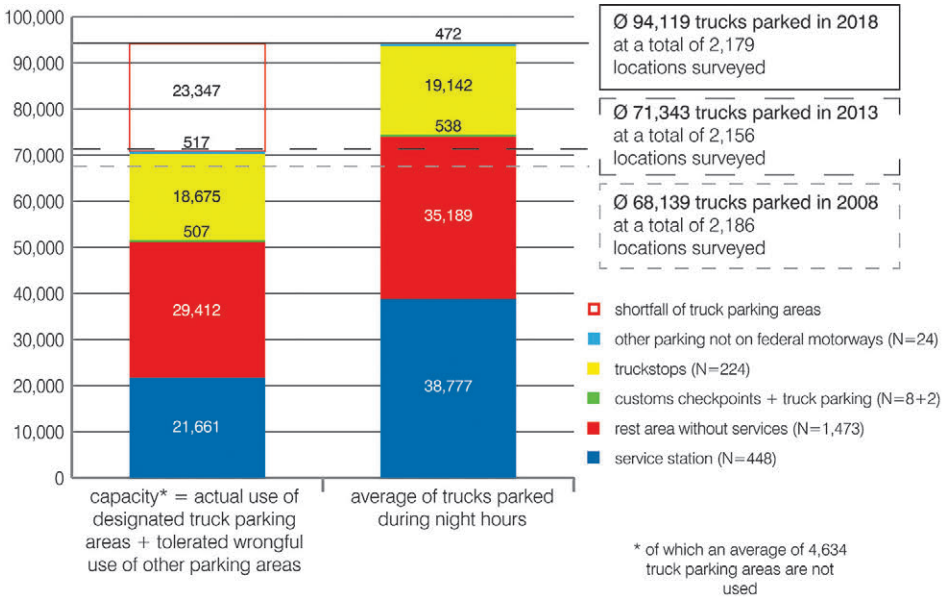
An estimate of the need for truck parking options along federal motorways (BAB) constitutes the basis to develop targeted solutions to improve the parking situation for trucks. Despite extensive action, the situation remains tight. This is why the Federal Transport Ministry commissioned BASt to evaluate a survey of trucks parked overnight along federal motorways conducted by the Länder road construction authorities. As previously in 2008 and 2013, a nation-wide survey was also carried out in 2018 using the surveying method developed by BASt in 2008. On three out of four nights, the number of parked trucks on the surveyed locations was counted at a randomly selected point in time during the night hours.

On average, about 94,000 parked trucks were counted on each surveyed night in 2018. In order to identify how many truck parking spaces are lacking, the total number of trucks parked was compared to the identified total capacity of about 71,000 parking spaces across all of the almost 2,200 locations surveyed. This has shown a shortfall of about 23,000 regular parking spaces for trucks along the federal motorways in Germany.

Compared to the 2008 and 2013 surveys, a negative balance was also found for the first time for the surveyed population of truckstops. This means that there too, the average number of trucks parked overnight in 2018 exceeded the number of permissible parking options. Above all, however, the total number of trucks parked overnight has risen significantly from about 68,000 in 2008 to 71,000 in 2013 to about 94,000 trucks in 2018.

The development in the volume of heavy goods vehicle traffic is one explanation for the difference between the increase in the number of trucks from 2008 to 2013 and from 2013 to 2018. While the volume was lower in 2013 than in 2008, it had increased by 15.5 per cent by 2018. Changes in general conditions, such as changes in logistics processes, are assumed to be another possible explanation for a change in parking behaviour. Finally, many new parking spaces have also contributed to making it possible to count more trucks. The trucks counted on these new parking spaces may not have been included in previous surveys as the shortfall in parking options caused drivers to park their trucks in secondary road networks instead. These would thus have been counted only in exceptional cases.

As in 2008, the 2018 census is also the basis for estimating the future need for truck parking options. Using the new data, the trend projected in 2008 was updated. Taking the expected increase in heavy goods vehicle traffic as a basis – but with the conditions otherwise like the status quo – the need for truck parking spaces can thus be estimated for the forecasting period. On this basis, network concepts can be developed. ■



Capacities and trucks parked overnight on and along federal motorways in Germany (last update: April 2018)

Light emissions

Dirk Heuzeroth, physicist, head of section, Dr Sandra Jacobi, physicist, Jan Sauer, biologist and Dr Andreas Walkling, lighting engineer, “Environmental Protection“ section

Artificial lighting is an essential part of a safe and efficient road infrastructure. The continuous increase in artificial light, the trend towards whiter street lights as well as technical advances in light engineering – for example, LED and laser light – have, however, transformed many night landscapes. We are learning more and more about the sometimes grave consequences for humans and nature.

Since its existence, humankind has been shaped socially and genetically by a natural day-night cycle. The circadian rhythm regulates important evolution-related physiological and biochemical processes. Melatonin synthesis, for example, is suppressed by artificial light; insomnia, cardiovascular disorders, weakened immune systems and metabolic disorders are associated with it. But it is not only people who are influenced by artificial light, animal and plant species also react to artificial light and disrupted day/night cycles. Artificial light is a deadly trap, for example, for many nocturnal insects and can also act as a migration barrier for many other species (amphibians, bats).

For these reasons, light emissions are considered harmful effects on the environment pursuant to the Federal Immission Control Act (BImSchG), if, as a result of their nature, extent or duration, they are liable to cause hazards, considerable disadvantages or considerable nuisance. It is therefore desirable to cap or even reduce the disrupting impact of artificial light on people and nature in residential areas and nature reserves or other sensitive habitats.

Interdisciplinary expert workshop

An interdisciplinary expert workshop was hosted at BASt in cooperation with the German Lighting Society (LiTG) to obtain an overview of current knowledge on light emissions in road environments. The workshop focused on road safety, energy and resource efficiency, nature and health protection, as well as on planning and designing lighting systems. After a number of introductory presentations which looked at light emissions from the perspectives of road safety, lighting engineering, nature conservation and possible solutions, shortcomings in planning and implementing street lighting facilities were discussed, a vision for ideal lighting and steps for its implementation were outlined.

To this end, additional research was framed on the causal relationship between dosage and impact, assessing the lighting quality that is necessary for orientation and recognition purposes – such as light intensity, uniform light, colour – and its resulting impact on people as well as fauna and flora.

The many-facetted ideas and approaches to dealing with light emissions

photo: DEGES/René Legrand

drafted during the implementation phase of the workshop are now being pursued in the newly established “Light emission” working group of the Road and Transport Research Association (FGSV). The aim is to analyse and classify the impact of street lighting on road safety in order to then reconcile potential measures with road safety requirements. ■

from left: Dr Andreas Walkling, Dirk Heuzeroth, Dr Sandra Jacobi and Jan Sauer

Removing oil spills on traffic spaces

Marco Schmidt, spatial planning expert, “Traffic Statistics, BISStra“ section and Christopher Schirrmeister, mechanical engineer, “Traffic Management and Road Maintenance Services“ section

According to estimates, roughly 10,000 incidents cause damage across Germany every year when automotive fluids – primarily engine oil or diesel – leak onto traffic spaces. These contaminations can have an adverse impact on road safety by reducing the road’s skid resistance. The authority responsible for road construction and maintenance is obliged to ensure that roads are cleaned adequately and professionally so they can be swiftly reopened for traffic.

Two established cleaning methods are regularly deployed to clean contaminated traffic spaces: dry cleaning with an oil-binding agent and mechanical wet cleaning using high pressure water-suction technology. The mechanical wet cleaning method and associated costs that are usually higher often lead to legal disputes on the proportionality and necessity of the cleaning expenses. The reason given for mechanical wet cleaning is often that this method is the only one to ensure a road is sustainably safe for traffic, unlike dry cleaning using an oil-binding agent.

Two research projects aimed to test and compare the effectiveness of the two usual cleaning methods deployed in practice under laboratory and real conditions. An external contractor was commissioned with the laboratory study, while the practical tests were conducted by BASt itself.

Dry cleaning using an oil-binding agent

When the dry cleaning method is employed, oil-binding agents suitable for use on traffic spaces are applied onto the contamination and worked into the surface with brooms or road sweeper and then removed again. It may be necessary to repeat the application multiple times, depending on the type and quantity of the leaked automotive fluid.

Mechanical wet cleaning

In this method, special cleaning machines with varying operating widths are employed to drive over the contaminated road at low speed. Water is sprayed onto the road using high pressure nozzles and suctioned off afterwards. These cleaning machines sometimes use surfactants and heated cleaning water, which are supposed to enhance the cleaning success.

Comparison of cleaning methods

Basically, the tests conducted show that both professionally applied oil-binding agents and suitable wet cleaning machines can produce skid-resistant and thus safe traffic spaces. The two procedures can be considered on a par as regards this property. In mechanical wet cleaning, the use of surfactants or heated cleaning water generated only low additional positive effects. Here in fact, the speed of cleaning has proved to be the decisive factor. With regard to dry cleaning, it needs to be noted that no dangerous secondary bleeding effect occurs when oil-binding agents are applied professionally, even with subsequent irrigation.

The studies are the basis for recommendations that are required at Länder level for a removal of automotive fluids on traffic spaces in line with the requirements. The findings were included in the Road and Transport Research Association’s working paper “Removal of oil stains on traffic spaces” that was published in 2019. ■

BaustellenCheck

Andreas Coumanns, traffic engineer, Dr Kerstin Lemke, civil engineer, head of section, Jennifer Sammet, physics laboratory assistant and Matthäus Zelazny, traffic engineer, “Highway Design, Traffic Flow, Traffic Control“ section

Roadworks to maintain, renew and extend German motorways frequently cause traffic congestions and delays. Precise information about ongoing and future roadworks can prevent traffic congestion by giving advance notice to road users and, where appropriate, offering alternative routes.

At www.baustellen-check.de, structured roadworks information on all the long-standing construction sites in the network of Germany’s federal motorways reported via the Mobility Data Market Place (MDM) is made available to interested users. The information is presented in a graphically appealing and intuitive manner. Numerous filter options make the information easy to handle.

mFUND funding project proFUND

BASt’s project partner TraffGo Road GmbH was instrumental in developing BaustellenCheck in the course of the “proFUND” project (reviewing and optimising the report qualities on federal motorways and tolled sections of rural roads). ProFund is a project financed by the “mFUND” innovation programme of the Federal Transport Ministry where BASt and INRIX Europe GmbH cooperate. It aims to provide road users with uniform, high-quality and user-friendly information about ongoing and future roadworks and to sustainably improve the data quality of roadworks information for all users across Germany.

The functions of BaustellenCheck

With BaustellenCheck, users have the possibility to give their feedback both on the roadworks they have passed through and on the roadworks alerts they have received. They can, for example, report corrections to inaccurate roadworks information – e.g. a wrong speed limit – or report when announced roadworks have already finished or an existing roadworks site has not been announced. This user feedback is evaluated using scientific methods and then made available to the competent authorities in aggregate form.

Another function of BaustellenCheck consists of the possibility users have to submit a rating of how they felt about a roadworks site. This data is evaluated in order to identify additional decisive parameters that influence the users’ perception of roadworks.

BaustellenCheck also uses floating car data (FCD) from INRIX to inform users about the expected delay time at roadworks. FCD consists of GPS-based information on the location from satellite navigation systems or smartphones used to describe the traffic situation. Current as well as historical traffic data is used to provide a reliable forecast.

Individual roadworks which user feedback or FCD analyses show to cause particular problems are validated by passing them with BASt’s MESUV measuring vehicle (measuring system to record road and traffic data). BaustellenCheck offers a voice-operated memo function to ensure users are not distracted while driving. This enables them to record and store their observations for later use.

Using BaustellenCheck gives users the opportunity to actively contribute for the first time to improving future roadworks. ■

www.baustellen-check.de

from left: Dr Kerstin Lemke, Andreas Coumanns, Jennifer Sammet and Matthäus Zelazny

Digital crash tests – crash simulation

Dr Bertold Fröhlich, physicist, Ilja Jungfeld, civil engineer, and Holger Schwedhelm, civil engineer, “Highway Equipment“ section

Numerical simulations in highway equipment

Vehicle crashing into a safety barrier in a curve

Digital progress is becoming increasingly noticeable also in highway equipment. The numerical simulation of crash tests is increasingly gaining significance in identifying and evaluating performance data for vehicle restraint systems (crash barriers). More and more European manufacturers of vehicle restraint systems are using simulation calculations both when developing new systems and when studying the influence of different utilisations and marginal conditions.

The European EN 1317 standard enables a simulation-based evaluation of modifications to systems that have already proved their efficiency in real crash tests with vehicles – usually in the scope of CE label certification procedures.

from left: Ilja Jungfeld, Dr Bertold Fröhlich and Holger Schwedhelm

Numerical simulations on the basis of finite element models are also being used by BASt in its research activities. In a number of BASt research projects, for example, it was possible to cost-efficiently extend the scope of tests and thus the significance of test results by conducting numerical analyses.

Numerical simulation calculations enable extensive parameter analyses in a significantly more strategic and thus target-oriented manner than previously possible using real crash tests.

But before the results of numerical simulation can be trusted, it is necessary in any case to compare the results from real crash tests and related simulation calculations and to

transparently document this validation process.

European standardisation

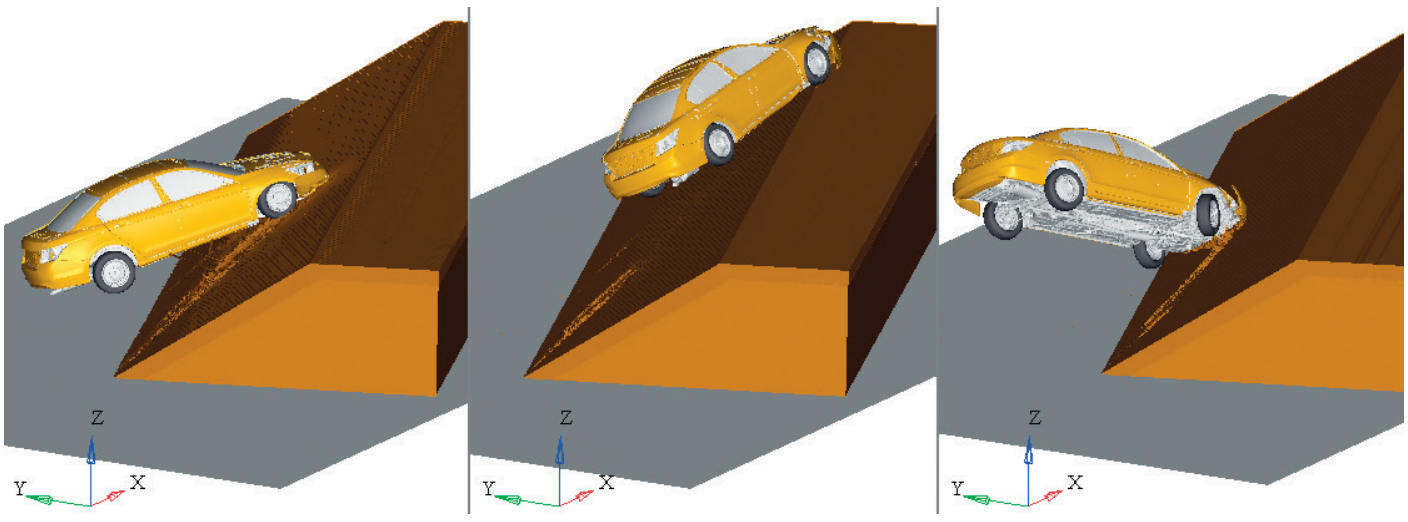
The extensive regulations necessary were developed at the European level with the participation of BASt and will be made available soon with the publication of EN 16303. They form the first harmonised basis to use numerical simulation procedures for EN 1317 (vehicle restraint systems) and EN 12767 (bearing structures) and can thus also be taken into consideration for future scientific research and verification methods.

Just like the validation requirements for virtual testing methods, the related marginal conditions must also be continuously further developed too. In this context, BASt is collaborating in efforts to develop minimum requirements for user skills, for example, to employ numerical simulations in Europe.

Simulation studies conducted

In the meantime, BASt has conducted numerous studies on current issues using numerical simulations. These are based on simulation models validated by real crash tests. This made it possible to assess in a parameter study, for example, the influence of the radius of curvature of curves on the performance of vehicle restraint systems: the impact on passengers can increase, but it is not likely that the vehicle will break through the barrier in the radii of curvature and safety barriers studied.

Numerical simulations may also be helpful in assessing obstacle-free lateral roadside areas: there is a general risk with earth mounds that there will be increased passenger impact or that vehicles will tip over onto their sides. Numerical simulations can help here to indicate relevant parameter constellations, such as slope angle, surface, speed, which would then need to be effectively confirmed in real crash tests. The two projects would not have been possible to the same extent solely with real crash tests. ■



Vehicle crashing into earth mounds (different surfaces)

Vehicle Engineering

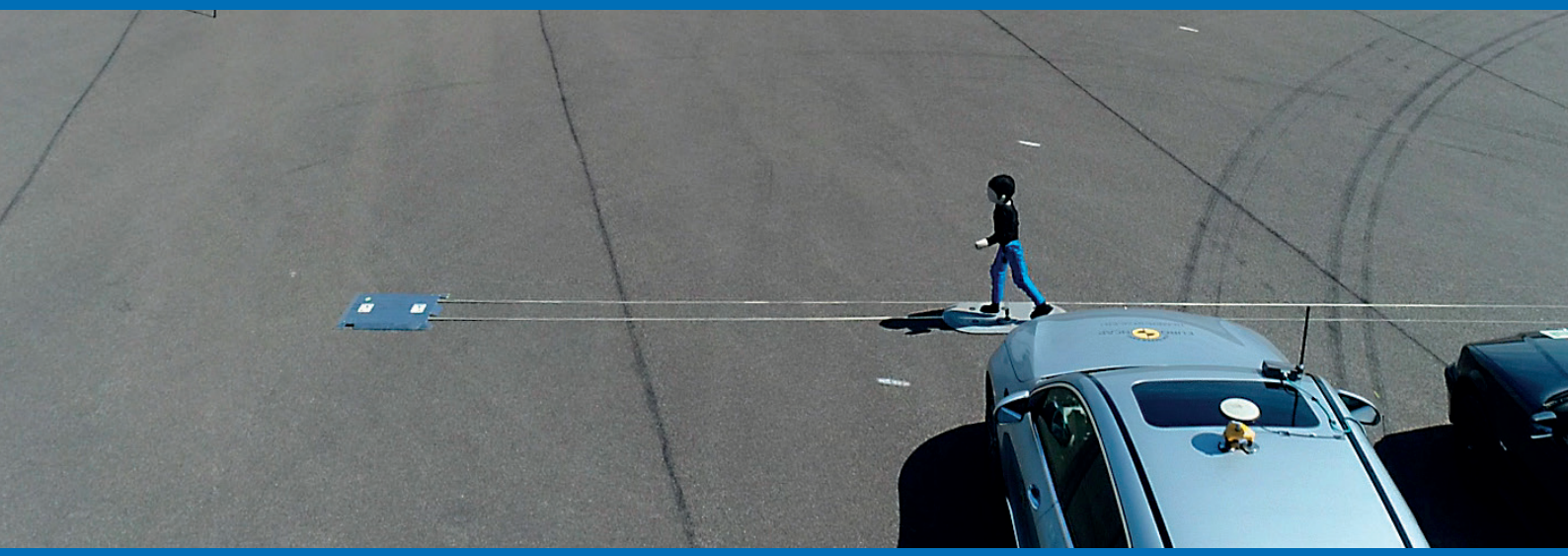
Safety assessment of man-machine interaction

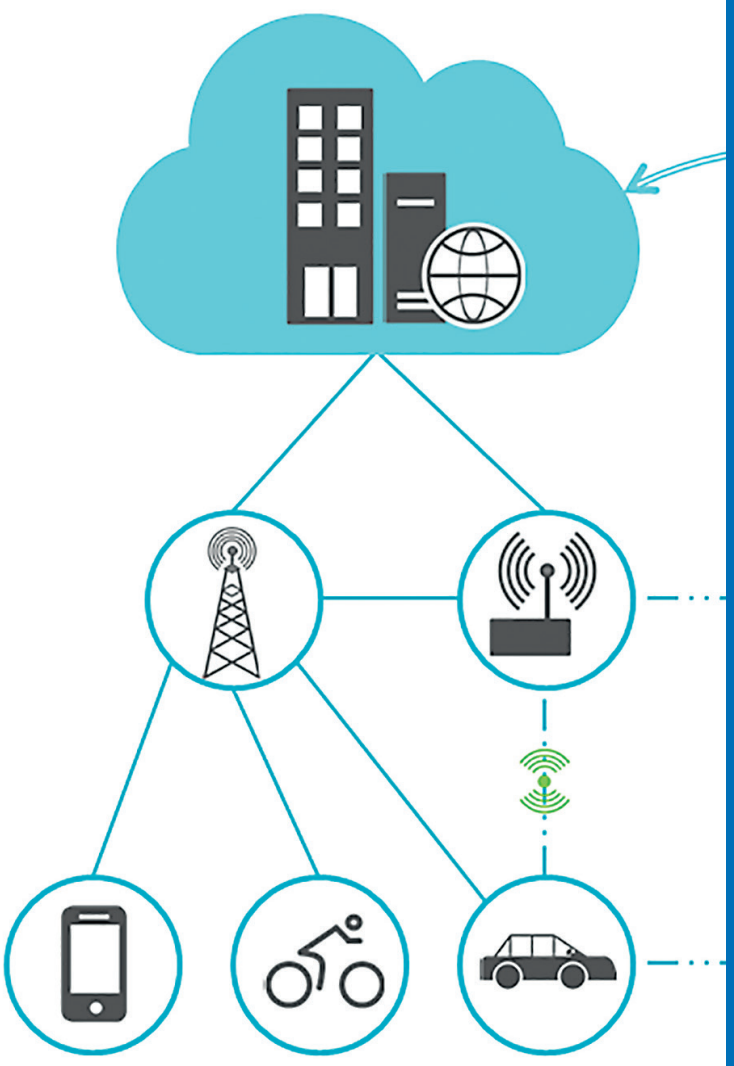
Level 3 automation in real traffic

Legal requirements for automatic emergency braking systems in passenger cars

Data exchange in road traffic

20 years of GIDAS





Safety assessment of man-machine interaction

Thorben Brandt, research assistant, Dr Heike Hoffmann, psychologist and André Wiggerich, psychologist, “Automated Driving” section

Continuously assisting driving functions have already been widely included in driver assistance systems of the most recent new vehicles. These systems can support drivers in performing the task of driving in both continuous longitudinal and lateral control, but they need to be monitored permanently. At the same time, drivers should always be able to take corrective action as soon as the systems reach their limits, which means that drivers continue to play a key role and cannot turn away from the traffic situation.

Surveys show that there is a lot of uncertainty among drivers about their role and responsibility in interacting with the systems. Initial accidents in the US involving vehicles with these systems suggest that drivers find it difficult to comprehensively understand the systems and to behave correctly. The particular complexity here is that monitoring the functions has often become the driver‘s sole task, which means exercising the driver’s role has changed fundamentally.

Scientific studies show that people generally do poorly when their role is to monitor the system on an ongoing basis. By implication, it must be assumed that a driver‘s continued active involvement in the driving function should have a positive impact on the driver’s understanding and behaviour, and in turn the safety of man-machine interaction (MMI).

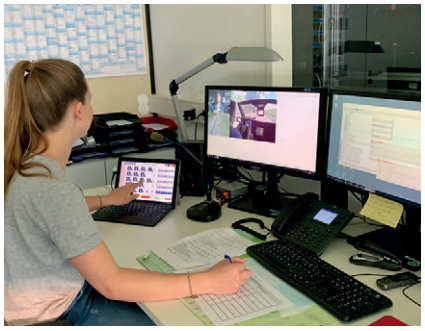
As there are already a wide range of systems from different manufacturers – which also contain differing functionalities – suitable tools do not yet exist to extensively assess this aspect in a standardised manner. Different systems can thus only be compared to a limited extent. This is why one project aimed to develop a tablet-based combined observation and interview instrument for studies with test persons with which to evaluate the interaction behaviour between driver and system in varying test situations in a standardised approach.

from left: André Wiggerich, Dr Heike Hoffmann and Thorben Brandt

The method is designed in such a way that trained experts observe the interaction behaviour of a test driver in defined situations using varying categories and afterwards evaluate whether, for example, mistakes were made in operating the system or if other road users were jeopardised because of a certain behaviour. The results from different test drivers are collated and the MMI safety of the system to be evaluated is estimated.

Driving simulator study

In an initial step, this procedure was tested in the scope of a study in BASt’s driving simulator. 56 test persons participated in the study. They were asked to drive on a monotonous motorway section for about 35 minutes at a speed of 120 kilometres per hour. One half of the group experienced a very reliable system that was constantly active without the driver needing to take action. The test persons’ task was thus primarily to monitor the system visually. The other half of the group experienced a system which failed briefly about every two minutes, so the drivers had to intervene and steer the vehicle themselves. The intention was that in these test conditions through the system‘s design be required to be continuously actively involved. The interaction performance was measured and evaluated by setting up two test scenarios in which the test drivers had to take over the steering function in a narrow curve or to avoid an obstacle in their lane. The test persons were all informed beforehand about the limits of the system and



Experts observe and evaluate man-machine interaction using a standardised tablet tool

instructed to intervene in these situations without being prompted.

The study's results show that the test persons with the very reliable system had difficulties in reacting appropriately in the two situations where the system reaches its limits. Though all the test persons were vigilant and had their hands on the steering wheel at all times, the drivers in this group were less capable at taking over steering in the curve early enough or avoiding the obstacle in time. It can be concluded from the results that a changed perception of the driver's role can lead to a wrong subjective impression and misunderstandings in this group. Despite prior information and instruction, this had a negative impact on the safety of the MMI when the system reaches its limits. The tablet tool made it possible to reliably measure and evaluate the differences between the two simulated systems.

Test track study

As a next step, the portable table tool enabled a trial to analyse on a test track for the first time whether this effect also occurs in real production vehicles. In a second study with 40 test drivers, two series production systems from different manufacturers were compared. The two systems differ in the extent to which they involve drivers in the driving task. With the active system, each test person drove for about 30 minutes on a 1.6 kilometres long circular route at an average speed of 50 kilometres per hour. Towards the end of their drive, the test persons had to intervene in controlling the system and drive around an obstacle without advance notice.

The results of the second study also show that a more reliable system, in which the drivers' main role is to monitor the system, causes difficulties in the drivers' understanding of the situation and their behaviour. Taking corrective action was better managed by the drivers of vehicles which were designed from the start to involve the drivers more actively in the driving task. In this context, too, the tablet tool was a reliable means to evaluate the safety of MMI in the two systems studied.

Summary

The test procedure offers for the first time the possibility to evaluate and compare the design of continuously assisting systems as regards MMI safety. The results can be used, for example, in consumer protection to differentiate future assistance and automation systems on the basis of MMI. This will foster a safe design of the systems. ■

The tablet tool can be used in the future to evaluate the safety of man-machine interaction in series production vehicles in studies with test drivers on proving grounds

Level 3 automation in real traffic

Anne Klamroth, psychologist, Torsten Marx, electrical engineer and Alexander Zerbe, Master of Science sensor systems and cognitive psychology, “Automated Driving” section

The PEGASUS project (project to establish generally accepted quality criteria, tools and methods as well as scenarios and situations for the approval of highly automated driving functions), which was completed in June 2019, aimed to close substantial gaps in the processes between testing Level 3 driving functions and having them approved. For this purpose, it was necessary to develop a procedure to verify and test automated driving function in order to enable a swift introduction of automated driving in practice. The motorway chaffeur was deployed as a future-oriented application model; it enables the utilisation of a Level 3 function on motorways and motorway-like roads. Besides 17 partners from academia and the business sector, BASt, participated in the project as an associated partner on behalf of the Research Association Automotive Engineering (FAT).

from left: Torsten Marx, Anne Klamroth and Alexander Zerbe

At a Level 3 automation stage, drivers can transfer the steering of the vehicle fully to the system in user cases specifically defined by the respective manufacturers of the systems, abandoning the task of driving and engaging in non-driving activities. The system does not need to be monitored, but the drivers must, however, be prepared to take over the driving function at any time when prompted by the system. BASt’s aim was to identify potential risks that may arise from the interaction between Level 3 vehicles and drivers. The influence of traffic density on the driver‘s performance in taking back control was reviewed first in a field test on German federal motorways in the Cologne/Bonn region. As a follow-up, the tests then focused on the question whether a preceding automated driving experience has an impact on how drivers handle unexpected incidents immediately after successfully having taken back control.

Interaction concept

Previous studies have primarily analysed the interaction between automated vehicles and human drivers in driving simulators. These offer the advantage that even critical driving manoeuvres can be observed in detail and analysed in a safe environment. But there is always the question whether the results obtained can be translated into a real traffic environment. This is why the present studies were conducted with BASt’s own test vehicle. Operating the test vehicle in public road traffic is permitted under specific conditions (as an exception).

Study in real traffic

The initial study with 39 test drivers took place in real traffic; the road section included seven situations of taking over vehicle control.

The first question to be analysed was how long the test persons needed to confirm their preparedness to take over control when requested to do so after an automated drive. The take-over periods took 3.58 seconds on average, whereby the fastest 10 per cent of the test drivers needed 2.02 to 2.48 seconds and the slowest 10 per cent needed 5.46 to 8.24 seconds. The test drivers were divided into two groups to test the influence of ambient traffic: the Normal Traffic group drove along the motorway section at 9.30 am and the Commuter Traffic group at 3 pm. An analysis of the two groups showed that there are indeed differences in the take-over periods needed. At an average of 3.21 seconds, the test drivers in commuter traffic showed significantly shorter take-over times than the test drivers in normal traffic (3.87 seconds on average). A direct comparison of the take-over periods in moving traffic (speeds higher than 90 kilometres per hour) and congested or stop-and-go traffic (speeds lower than 60 kilometres per hour) results in a similar finding. Drivers in moving traffic need significantly longer to confirm their willingness to take over vehicle control. The two findings may indicate that the dynamism of the traffic situation plays a decisive role: there is more pronounced variation at high speeds while lower speeds on motorways are more characterised by monotony.

Besides the take-over time needed, the drivers‘ subsequent lateral control behaviour is of course also of interest: Do the drivers succeed in keeping the vehicle within the lane after taking over control? Graphical analyses of the lateral control behaviour have shown that the test drivers usually tend to keep the vehicle in the middle of the lane or steer it back there. Some drivers were observed, however, to exhibit a tendency not to take major corrective steering action when traffic was very dense, if possible. Overall, no safety-critical types of behaviour were found.

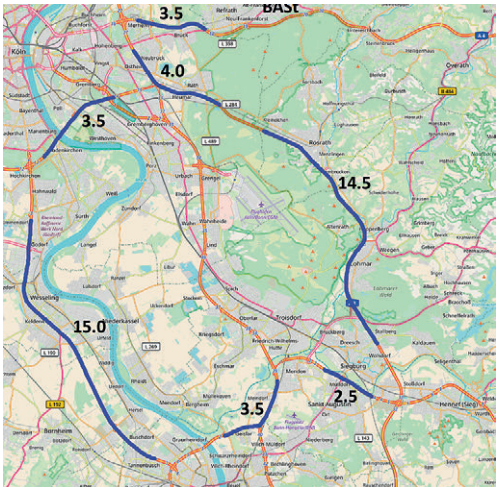
The analyses also included the drivers' gaze behaviour when taking over control. Drivers often only looked straight ahead for visual assurance. Mirror checks and shoulder checks were frequently neglected.

Study on testing track

The surprisingly short take-over periods and gazing only forward to check traffic ahead gave rise to the following question: Can drivers react adequately when a leading vehicle brakes suddenly if they have taken back vehicle steering only a short time before this happens? The study was conducted in a safe environment on proving grounds built to simulate a motorway.

It showed that 80 per cent of the 20 test drivers involved in the study reacted to a heavily decelerating leading vehicle only by braking, while the remaining 20 per cent also swerved to avoid a collision. Though another vehicle was present in the rear traffic area, their collision-avoiding manoeuvre was hardly secured by visual checks.

The study also shed light on a possible system limitation for future Level 3 driving functions: motorway exits. Does the drivers' curve-driving performance decline when they are requested to take over control of the vehicle shortly before exiting the motorway? The curve-driving performance of 29 test drivers after driving exclusively manually was compared to their performance shortly after taking back vehicle steering. The result was that the curves did not cause any problems in either case: there were no declines in performance.



Test drive routes indicating the length of automated driving (blue) in kilometres (photo: OpenStreetMap)

Conclusion

In summary, it appears that different traffic environments and situations may have an influence on drivers' take-over behaviour. It is recommended that future drivers of Level 3 vehicles be informed about correct take-over behaviour and better visual checks. ■

Legal requirements for automatic emergency braking systems in passenger cars

Dr Patrick Seiniger, mechanical engineer, deputy head of "Active Vehicle Safety and Driver Assistance Systems" section

Accidents are often caused by human error, for example, when traffic situations are incorrectly assessed or drivers are inattentive. Automatic emergency braking systems can compensate for human error to a certain extent by braking a vehicle automatically in the case of an impending collision or activating a warning signal in a timely manner.

First automatic emergency braking systems – RADAR sensors coupled to the braking system and warning function – were developed in the middle of the last decade and were severely limited in detecting critical situations. The first systems were only capable of braking directly before an accident and they could not recognise standing vehicles. The capabilities of automatic emergency braking systems have been gradually improved since then. Today, they are capable of detecting a broad spectrum of accident situations – by using image recognition algorithms and sophisticated RADAR and laser distance measurement sensors – and can often prevent accidents or at least have a positive impact on the outcome of the accident.

Voluntary introduction in consumer protection

Uniform requirements for automatic emergency braking systems did not exist for a long time. Only about 10 years after the first systems were launched did the European New Car Assessment Programme (NCAP), with substantial assistance from BASt, develop initial assessment criteria for automatic emergency braking systems and introduce them into vehicle ratings – in 2014 for rear-impact collision situations, and as of 2016 also for unprotected road users.

Their inclusion in consumer protection ratings motivated car manufacturers to widely equip new vehicles across the board with corresponding functions, so that today there is hardly any vehicle that does not have or could not be fitted with an emergency braking system. This equipment continues to be voluntary for manufacturers. Systems with differing performance strengths are possible.

Legal introduction with binding minimum standards

A complete approach to equipping all new vehicles with automatic emergency braking systems – that comply with binding minimum standards – is only possible if these minimum standards are required for vehicle type approval, i.e., for the market approval of vehicle types. For Europe, the EU has stipulated that all new vehicle types (passenger cars and light-duty commercial vehicles) need to be equipped with an automatic emergency braking function for rear-impact collisions starting in May 2022, and for accidents involving unprotected road users as of May 2024. Two years after the dates mentioned, vehicles without these systems will no longer receive type approval.

Binding requirements for this have been developed since 2017. BASt represented Germany in the competent working group and has decisively shaped the corresponding regulation.

How do automatic emergency braking systems intervene?

Legal requirements aim to define a reasonable minimum distance. For automatic emergency braking systems, this usually means finding a compromise between road safety – the number of accidents prevented increases with early braking intervention – and system robustness – probability of false braking increases with an early braking intervention.

The working group's approach was to define the requirements based on automatic braking at a point in time when human drivers would no longer avoid accidents. BASt conducted its own measurements to provide guidance on what human drivers can accomplish. The conclusion is that in extreme situations and under perfect conditions, drivers can avoid an accident up to about 0.7 seconds before impact – average drivers, however, are presumably no longer be capable of initiating a successful anti-collision manoeuvre even at 0.9 seconds before the accident.

Translated into legal requirements, this means that the usual automatic emergency braking systems can safely initiate braking at about 0.9 seconds before an impending collision without overriding the driver. They are thus capable of avoiding impact in the case of vehicles with

Target object for rear-impact accidents

normal load at a differential speed of 42 kilometres per hour. For passenger cars with a full load, the limit is at 40 kilometres per hour and for light-duty commercial vehicles with full load at 35. This applies to accidents with both other vehicles and pedestrians. A collision cannot be avoided at higher speeds, but the vehicle's speed can be reduced significantly.

Test cases

Drive tests were conducted using targets which do not cause damage in a collision in order to show the effectiveness of automatic emergency braking systems. The legal requirements for automatic emergency braking systems stipulate a wide range of test speeds at which the systems must prove their effectiveness. A total of 20 individual test cases are defined in the regulations.

Current state of regulation development

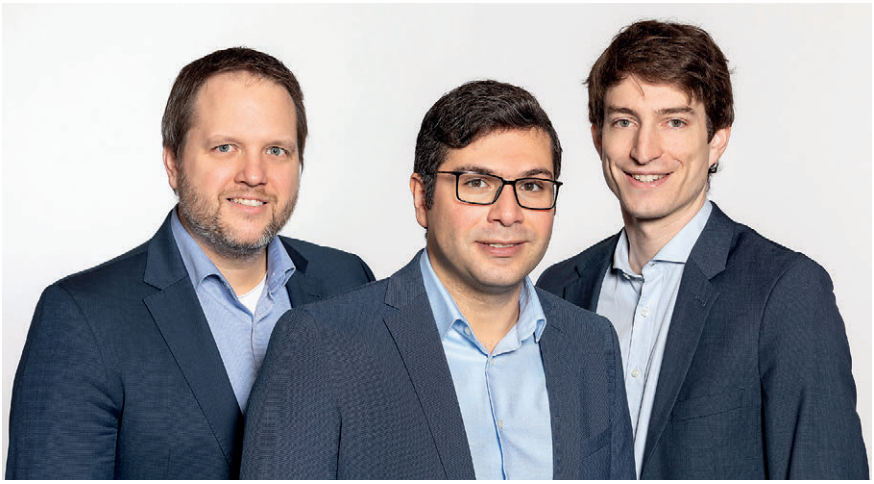
The preparatory work for a regulation on automatic emergency systems (UN R152) has been largely completed and approved by the corresponding UN bodies. Final discussions are dealing with practical requirements for accidents involving bicycles. Currently, there are far too few market-ready automatic emergency braking systems for this purpose. It is nonetheless clear: In the near future, all passenger cars will be equipped with efficient automatic emergency braking systems for road safety purposes. ■

Target object for accidents involving pedestrians

Data exchange in road traffic

Holger Drees, physicist, Farzin Godarzi, electrical engineer and Timo Hoffmann, geographer, “Connected Mobility” section

Digitisation is making great strides in almost every field of life in our world. In road traffic, more and more vehicles are equipped with a fast-growing number of sensors and road infrastructure is supplying ever increasing data volumes. Enabling data exchange among all those involved in road traffic by connecting them promises a significant increase in road safety and efficiency. Supported by the rapid development in transmission technologies, this data traffic is increasingly taking place in the background. For some time now, BASt has committed itself at various levels to ensure that exchanging data is enabled across differing systems, without discrimination and in a safe and reliable manner.



from left: Timo Hoffmann, Farzin Godarzi and Holger Drees

Many players with a great variety of interests are involved in the activities presented below. Varying goals and approaches often make it difficult to agree on harmonised data exchange standards.

Data Task Force – Data For Road Safety

Warnings about road hazards for vehicles and their drivers can prevent accidents and save lives. Vehicles also in many cases recognise dangerous situations on the road such as black ice most quickly and in the most detail. To date, however, there is usually no warning for following vehicles.

In the “Data For Road Safety” project, the public-private Data Task Force, founded in 2017 on the basis of a high-level structured dialogue on automated and connected driving, is now working on an organisational and technical framework to exchange safety-relevant traffic information across the European Union pursuant to Commission Delegated Regulation 886/2013. The EU Member States, car manufacturers and other industrial partners involved are aiming to set up a process chain which makes vehicle-generated, road-safety-relevant data accessible via the OEMs‘ (Original Equipment Manufacturers) IT back ends. This data will be available via national access points – in Germany via the Mobility Data Market Place (MDM) – as a starting point to establish traffic warnings for road users.

Hybrid cooperative traffic systems

To warn of dangerous situations as fast as possible is also the purpose of cooperative intelligent traffic systems (C-ITS) that use a communication network among road users. Messages can be distributed using dedicated short-range communication technologies – such as ETSI, ITS-G5 – or long-distance communication technologies such as mobile communications.

The concept of hybrid communication was developed in a new working group on the C-Roads platform to achieve maximum geographical coverage and optimum network capabilities in the scope of C-ITS. The aim is to offer inter-operable C-ITS services with flexible exchange options among road users all across Europe, i.e., the same information is transmitted regardless of the communication technology employed.

The real-time exchange interface for C-ITS messages among all C-ITS service providers via back end communication has been specified as an initial step towards delivering hybrid communication. The specification comprises:

- Internet Protocol (IP) – to establish communication channels
- Transport Layer Security – to secure the communication channels
- Advanced Message Queuing Protocol (AMQP) - for message protocol
- Quadtree Method – for geo-localisation of C-ITS services.

The back-end communication is a key aspect of hybrid communication. The 18 Member States of the C-Roads platform agreed to use back-end communications to exchange C-ITS data across borders to ensure inter-operability and harmonised C-ITS services.

Mobility Data Space

When systems are developed separately, there is the risk that they may not ne able to interact or only with difficulty. The Mobility Data Space is intended to be established as a data ecosystem for any type of data exchange in the mobility sector with uniform standards and rules.

The concepts and technologies of the International Data Spaces Association serve as a basis. One core function of these Data Spaces is a secure and effortless data exchange among data providers and data recipients. Connectors on both sides ensure that there is an adequate level of IT security and that the data providers' conditions for using their data are complied with, thereby creating a safe data space. Data apps within the connector environment can thus also process confidential data which is never permitted to leave the environment as raw data. The processed data which does leave the environment must meet data protection requirements and must make it impossible to derive any conclusions about the original marketable data.

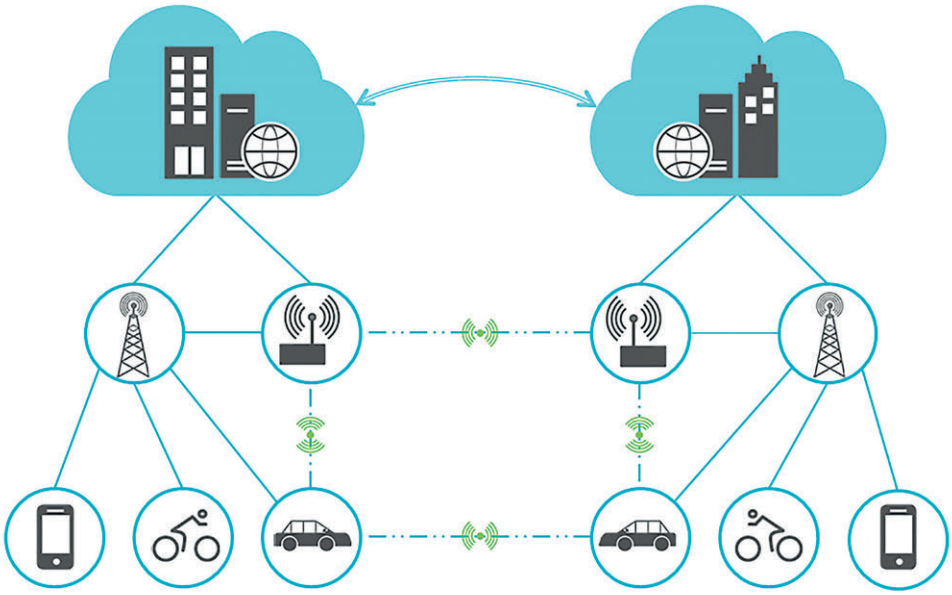
The concept is supplemented by central elements:

- Connectors report their data supply, including licencing and utilisation conditions, to a meta data register.
- An identity management system creates mutual confidence in certified connectors.
- Jointly used ontologies enable IT systems to understand each other and be interoperable.
- Data apps are published in the App Store.

These concepts have already mostly been demonstrated in other fields of utilisation. They are currently being adapted to the mobility sector to also place the MDM into a broader context. By connecting the MDM with other existing platforms, the accessibility of an enhanced data supply is facilitated, thus increasing the MDM's range and use.

Future connected mobility

The developments in the fields of communication technology, data processing concepts and data protection standards are proceeding at a tremendous speed. At the same time, simple possibilities to exchange data across domains and administrative borders are needed to enable multi-modal mobility services of a growing number of mobility providers. BASt is participating in various projects to co-shape and create the digital basis and preconditions for this. ■



20 years of GIDAS

Sandra Breunig, physicist, Marcus Wisch, mechatronics engineer, “Passive Vehicle Safety, Biomechanics”, Janine Kübler, civil engineer, head of “Highway Equipment” section and Daniel Sander, mechanical engineer, “Active Vehicle Safety and Driver Assistance Systems” section

What is GIDAS?

The German In-Depth Accident Study (GIDAS) is one of the world’s largest and most significant projects in the field of in-depth traffic accident research. Immediately after traffic accidents involving at least one injured person occur in the Hanover and Dresden conurbations, the accidents are documented in minute detail – particularly as regards technical and medical aspects – on the basis of purely scientific aspects in accordance with an established survey methodology, and are reconstructed afterwards. The GIDAS collaborative project between BASt and the Research Association Automotive Engineering (FAT) has existed since 1999 and currently captures roughly 2,200 accidents per year.

The staggered-shift system used by the survey team in conjunction with geographical and urban design parameters (urban and rural areas and motorways) ensure a balanced collection of traffic accidents of all types and severity of injuries on every day of the year. The accident data from the two locations are collected in one joint data base to be used for information on a wide range of research areas concerning “passive and active vehicle safety”, “traffic and emergency medicine” and also “highway equipment and road condition”.

The accident data collected, which can largely be considered representative for Germany on the basis of spot checks, has been used since then for a wide range of road-safety related research and has brought about improvements. For regulators, GIDAS offers the possibility to closely observe accident situations, identify both positive and negative developments early on and transfer practical insights into regulations. Car manufacturers and suppliers can improve their technologies on the basis of the data, thus making traffic safer for all users.

from left: Sandra Breunig, Daniel Sander, Janine Kübler and Marcus Wisch

Vehicle safety and infrastructure

Besides numerous findings which have been included in legal requirements for passive vehicle safety – for example, concerning the safety of occupants in passenger cars and pedestrian protection – information on the pre-collision phase (run-up to the accident) is also increasingly being used in drafting legal requirements for active vehicle safety systems and driver assistance systems.

The speed requirements and accident situations defined in the new regulation for turn-assist systems in trucks and buses (UN Regulation No. 151: “Blind Spot Information Systems for Heavy Vehicles”, mandatory for new vehicle types starting in 2022) are essentially based on evaluations of driving and collision speeds of those involved in turn accidents surveyed under GIDAS.

Evaluations based on GIDAS data also contribute considerably to identifying critical traffic situations and developing relevant testing scenarios in the field of consumer protection. A case in point is data on the speeding behaviour of collision opponents, collision point and layout of the intersection in the testing scenarios extracted from GIDAS, which is used by Euro NCAP to evaluate intersection assistance systems as of 2020.

The infrastructure sector is another focal area for the use of GIDAS data. This GIDAS data is used, for example, for detailed analyses of crash situations at traffic sign installation systems (e.g. sign brackets) and of accidents at vehicle restraint systems. In turn, these analyses

A GIDAS example case that was analysed in-depth in view of traffic accidents between 2 passenger cars at intersections – vehicle A: Turning vehicle and vehicle B: Vehicle with right of way

can be the basis to develop parameters for crash tests or identify potential construction improvements.

Ceremony to celebrate 20th anniversary

On 11 July 2019, a symposium was held in Dresden under the patronage of the Federal Transport Minister Andreas Scheuer to celebrate the GIDAS project's 20th anniversary.

In addition to looking at the historical development of accident research which also began at BASt in the 1970s, the future of the GIDAS project was discussed. The willingness and necessity to continue the project and make it usable for addressing the challenges of future mobility – increasing traffic volumes, new mobility concepts and drive technologies, demographic shift, increasing traffic automation, traffic electrification and connectedness – was confirmed by all participants. It became clear that the human aspect and the field of psychology need to brought into focus even more strongly. Therefore, the coming years will be used intensively to create an even better project structure that will last for at least another 20 years. ■

www.gidas.org

Keynote speakers at the symposium (from left): Horst Kretzschmar (Chief of Police, Saxony), Stefan Strick (BASt president), Guido Zielke (head of "Road Traffic" department at the Federal Transport Ministry), Henrik Liers (CEO VUFO GmbH), Prof. Horst Brunner (TU Dresden), Bernhard Mattes (VDA president), Dieter Scheunert (Daimler AG) und Andre Seeck (head of "Automotive Engineering" department at BASt) (photo: Daniel Grosche, VUFO GmbH)

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HilfeFinder

für Verkehrsunfallopfer
mit psychischen Folgen

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Road Safety

Virtual reality in road safety activities

BASt‘s bicycle simulator

Evaluation of driver fitness courses

Online portal to find help: www.hilfefinder.de

Influencers in road safety communication

Reducing young novice drivers‘ risk of accidents

Virtual reality in road safety activities

Benjamin Schreck-von Below, traffic engineer, deputy head of section and Kristin Weirich, educational scientist, head of #AUGENBLICKWINKEL360 project, “Safety Concepts, Safety Communication” section

Road safety for cyclists

Cycling is in fashion. It is a mobility trend that is rising slightly across Germany, most prominently so in big cities. According to the “Mobility in Germany 2018” study, 78 per cent of households owned at least one bicycle in 2017 and 8 per cent already had a Pedelec (bicycle with electric pedalling assistance). This amounts to 72 million bicycles in German households (of which 4 million are Pedelecs). This number has risen by 5 million since 2002.

But not only the number of existing bicycles has increased but also their utilisation. The number of trips made by bicycle increased from 24 million per day in 2002 to 29 million in 2017. The share of cycling in the modal split thereby increased from 9 to 11 per cent across Germany in the same period.

The expected continued increase in cycling and the socially and politically intended increase in the attractiveness and promotion of cycling will have consequences for other areas too. The number of accidents involving cyclists shows a negative trend. The significant decline in the number of fatally injured cyclists should be highlighted as a positive trend, but this development has been stagnating since 2010 at about 400 deaths per year. This is why road safety for cyclists remains the focus of efforts to improve road safety. Because the cycling infrastructure shows gaps and networks are incomplete, it is used incorrectly and not well-accepted. Cyclists in general frequently run into interactions with other road users.

Besides infrastructure measures, other areas of cycling traffic also need to be taken into consideration to further reduce the number of accidents. Road safety activities should focus more intensely than before on the behaviour of all road users. There is ample room for improving the communication of road safety message for enhanced clarification, information and awareness with appropriate means of reaching out to the target groups. Mutual respect is vital in view of discussions on who can use which space in a constricted road environment. Digitisation offers numerous opportunities to develop new digital learning methods. The increase in cycling traffic, including a number of differing age groups and differentiated user demands, shows a particular need for contemporary, innovative forms of outreach.

Scene from the 360 degrees “Overtaking” video (Video: headtrip immersive media GmbH)

The #AUGENBLICK-WINKEL360 VR project

Using Virtual Reality (VR), we can visit distant locations such as the sun, past epochs such as the Inca empire and – as is the case for BASt’s project – get on a bicycle. Until a few years ago, the new technology of computer goggles was considered a short-lived hype, but today it has convinced not only the gaming and entertainment industries but also business and educational institutions.

The #AUGENBLICKWINKEL360 pilot project was developed in 2019 against this backdrop. Embedded in a blended learning scheme (combining the benefits of face-to-face training sessions and e-learning), the VR application is used to raise awareness fof hazards involving cyclists and car drivers in road traffic. This project aims to collect initial lessons learnt concerning the acceptance and effectiveness of this new medium.

Three short films (turning, dooring and overtaking) illustrate situations of conflict between car drivers and cyclists. The users experience the rides from the perspective of a car driver and then again from the cyclist’s perspective. Conveying lively

impressions in such a traffic environment supports both learning new facts and transferring knowledge from theory to practice. The VR application focuses on raising awareness for the "visibility and usability of marked cycle lanes, especially advisory cycle lanes" topic.

VR as a marginal topic in traffic education

This medial teaching and learning method has so far been a marginal topic in traffic education, but its deployment offers a lot of potential towards becoming a permanent fixture in this area. One possibility could be its use as a flexible and cost-efficient component in target-group-oriented programmes, such as the one for young drivers (Young Drivers Campaign). Because everything may go completely wrong in this world. There are no real consequences – only in terms of learning outcomes for the individual participant.

Results of brief evaluations of #AUGENBLICKWINKEL360

Brief evaluations conducted on BASt's Road Safety Day (June 2019) and the Open House event at the Federal Transport Ministry (August 2019) showed initial findings to help with further research. Almost half of the 127 people interviewed, aged between 5 and 82, chose the "Turning" short video. About one third of them stated that they had already tried a VR application before. Using a questionnaire, visitors were asked to rate their expectations, the depiction of traffic scenarios, the comprehensibility of the message and the user friendliness of the application.

- 92 per cent rated the VR application very good to good.
- 90 per cent rated the VR goggles' simulation of reality very good to good.
- 89 per cent of the people interviewed found how the change of perspective was presented very good to good.
- 83 per cent found the ease of use of the VR goggles very good to good

Many ideas and suggestions were collected in numerous conversations and feedback on social media for future short films following the same pattern. After this successful kick-off, new VR videos are being designed that will also be available on YouTube as of spring 2020. Interested parties can follow the progress of these activities Instagram under the tag "augenblickwinkel_360". ■

#AUGENBLICKWINKEL360

#AUGENBLICKWINKEL360

Scene from the 360 degrees "Overtaking" video (Video: headtrip immersive media GmbH

BASt's bicycle simulator

Fabian Surges, psychologist, deputy head of section and
Dr Martina Suing, psychologist, "Road User Behaviour and Mobility" section

Experimental behavioural research to increase cycling safety

To make cycling even more attractive and safer in the future, it is necessary to better understand and predict the behaviour of cyclists in different situations. Conducting studies in a bicycle simulator is one method to analyse this behaviour. These studies offer a number of advantages compared to studies in real traffic: On the one hand, standardised traffic situations can be reproduced in a way they cannot be in real traffic conditions. On the other, a test person's behaviour in critical and thus hazardous situations can be analysed in a simulator without endangering either the test person or other road users.

BASt's bicycle simulator (photo: Guido Rosemann, BASt)

BASt's bicycle simulator

Since 2018, BASt has been operating a bicycle simulator to take advantage of the benefits simulators offer in the field of cycling safety research. The simulator was first adapted for use in the scope of research projects. The virtual environment is generated by a total of 10 combined monitors, enabling a 300-degree view in HD quality. A cycling feeling that is as realistic as possible is intended to be created by mounting the simulator on a slightly moving floor plate and using a PC-controlled bicycle trainer with variable pedal resistance. All parameters of cycling behaviour, e.g., steering motion, braking reactions and pedalling frequency, are recorded and can be reviewed in detail at a later stage.

First feasibility study

A feasibility study initiated in 2019 is intended to review the extent to which the bicycle simulator observing cycling behaviour is suitable for experimental tests with older cyclists, a particularly vulnerable group in bicycle traffic. This review includes aspects such as whether differences can be observed in the cycling and compensation behaviour of senior cyclists compared to middle-aged ones. Another analysis addresses how critical traffic situations are perceived in the bicycle simulator and whether there are age-related differences for the occurrence of simulator sickness – a type of discomfort comparable to the phenomenon of motion sickness (kinetosis). The findings from this preliminary study are to be used as a basis for future studies and provide important information to further improve the bicycle simulator and design the virtual test tracks.

Outlook on bicycle-simulator-based research

With the help of BASt's bicycle simulator, additional studies on road safety issues will be conducted in the future. Initially, topics such as distractions during cycling (for example, using smart phones), specific characteristics of using Pedelecs and the interaction between cyclists and other road users are of particular interest. ■

Evaluation of driver fitness courses

Dr Simone Klipp, psychologist, “Fitness to Drive, Driver Training and Improvement“ section

In May 2014, the multiple offender penalty points system, which used to be managed by the Federal Motor Transport Authority (KBA) in Flensburg on the basis of the Central Register of Traffic Offenders, was switched to the driver fitness assessment system. It is now being managed on the basis of the Register of Driver Fitness. With the introduction of the new system, driver retraining and improvement programmes for drivers with a record of traffic offences were replaced by driver fitness courses (FES) newly designed by BASt. At the same time, BASt was given the legal mandate to evaluate these courses. The evaluation’s aim was in particular to review “whether the driver fitness course has had an impact on improving behaviour with regard to road safety” (Section 4b, Road Traffic Act).

BASt has commissioned extensive research projects to fulfil its legal mandate, the results of which were submitted in a general report to the Federal Transport Ministry. The results were published as Printed Paper 19/11425 of the German Bundestag in early April 2019: Http://dip21.bundestag.de/dip21/btd/19/114/1911425.pdf (in German).

Description of studies

The following studies were conducted in the research projects coordinated by BASt:

- Identifying various indicators for traffic probation of those offenders participating in driver fitness courses (experimental group) and those not participating (control group) using the Register of Driver Fitness by the Federal Motor Transport Authority.
- Surveying road behaviour reported by drivers themselves: The two study groups were interviewed about their traffic probation during a specific period of time and compared.
- Interviews about attitude and behaviour: Using appropriate questionnaires, the participants in driver fitness courses were asked about their motivation, attitude and behaviour. Their answers were compared to those from non-participants.

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Results

The interviews with the FES course participants have shown that the seminars making them reflect upon their own behaviour have been well-accepted and that the participants intend to comply with the goals set during the seminar. A comparison with the control group has revealed statistically significant but only weak effects which are in line with the impact the driver fitness courses are intended to have: the participants showed more safety responsibility, a significantly enhanced awareness for risky driving behaviour and more knowledge about traffic rules and regulations. However, the changes in attitude and behaviour resulting from the course were not strong enough to express themselves in the participants’ road user behaviour.

Traffic probation indicators remained at the same level over a monitoring period of 24 months for both groups. There are, however, some systematic effects of note for sub-groups: women participating in driver fitness courses commit fewer traffic offences than women who do not participate in such courses. The same holds true for participants from urban regions who commit fewer traffic offences than non-participants from such regions. ■

Online portal to find help: www.hilfefinder.de

Dr Kerstin Auerbach, psychologist and psychotherapist, “Road User Behaviour and Mobility” section and Fabian Surges, psychologist, deputy head of section

Support with psychological distress after traffic accidents

Traffic accidents can cause not only physical injuries but also psychological problems. Anxiety, insomnia and concentration deficits are frequently reported effects. An accident can also sometimes have effects on more than just the persons directly.

As shown in the campaign “Take your foot off the pedal!” – “Perspectives of those who may be affected”, every fatal traffic accident affects an average of 113 persons. This includes first responders, witnesses and relatives, in addition to the persons directly involved in the accident. Accidents can cause psychological consequences in all these groups.

Initially, psychological consequences of accidents generally appear as an acute stress reaction. Most people affected can cope with this largely normal reaction independently and without any long-term effects. Some, however, may not manage on their own – they become mentally ill and develop, for example, post-traumatic stress disorders, suffer from depressive reactions and anxiety disorders [1]. Psychotherapeutic help is called for then at the latest.

Care for people suffering from psychological effects of accidents

In a study, BASt reviewed the care available for victims of traffic accidents who suffer from psychological effects [2]. The study concluded that though there are a multitude of institutions offering help to people with psychological traumas, there are hardly any facilities specialising in care for psychological traumas resulting from road traffic accidents. The landscape of psychological care is confusing and it is difficult for non-specialists to find appropriate information. A lack of knowledge can result in symptoms

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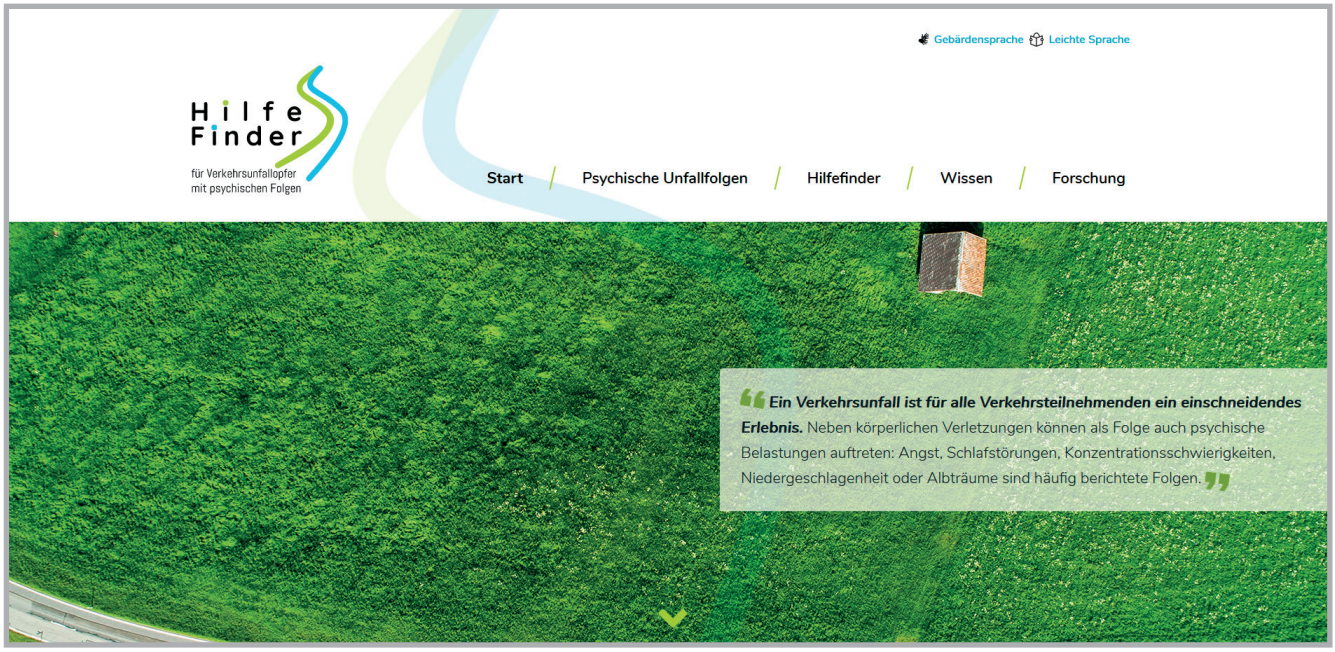

not being recognised appropriately and/or not taken seriously, which in turn may lead to a delay in finding suitable care services (for example psychotherapy). In the assessment of experts interviewed for the study, early access to professional help is an important measure in preventing or reducing the psychological effects of accidents.

Implementing the website www.hilfefinder.de

In cooperation with the German Road Safety Council (DVR) and German Association for Road Traffic Victims (VOD) BASt developed an Internet portal for finding help www.hilfefinder.de in order to improve the situation of people suffering from psychological effects of accidents. The website aims to comprehensively explain the psychological effects of traffic accidents. Persons involved in an accident, but also their relatives and other interested parties can familiarise themselves with typical symptoms, treatment methods and facilities, thus gaining a better understanding of the psychological effects of accidents and how to treat them. Regional facilities offering help at some notice and unbureaucratically can be found in a search using postal codes.

The website also highlights possible challenges which can result, for example, from a delayed onset of psychological effects or a delayed utilisation of adequate help. It aims to convey knowledge and provide tools to the people affected in order to overcome these obstacles. The website www.hilfefinder.de thus intends to contribute to promoting early and adequate care in the case of psychological effects after traffic accidents.

Current key scientific publications on the psychological effects of accidents are made available for research and field specialists. Future research projects have been planned that integrate the website, e.g., in the scope of evaluations or in recruiting test participants.

The online service will be updated continuously. A free leaflet to be handed to people affected can be ordered. ■

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www.hilfefinder.de

Influencers in road safety communication

Stefanie Kaup, communication scientist, “Safety Concepts, Safety Communication”

We come across the phenomenon of influencers particularly in the context of social networks such as Instagram and YouTube. People who are defined as influencers are characterised by their strong presence in social networks. With self-produced texts, images and videos they reach and inspire a great number of people. By giving insights into their (private) lives and interacting with their followers, they are considered particularly authentic and credible. This is why they are credited with a great potential to influence their followers‘ opinions, attitudes and behaviours.

For some years now, it has become clear that social networks are increasingly popular across every age group and social stratum. In contrast, content provided by the classic media is losing significance, especially among young people. For road safety messages to continue to reach their target audiences in the future, it is essential to take into consideration how the population is changing its media use. Influencers are also heard by target groups that in the past were difficult to reach in road safety communication – for example, people with a low socio-economic status, low educational level or a background of immigration. The current popularity of influencers suggests they might be deployed successfully – just like in marketing – in road safety activities.

First research project

A first research project was conducted in 2019 to gain a comprehensive overview of influencer communication, as a research field that is still new for BASt. It was intended to identify the potential of influencers for target-group-oriented outreach in road safety activities. This included an extensive review of the state of research on influencer communication. On the one hand, the project‘s findings are based on research on opinion leaders that has already been conducted since the 1940s. On the other, the project analysed the previously defined target groups of road safety campaigns (children, young drivers, senior citizens, cyclists, motorcyclists): it examined not only the vulnerability of each group in road traffic and the related communication measures in place so far, but also in detail each group’s media use.

Effects of influencer communication

Studies published nationally and internationally show that communication by influencers not only conveys information to the recipients but can also contribute to changing their attitude and behaviour. A core finding of this persuasion research is that the credibility credited to the source of the information or the influencer has an impact on changing people’s attitudes.

The influencers’ followers ascribe an expert status to them in a certain sphere of interest. Whether the influencers actually have expertise is less relevant than the fact that they are perceived as authentic and credible by their followers. They create closeness to their followers through the way they present themselves, their willingness to lead and communicative style. This closeness enables the creation of para-social relationships, i.e., emotional ties between followers and influencers that remain even beyond the reception context.

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Especially in the process of social identity development in adolescents, para-social relationships can play an important role. Influencers can provide guidance to arouse interest in new topics, process complex information for specific target groups and to show a clear stand as regards standards and values.

Best practice

Since 2014, organisations in the health sector have already been collaborating with influencers in their social marketing, and this marketing is similar to road safety activities in many ways. A case in point are influencers who are suffering from depression themselves and who in cooperation with the German Depression Relief Foundation talk about their experiences and how they deal with the illness, encouraging their followers to confront the topic themselves. Their followers appreciate the openness of their supposedly perfect role models and exchange their own experiences in video comments which are sometimes very emotional.

As road safety activities touch upon a multitude of interests and day-to-day topics, these provide a starting point for various influences to present suitable topics to their target audiences. Young women, for instance, could be convinced by style guides that a fashionable look and safety are not mutually exclusive – as appearance is the main reason why a majority of this target group is against bicycle helmets. Influencers who have just become parents themselves and report about their lives with children are well-suited for long-term cooperations in the field of children's safety in road traffic. Depending on how old their own children are, they can inform their followers about topics such as the use of child car seats or planning safe routes to school.


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When planning road safety campaigns in social networks, it is important to take into consideration that these media channels have certain specific characteristics. While Instagram for instance is a typical platform for images and not suited for long verbal messages, YouTube videos can easily be used to present and explain complex content. These target groups also use special forms of communication on different channels. Using YouTube's characteristic fact check format, young drivers can, for instance, be informed about typical statements and biases on road safety or about topical issues such as electric scooters.

There is no limit to the forms of cooperation between influencers and organisations also because the field of influencer communication is becoming increasingly professional. In subsequent projects, BASt is now developing implementation strategies for road safety activities and drafting and testing evaluation methods. ■

Reducing young novice drivers‘ risk of accidents

Dr Heidi Grattenthaler, psychologist, “Fitness to Drive, Driver Training and Improvement“ section

Results of the “High Risk Phase of Novice Drivers” project group

In October 2013, BASt was commissioned by the Federal Transport Ministry to prepare proposals in a project group identifying additional measures to reduce the risk of accidents by novice drivers during the phase in which they run the highest risk, i.e., when they start driving independently (high risk phase).

BASt set up the “High Risk Phase of Novice Drivers” project group (PGHR). It consisted of representatives of transport policy at Federation and Länder levels, experts from associations involved – such as the General German Automobile Club (ADAC), the German Road Safety Council (DVR), associations of driving instructors – as well as external scientists and BASt’s own specialists. The project group convened multiple times between February 2014 and October 2018 to work on its mandate. The results of the group’s work have been documented in a final report [1].

“Options model” project group proposal

The core of the project group’s joint result for a future design of the German system for novice drivers in their high risk phase of the results is the options model. Its essential points are the following:

- **Generally extending the probationary period:** A general extension of the probationary period to three years is suggested to urge novice drivers to pursue a cautious and compliant driving style for a longer time period.
- **Reducing probationary period upon participating voluntarily in qualification measures:** A reduction of the probation period is suggested as an incentive for participation. A maximum reduction of 12 months can be achieved in the scheme presented. This results in a minimum of 2 years of probation pursuant to the probation rules currently applicable.
- **Qualification measures:** Accompanied Driving (BF) and educational measures are proposed as qualification measures. Based on positive experience in terms of acceptance and road safety with a previous scheme allowing

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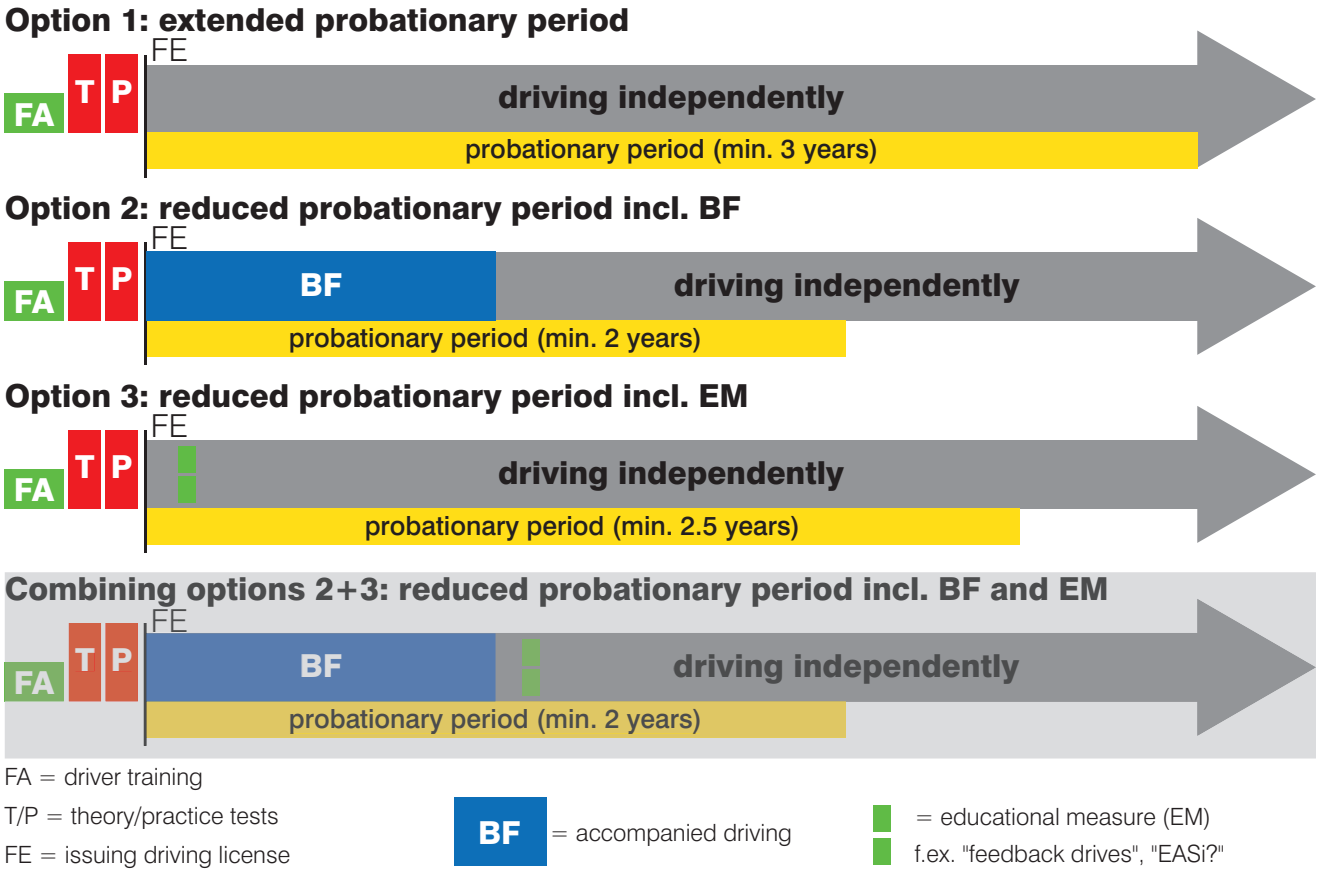
Project group ‘High Risk Phase of Novice Drivers‘: Options model



FA = driver training
T/P = theory/practice tests
FE = issuing driving license

BF = accompanied driving

= educational measure (EM)
f.ex. "feedback drives", "EASi?"

17-year-olds to drive if accompanied by an experienced driver, it is intended to make Accompanied Driving – without age restrictions – available to all novice drivers as an option in the future. Two specific educational measures addressing typical deficits in novice drivers‘ driving skills are included in the proposal as an additional option: improving traffic risk perception and risk prevention during “feedback rides” as an educational measure; exposing illusions of control while driving during the “Experienced, Alert, Safe?” (EASi?) educational measure. Accompanied Driving and educational measures can also be combined.

The options model takes into consideration that novice drivers are not in the same position after receiving their driving licence because of their varying living situations. An 18-year-old person living away from their familiar surroundings as a student or starting a new job might find it difficult to find a suitable experienced driver to accompany them. Novice drivers with a low income may also have difficulties affording the costs of participating in additional educational measures after the financial burden of paying for obtaining their licence. In contrast, driving under extended probationary conditions does not entail any problems with financial resources or additional costs. Thus while the extension of the probationary period should be mandatory, the measures to reduce the probationary period, such as Accompanied Driving and/or educational measures, should be introduced as voluntary options. ■

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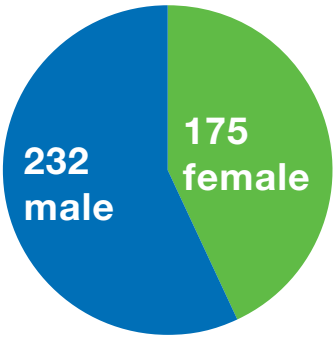


407
employees

trainees

44
reports
in our own publication series

scientists

16
lecturer positions
at universities

employees‘
average age

collaborating in

international

national

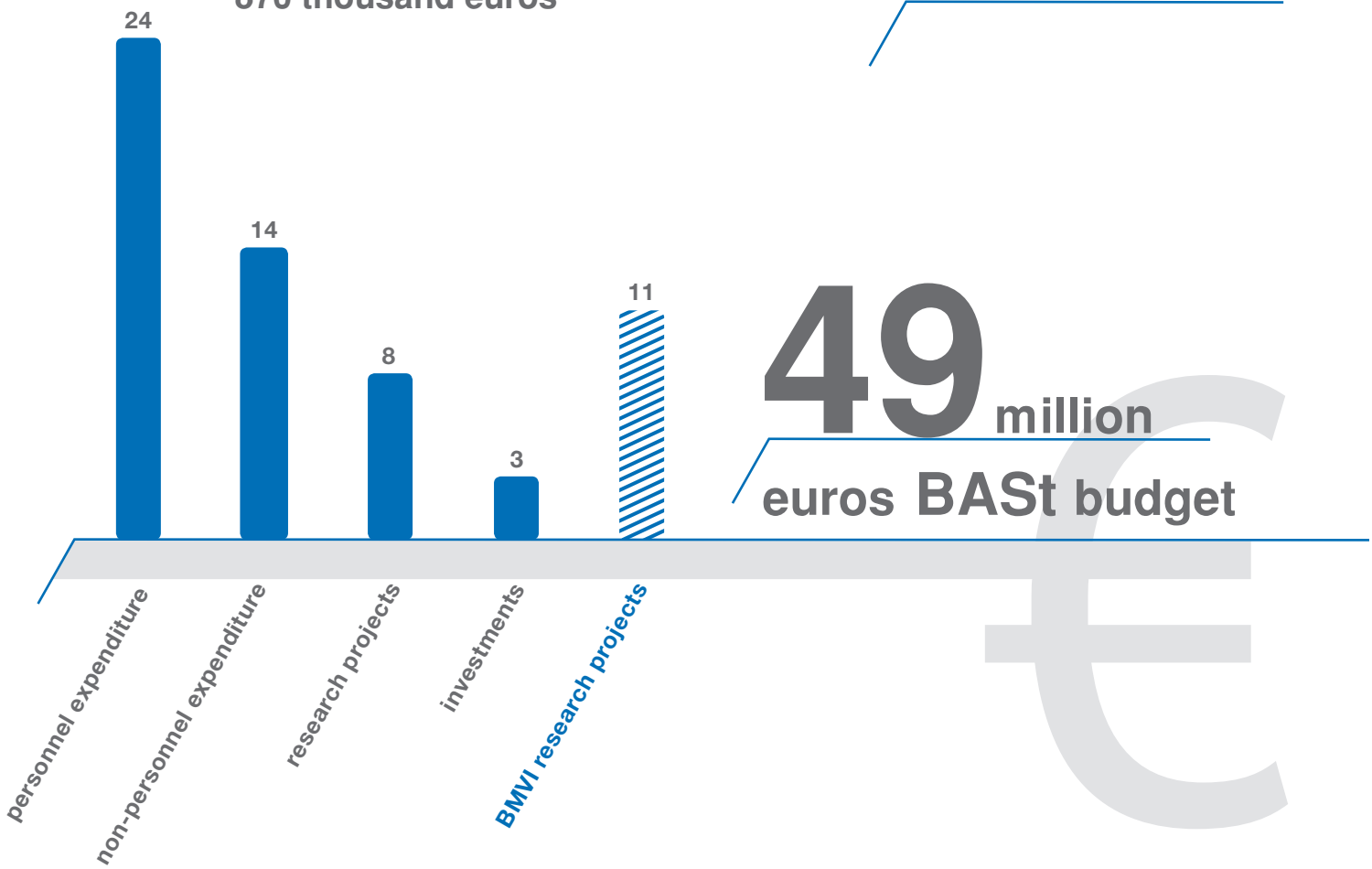
853 committees

around 250 own research projects

15 international projects

with staff costs of about 870 thousand euros

handling more than 300 external projects



49 million euros BASt budget

Teaching Assignments/PhDs/Appointments

Various awards, appointments and PhDs and selected teaching assignments at a variety of universities and faculties also show how successful BASt employees were in 2019.

Jennifer Bednorz: teaching assignment in civil engineering on BIM in bridge and engineering structures at the Technical University of Applied Sciences Cologne

Ralph Holst: teaching assignment in inspections and management of engineering structures at the Bauhaus University Weimar

Dr Jan-André Bühne: teaching assignment in business management at the Federal University of Applied Administrative Sciences

Dr Dirk Jansen: teaching assignments in highway engineering at the University Siegen

Dr Claudia Evers: teaching assignment in traffic psychology at the German Psychologists‘ Academy (DPA) Berlin

Dr Ingo Kaundinya: elected as chair of the “Road Tunnel Operations” technical committee by the World Road Association PIARC for the 2020-2023 period

Dr Torsten Geißler: lectures on Mobility Innovations and Digitisation and the Economy of Artificial Intelligence at the Zeppelin University (Friedrichshafen)

Dr Simone Klipp: teaching assignment in traffic psychology at the Institute for Experimental Psychology of the Heinrich Heine University Düsseldorf

Dr Heidi Grattenthaler: received her PhD in philosophy at the University of the Saarland in February 2019

Bernhard Kollmus: teaching assignment in „Road Safety in Planning, Drafting and Operating Roads“ at the Technical University Dresden

Dr Jürgen Krieger: elected as coordinator of the “Resilient Infrastructure” subject area by the World Road Association PIARC for the 2020-2023 period

Dr Tobias Paffrath: teaching assignment in civil engineering on the construction of asphalt roads at the University of Applied Sciences Münster

Dr Conrad Piasecki: received his PhD in technical sciences at the Technical University Graz in December 2019

Andre Seeck: teaching assignments in vehicle engineering at the Dresden International University (DIU) and the Technical University Graz

Dr Patrick Seiniger: teaching assignment in vehicle engineering on motorcycles at the Technical University Darmstadt

Elisabeth Shi: teaching assignment in statistics for business psychology at the Rheinische University of Applied Science Cologne

Dr Ulrike Stöckert: teaching assignment at the Ruhr University Bochum, faculty for Civil and Environmental Engineering, transport infrastructure chair

Dr Bastian Wacker: received his PhD in engineering at the Ruhr University Bochum in December 2019

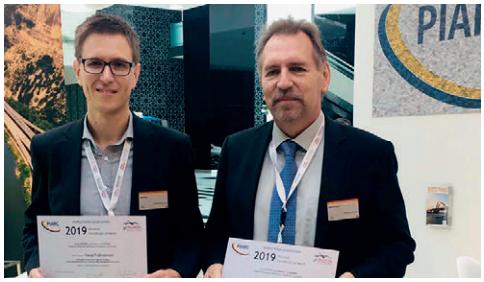
Dr Marko Wieland: lecturer at the Bavarian Bau-Akademie Feuchtwangen, the ABZ Mellendorf and the BFW Bau Sachsen in Dresden in the scope of concrete technology programmes

André Wiggerich: teaching assignment in statistics for business psychology at the Rheinische University of Applied Sciences in Cologne

Prof Dr Ulf Zander: honorary professorship in the civil engineering master programme at the University Siegen

Awards

Michael Chudalla was honoured by the Transport Minister Andreas Scheuer for his particular commitment as a BASt trainer for physics laboratory technicians.



Jens Dierke (left) and Rainer Lehmann were awarded with the Certificate of Merit in the “Young Professionals” category at the 26th World Road Congress for their paper on“Intelligent controlled compact parking – pilot implementation of a new parking management for trucks”.

Alexander Frey received the Best Paper Award for his lecture on “Drowsiness and vigilance in an automated real drive” at the 10th annual meeting of the Association of German Engineers (VDI).

Ann Kolter (2nd from left) and Jonas Räsch (left) were recognised at the Federal Ministry of Transport and Digital Infrastructure (BMVI) for their particularly good completion of their training at BASt as an administrative specialist and a building materials tester.

Bernd Lorenz (middle) received the „US Government Special Award of Appreciation“ at the ESV conference 2019 for his long-term collaboration in UN working groups on the worldwide harmonisation of motor vehicle safety regulations.

BASt Organisational Structure

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