Annual Report 2020

Reports of the Federal Highway Research Institute

Heft A 45

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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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Bergisch Gladbach, July 2021

Dear Reader,

The annual report was always a particular focus for our president, Stefan Strick, to give you insights into the latest results of our work. We defined the focal areas of the report with him every year, discussing which contributions to select. This was also the case with the current report.

You will be missing his words in the preface. We are sorry to inform you that we lost him far too early and unexpectedly in late February. He died at the age of 61 after a brief serious illness.

Stefan Strick had been the president of the Federal Highway Research Institute (BASt) since 2011. He decisively shaped BASt with his ideas during this time – and we intend to continue on this path. He was a member of many national and international committees. International cooperation was of particular importance to him. He committed to it in particular as the president of the Forum of European Highway Research Laboratories (FEHRL) from 2014 to 2016. He established numerous cross-border cooperations, for example, with Australia, Belgium, France, the Netherlands and Denmark, with Austria and Switzerland, as well as with Poland and the Czech Republic.

During his tenure, a testing facility that is unique around the world was created – BASt's demonstration, testing and referencing premises (duraBASt). Stefan Strick established the "Innovation Programme for Roads" funding programme as an instrument to strengthen innovative developments in road construction, and he consistently pursued the goal of forward-looking and comprehensive digitalisation in all areas of BASt research.

With Stefan Strick, BASt not only loses its president but also an esteemed and attentive colleague who was able and willing to listen. We will miss his character, his experience and competence, both highly respected in Germany and abroad. He placed a special focus on the next generation of scientists, for example, by supporting PhD programmes. Many young colleagues will be "heard", for instance, in this year's 2020 annual report.

About 60 authors report on ongoing BASt projects, ranging from re-evaluating the alcohol ban for novice drivers, to speaking roadworks, airbags for cyclists, drones measuring air pollutants, resilient road tunnels, to concrete pavement 4.0 and selected BASt projects in the scope of the BMVI Network of Experts.

They all have frequently worked from home – as so many did in this year shaped by the pandemic. "Mobile working" became the standard way of everyday working for many people. A retrofitted IT infrastructure, new processes and new means of communication have made it possible to successfully continue our research activities.

Allow us to show you the varied day-to-day work of BASt employees in 2020 with this report.

BASt's staff unit
Press and Communication


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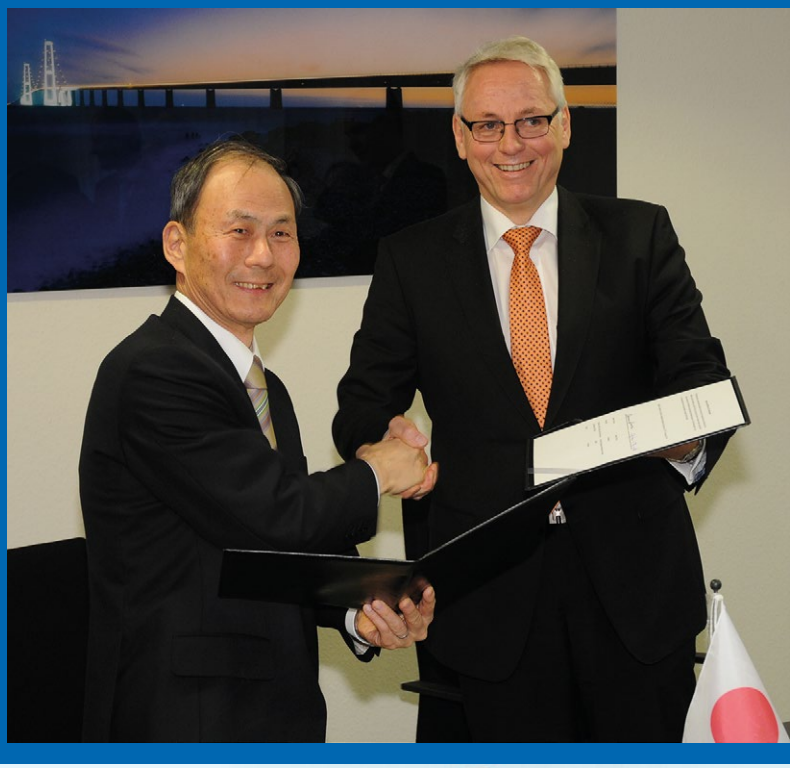

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Highlights 2020

Federal Highway Research Institute – digital new beginning

Digitalisation has arrived in almost every area of life. It feels as if the digital transformation in the public administration sector signals the fall of one of the last analogue bastions. According to clichéd thinking, it is impossible to imagine "officialdom" without civil servants' "beloved files". But it does work – very well in fact, as BASt, as a research institute, had the privilege to find out in a digital self-experiment. A lot of what happened in 2020 was of course shaped by the coronavirus pandemic, but BASt, with a forced digitalisation effort in its research operations, was able to confront the challenges with a transformation that began before the COVID-19 virus appeared.

These days, modern research includes capably handling very large volumes of data and applying digital investigation methods, such as "virtual reality" and "digital simulation" as well as conventional laboratory tests and field trials, which remain indispensable. Additionally, more and more sophisticated requirements are imposed to ensure IT security and data privacy. A research and IT strategy under a modern research management system is needed to successfully perform and accept research tasks. The system is intended to accompany the process of digital transformation and include appropriate project, requirements, process and information management to modernise research and administration. Even the work of the staff council is increasingly becoming digital.

For this endeavour, BASt, in almost all of its fields of work, has for several years been taking consistent steps towards a new digital level of development in the day-to-day work of a federal research institution, and had already been making quite a lot of headway. 2020 was just one particular step in this process, as it felt like "swift progress" became "high-speed racing". The situation forced many of the overall measures that had already been planned and prepared but had originally been envisaged for a later point in time to be implemented in 2020. These measures included all research and administrative areas and not only influenced the day-to-day work at BASt but changed it permanently.

Mobile working

Besides adapting hardware and software requirements, one milestone was establishing a strategic, IT-oriented research management system. The competences for this were bundled in a new department, processes were adapted and digitally transferred, an adapted data storage philosophy was consolidated. And in the pandemic BASt itself became a "space for experi-

Members of BASt's staff council (from top left): Sabine Fürneisen (chair), Dietlind Borst, Klaus-Jürgen Schenker, Guido Rosemann, Ilja Jungfeld, Karen Scharnigg, Yannik Roth, Michael Chudalla, Gabriela Treib and the youth and trainee representative Miriam Cremer

ments". Virtually overnight, "mobile working" as a work alternative for a better work-life balance, a concept developed and agreed upon previously in a collaboration between the agency's leadership and the staff council – practised in a pilot phase since spring 2019 – became the dominant form of working for many research and administrative staff members at BASt in 2020. A series of measures were necessary to do so, enabled only due to the enormous efforts, admittedly some courage and remarkable commitment from all colleagues at BASt – on both sides, leadership and employees.

New framework conditions, processes and technologies

The existing IT infrastructure was adapted, expanded and operated efficiently. The formal framework conditions were created and the employees were kept informed continuously and included in the development processes – and this all occurred while day-to-day research activities were ongoing. In addition to their regular work, all employees had to deal intensively at high speed with new framework conditions, new processes and new technology and implement them in their daily routines. Almost daily, there were individual or BASt-wide firsts: the first completely digitally processed file, the first digital presentation at an online conference, or the first digital staff meeting – all these have now become familiar tools. And the difficulties were always in the details: "Can you see me?" and "Can you hear me?" were certainly among the most frequently used phrases in 2020. It became apparent that digitalisation is not only digital in nature but requires many analogue changes too. It was necessary not only to gain experiences with a new communication technology for online meetings, but also to develop and consolidate a new communication culture.

2020 has not only shown the benefits and opportunities digitalisation offers research at BASt, but also that behind these there are always colleagues jointly and successfully mastering challenges of this magnitude.

Looking at the outcomes, the conclusion can be drawn: Despite – or perhaps because of – the necessary efforts towards digitalisation, this unique year 2020 has been a successful one for BASt and its employees.

BASt's staff council

Reorganisation – new M department

Research Management, IT-Strategy	Research Coordination, Research Controlling	IT-Administration	IT-, Project-, Process Management	IT-Portfolio Management

It is likely that no other year before 2020 has shown so clearly how important a well-structured and organised IT management is for an institution such as BASt.

BASt is asking itself important questions with its new Research Management, IT Strategy department, which was set up in March 2020: what changes can be expected in the IT landscape in the medium term? How can technological innovations be incorporated into the portfolio of specialist applications? How can we ensure that the complexity of BASt's IT remains transparent and manageable? What does the optimum IT support for research at BASt look like?

Karsten Strauch is the head of the department. He is a graduate in education with computer science as his minor and a focus on information management. Karsten Strauch has been with BASt since October 2007. He headed the "Information and Communication Technology" section and most recently the "Coordination Office, Requirements Management" office.

Dr Karl-Josef Höhnscheid was appointed deputy head of department and head of the "IT Portfolio Management" section. The economist has been a BASt employee since January 2000 and held a number of leadership positions, most recently as the head of the "Research Controlling" office.

Anke Wohlfeil was the interim head of the "Information and Communication Technology" section. In March 2020, she took over as the head of the "IT Administration" section. She is a computer scientist and has been with BASt since 1997.

The position of the head of the "Research Coordination, Research Controlling" section is still vacant. Dr Jan-André Bühne was appointed interim head of the "IT, Project, Process Management" section.

Changes at the leadership level

Dr Kirstine Lamers became the head of the General Administration department in March 2020. Holding a PhD degree in Law, she has been working at BASt since 1995 and most recently headed the "Human Resources and Procurement and Legal Services" section.

Dr Johannes Stalberg took over as head of the "Human Resources, Legal Services, Organisation" section in July 2020. The lawyer has been a BASt employee since March 2017.

Michael Rohloff was the head of the "Traffic Engineering" department for 12 years. He retired in September 2020. He was the deputy president of BASt and headed the "Traffic Management" working group at the Road and Transport Research Association (FGSV).

Dr Lutz Pinkofsky became Michael Rohloff's successor in January 2021. The mathematician and geographer has been with BASt since 1998. Dr Pinkofsky held various leadership positions. He was the head of the "Research Controlling, Quality Management" office and head of the "Road Construction Innovation" group.

Cooperations

BASt is working together with sister institutions and organisations around the world. This enables an intense exchange of scientific experience. Furthermore, cooperation agreements are strengthening collaborations.

On 6 February, a Memorandum of Understanding was signed to seal the cooperation between BASt and the 5G Automotive Association (5GAA). 5GAA is the organisation advancing developments in C-V2X and 5G. Dr Lutz Rittershaus (top, third from the left) represented BASt at the signing in Brussels (picture: 5GAA).

The presidents of the Russian Road Scientific Research Institute ROSDORNII and of BASt, Alexey Varyatchenko (right) and Stefan Strick, signed a Memorandum of Understanding on 27 February with which they highlighted the significance of the future exchange of knowledge and experience between the 2 research institutes.

On 28 February, the president of BASt, Stefan Strick (left), and Terbish Byambaa, president of the Mongolian Road Association, and Ute Hammer, managing director of the German Road Safety Council (DVR), signed a Memorandum of Understanding as a basis for future cooperation in the field of road and transport research between Mongolia and the German partners BASt, DVR and the Association of Road Construction and Transport Engineers Saxony-Anhalt (VSVI).

Guests

As a practice-oriented, technical-scientific research institution of the Federal Government, BASt regularly receives visitors from the fields of science, industry, politics and administration. Since March, the number of visits was heavily restricted due to the pandemic, so that it was only possible to invite a few guests.

Representatives of the Autobahn GmbH, the Federal Ministry of Transport and Digital Infrastructure (BMVI) and BASt met for an exchange of ideas on common issues in the roads sector on 4 August. The president of BASt, Stefan Strick, received, among others, Stephan Krenz, the CEO of the Autobahn GmbH, and Birgitta Worringen, Head of Directorate at the Federal Trunk Roads directorate general of the BMVI.

Dr Tamara Zieschang, State Secretary at the BMVI, visited BASt on 3 September. She was accompanied by Guido Zielke, Director-General Road Traffic and Transport, and Gerhard Rühmkorf, head of the Road Investment Policy, Structural Maintenance, Financing directorate.

Bundesanstaltfuerstrassenwesen

Since May 2020, BASt has been active on Instagram with its Bundesanstaltfuerstrassenwesen account. Besides current research findings, insights into how BASt works can be found there, as well as intriguing facts and data about the general topic of road and transport. With this channel, BASt intends not only to present itself to a larger target group but also to make research more transparent.


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LASSEN SICH EURE KIDS IMMER KORREKT ANSCHNALLEN? 🤷‍♂️
GIBT ES DA VIELE DISKUSSIONEN? 🤷‍♀️
(WIR BEHANDELN EURE ANTWORTEN WIE IMMER ANONYM)
Gibt es viele Diskussionen beim Thema Anschnallen mit euren Kids?
Schreibe etwas ...

Road User Behaviour

Re-evaluation of the zero tolerance law for novice drivers

Pilot project influencer campaign #wirgeben8

Effectiveness of emergency braking systems for trucks – an analysis of rear-end collisions on federal motorways

The “Young Drivers Campaign” is now “YOUNG+SAFE+READY TO GO”

Performance or recklessness – risk factors in motorcycle traffic

Re-evaluation of the zero tolerance law for novice drivers

Dr Claudia Evers, psychologist, head of the "Road User Behaviour and Mobility" section and Leon Straßgütl, economist, "Accident Statistics, Accident Analytics" section

The alcohol ban has been applicable since 1 August 2007 for novice drivers during their probationary period and for novice drivers under 21. It was evaluated for the first time shortly after it was introduced [1]. The evaluation showed a significant decrease in the number of alcohol-related accidents and alcohol-related traffic offences as well as a high acceptance rate for the measure. The alcohol ban thus had an impact within a short period of time.

In the latest re-evaluation [2], the longer-term effects of the alcohol ban have now been analysed. The question was whether the alcohol ban also has a socialising effect on novice drivers. The consequence of this socialising effect would be that people who were accustomed as novice drivers to separate drinking and driving would continue this behaviour as their driving years continued – even once the ban no longer applied to them. Another component of the analysis was the effect the alcohol ban has on today's novice drivers.

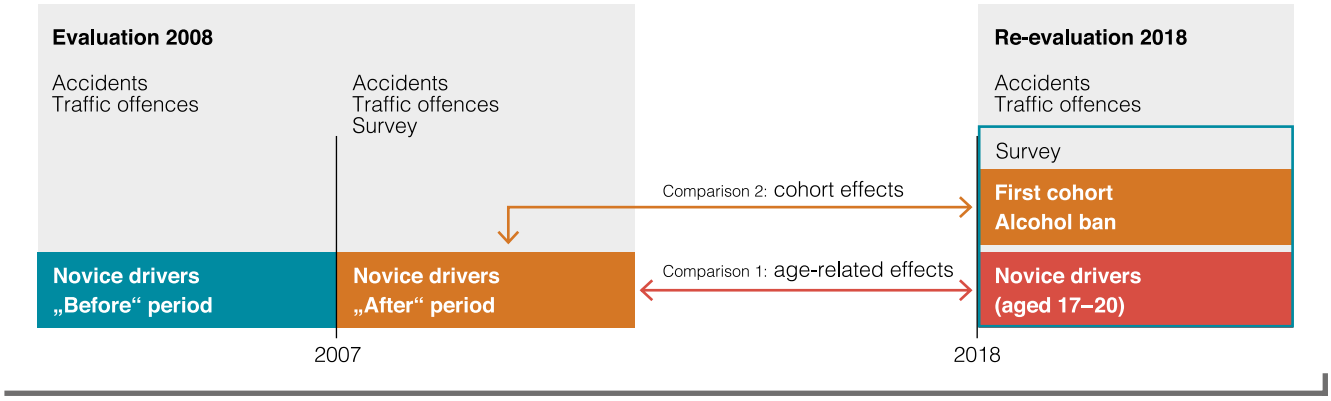
The analysis was conducted in three parts: reviewing the long-term effects of the alcohol ban for novice drivers on

- alcohol-related accident situations, and
- alcohol-related traffic offences
- as well as how attitudes towards the alcohol ban developed over time.

Official accident statistics data as well as data from the Register of Driver Fitness (FAER) of the Federal Motor Transport Authority (KBA) were used, and a representative survey was conducted to record views on the alcohol ban for novice drivers.

Results

The number of drink-driving accidents of the first cohort subject to the law declined more sharply in the long term than the accident rates in the reference groups. The reference groups were composed of accidents of the first cohort not related to alcohol, and of drink-driving accidents of older cohorts. This showed that drink-related accidents decreased in the first cohort, and not only during the application period of the alcohol ban. Even after the end of their probationary period or after turning 21,



Schematic representation of the two evaluations of the alcohol ban for novice drivers

they performed better in terms of the number of accidents related to drink-driving than the reference groups. The share of novice drivers driving under the influence of alcohol has also dropped more pronouncedly since the law was introduced than that of experienced drivers.

The analysis of alcohol-related traffic offences confirms this outcome. The number of drink-related offences also decreased significantly in the long term in the group of young novice drivers compared to the group of older drivers and experienced drivers.

The results of the representative survey show continued very high acceptance of the alcohol ban among today's novice drivers, one that has even increased compared to the first evaluation. The acceptance of the alcohol ban also increased among the cohort for which it became applicable upon its introduction in 2007. Accordingly, the measure can also be considered reasonable in the long term, even though the drivers themselves are no longer affected by the law.

For novice drivers today, driving a car and consuming alcohol are both less significant than for novice drivers in 2008 during the first evaluation. The same is true for the cohort of older interviewees who were the first cohort of novice drivers to whom the alcohol ban applied. These two developments – decreased significance of driving and lower alcohol consumption – seem to be less age-specific, and more an indication of longer-term societal trends which can support both the effectiveness and the acceptance of the alcohol ban for novice drivers.

Conclusion

The results from the re-evaluation of the alcohol ban for novice drivers confirm the positive findings of this law's first evaluation. Compared to the first evaluation conducted shortly after the measure was introduced, acceptance, already high at the time, has increased even further. The long-term decline in the number of drink-related accidents and traffic offences are clear proof that the alcohol ban for novice drivers will benefit road safety also from a long-term perspective.

The law not only has an immediate effect on the target group of novice drivers, but also shows positive effects in later years when the law no longer applies to them. Thus it has a long-term socialising effect on the consumption of alcohol in road use. Societal trends are a supporting element in the high acceptance and effectiveness of this measure: the significance and consumption of alcohol has declined – among young adults, but also in society in general. ■

References

[1] HOLTE, H., ASSING, K., PÖPPEL-DECKER, M. and SCHÖNEBECK, S.: The Zero Tolerance Law for novice drivers Alkoholverbot für Fahranfänger, Berichte der Bundesanstalt für Straßenwesen, Heft M 211, 2010

[2] EVERS, C. and STRAßGÜTL, L.: Re-evaluation of the zero tolerance law for novice drivers Re-Evaluation des Alkoholverbots für Fahranfänger, Berichte der Bundesanstalt für Straßenwesen, Heft M 305, 2020

Pilot project influencer campaign #wirgeben8

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

Under the hashtag #wirgeben8 (we are watching out), BASt conducted its first influencer campaign in social networks in September 2020. In cooperation with BASt, 9 influencers developed a total of 27 Instagram stories, 9 Instagram posts and 3 YouTube videos to raise awareness among parents about the topic of the safety of their children in traffic and to inform them about appropriate road user behaviour.

Influencer is the term for people who have a wide reach in social networks with their home-produced content. Their followers perceive them as authentic and credible based on their strength of character, communicative activities and competence in certain subjects.

Research project on employing influencers

The #wirgeben8 pilot campaign was part of an ongoing research project being implemented by a consortium consisting of earnesto GmbH, the Technical University of Applied Science Cologne and the University Erlangen-Nuremberg.

The project is pursuing two key objectives: on the one hand, making the entire process of developing the strategy and content of an influencer-based campaign transparent for stakeholders in road safety activities. On the other, identifying success factors for working with influencers with the help of a formative evaluation and deriving recommended actions for practitioners in road safety activities.

A previous BASt research project [1] showed the potential influencers have to reach different target groups involved in road safety activities. The #wirgeben8 campaign was developed to follow up on these findings.

Planning the campaign

A very wide range of information is already available for parents, as they are primarily responsible for the road safety education of their children and influence their road user behaviour as role models. Personal initiative is, however, a precondition to taking part in face-to-face events or using internet content. This leads to particularly those parents looking for information who are already aware of the importance of road safety issues. Addressing this target group with the help of influencers offers the benefit of reaching parents in social media formats they are already using on a day-to-day basis.

The basic behavioural tips that the influencers were to communicate on Instagram and YouTube were derived from an understanding of the vulnerability of children in road traffic: accident statistics clearly show that especially very young children are frequently injured as passengers in car accidents. As they grow older, children become more frequently involved in road accidents as pedestrians, and later as cyclists. On this basis, 8 tips were developed for each topic: children as car passengers, as pedestrians and as cyclists.

The influencers were selected in accordance with broad quality and quantity criteria: for example, potential influencers were assessed as to how and to what extent they are already addressing issues that could be taken as reference points for the campaign. Besides the content fit and background checks, analysis tools were used to obtain information on their reach and what type of followers they have.

This led to a selection of 9 influencers who, based on the experience with their own children, were suitable as authentic and credible advocates for the rules. Depending on their current life situation, 3 influencers with an extensive reach (heroes) and 6 with a medium-range reach (macros) were assigned to the groups “children as passengers”, “children as pedestrians”, “children as cyclists”. Each topic was individually processed by one hero and 2 macro influencers.

Screenshot of @daddy.channel’s Instagram story during phase 1

Screenshot of @mamiblock's YouTube video during phase 2

Campaign phases

The title of the campaign #wirgeben8 expresses the influencers' joint statement: to watch out in road traffic, but also refers to the 8 tips shared by each influencer with his or her community. The hash tag combines all the content throughout the 3 campaign phases and constitutes a recognition factor.

The campaign's topic was introduced in its first phase with the influencers publishing an Instagram story on something related to road safety they had recently experienced themselves or on starting the school year as the news peg. In this context, the followers were asked to share their opinion on the situation described with the influencers or to report their own encounters with road safety education issues. Some influencers showed the answers they had received in a subsequent story to promote an exchange of opinions within their community.

In the second phase – the core of the campaign – 2 days later, the influencers started to convey knowledge. While the macro influencers posted tips concerning the subject in Instagram stories, the heroes developed YouTube videos. 2 of the heroes were supported in their work by road safety specialists of the North Rhine-Westphalia police force and the Accident Prevention Organisation. As the users on YouTube have a longer attention span than those on Instagram, it was possible here to elaborate on the tips in more detail. The third influencer deliberately did not receive any support from a specialist to be able to evaluate afterwards the specialists' influence on the credibility of the content.

In both the Instagram stories and the YouTube videos, the influencers also linked their content to the content of the others in order to raise awareness of the other road safety issues. All the influencers made their tips available again in Instagram posts to enable followers who are not using the story function to watch and save them. Additionally, influencers with a low reach (nano influencers) were made aware of the campaign and invited to participate using the hash tag.

In the third phase, the influencers referred to their knowledge tutorials again, shared their followers' reaction to the tips and drew attention to a questionnaire that was part of the campaign evaluation.

Evaluation

Both qualitative and quantitative research methods are being employed in the currently ongoing evaluation phase to be able to assess the campaign's success and make recommendations to practitioners. This will enable a comprehensive insight into the user perspective and the associated potential of using influencers in road safety activities. ■

Refereances

[1] DUCKWITZ, A., FUNK, W., SCHLIEBS, C.: Road safety communication via influencers in social media Zielgruppengerechte Ansprache in der Verkehrssicherheitskommunikation über Influencer in den sozialen Medien: Berichte der Bundesanstalt für Straßenwesen, Mensch und Sicherheit, Heft M 302, 2020

Effectiveness of emergency braking systems for trucks – an analysis of rear-end collisions on federal motorways

Leon Straßgütl, economist, "Accident Statistics, Accident Analytics" section and Daniel Sander, mechanical engineer, "Active Vehicle Safety and Driver Assistance Systems" section

Rear-end collisions of goods transport vehicles (Gkfz) and buses play a significant role in accident situations on federal motorways (BAB). In 2018, they made up roughly 38 per cent of the accidents on federal motorways caused by goods transport vehicles and buses. The numbers indicate a slightly upwards trend.

Advanced Emergency Braking Systems (AEBS) can prevent rear-end collisions or at least mitigate the severity of accidents. The AEBS's function is to warn drivers of the possibility of a collision and to initiate autonomous emergency braking should there be no adequate response from the driver, such as braking or swerving. For this purpose, the system continuously monitors the difference in speed as well as the distance to the preceding vehicle and calculates the time remaining before a potential collision – time to collision (TTC). If the TTC falls below a critical mark, the AEBS will intervene.

In Regulation (EU) No 347/2012, the European Commission calls for mandatory equipping goods transport vehicles and buses with AEBS. The Regulation envisaged a gradual introduction in 2 approval levels. In each approval level, the regulation was introduced first for new vehicle types and then for all new vehicles. The project aimed to evaluate the effectiveness of the Regulation in the scope of an ex-post analysis of accident rates [1].

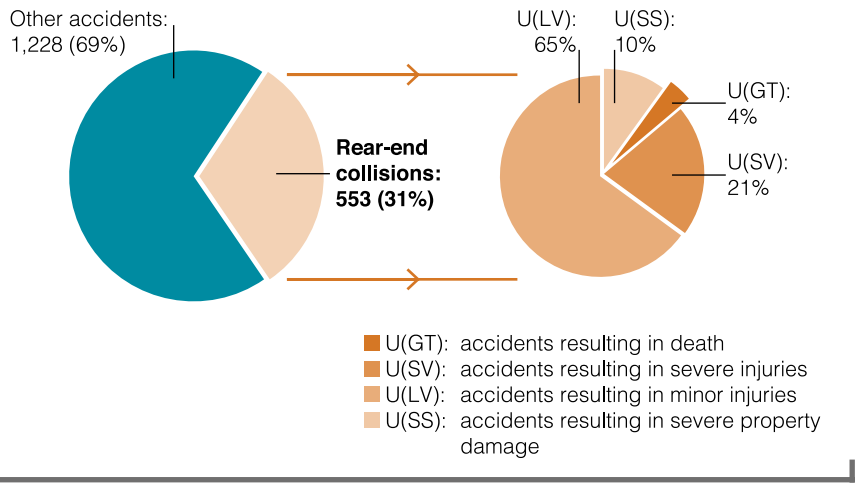
Accident analysis

The effect of approval level 1, which entered into force on 1 November 2015 for the type-approval of all new vehicles, was analysed. The first approval level requires that the speed reduction of a vehicle in an imminent collision with a stationary target needs to be at a minimum of 10 kilometres per hour. When it is a moving target (test velocity 32 ± 2 kilometres per hour), the collision must be prevented by the AEBS. This applies to all goods transport vehicles and buses exceeding the permissible gross weight of 8 tonnes.

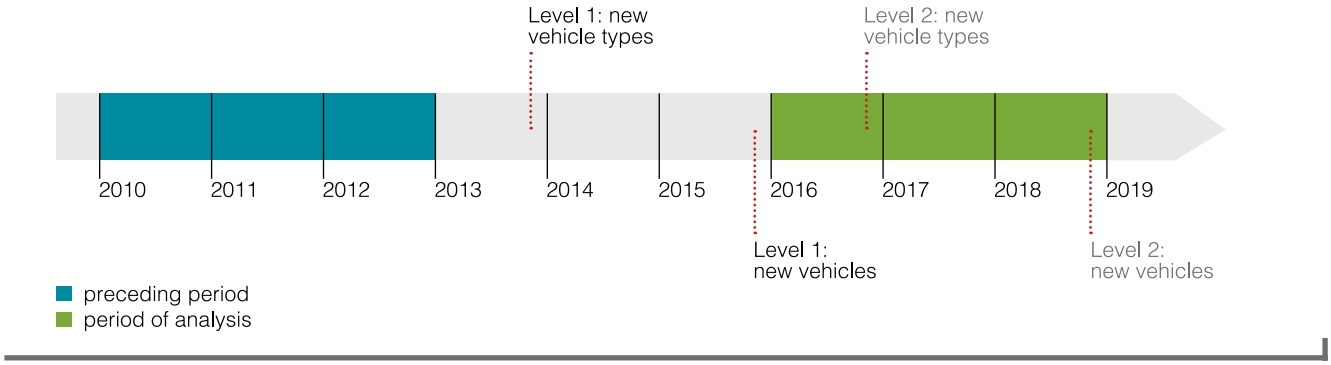
Official road accident statistics formed the basis of the analysis, including supplementary automotive engineering data from the Federal Motor Transport Authority. This data is available only for vehicles registered in Germany, and because of this, the analysis was limited to these vehicles. Accidents resulting in personal injuries and accidents resulting in severe property damage were included in the analysis.

In a first step, the vehicles for which the Regulation applies were identified in the accident data. There is no particular code for rear-end collisions in the accident data. This is why in a second step, various accident situations on federal motorways were differentiated from one another: besides rear-end collisions, definitions were made for accident scenarios, including failure to maintain lane and other accidents. Failure-to-maintain-lane accidents were later excluded from the analysis as a lane departure warning system was introduced as a mandatory requirement in the study period for the vehicles under review.

The review group consisted of rear-end accidents caused by newly approved goods transport vehicles and buses on federal motorways. This was compared to 2 reference groups: rear-end collisions of older goods transport vehicles and buses not regularly equipped with an AEBS, and other accidents of newly approved goods transport vehicles and buses in which the AEBS



Percentage and differentiation of rear-end collisions caused mainly by goods transport vehicles and buses on federal motorways 2018



Gradual introduction of emergency braking systems and review periods

did not play any role. These groups were compared in a preceding period (2010 to 2012) and a period of analysis (2016 to 2018).

Outcome

The number of rear-end collisions in the review group plummeted in the time between the preceding period and the period of analysis. At the same time, the number of accidents in the reference groups increased significantly. The overall effect of the Regulation during approval level 1 was thus about -37 per cent. It is important to note, however, that individual manufacturers had already installed emergency braking systems of approval level 2 in some of the goods transport vehicles even before the EU Regulation was introduced. The actual effect of level 1 may thus have been slightly overrated. Conversely, individual goods transport vehicles were already equipped with AEBS even in the preceding period.

Besides the total number of rear-end collisions, the severity of the accidents also decreased more sharply in the review group than in the reference groups. Particularly the number of accidents resulting in severe injuries decreased more strongly in the review group than in the reference groups.

The results of the study show that emergency braking systems are an important contribution to road safety. The use of such systems has led to a significant decline in recent years in both the number of rear-end collisions and the severity of these accidents on federal motorways.

Nonetheless, despite AEBS there is still a large number of rear-end collisions that were not avoided. This means further action is needed to increase the road safety of heavy goods transport vehicles and buses. ■

References

[1] STRAßGÜTL, L, SANDER, D.: The impact of Advanced Emergency Braking Systems on the development of rear-end collisions of trucks on German motorways Einfluss von Notbremssystemen auf die Entwicklung von Lkw-Auffahrunfällen auf Bundesautobahnen, Heft F 139, 2021

The “Young Drivers Campaign” is now “YOUNG+SAFE+READY-TO-GO”

Kristin Nickel, educational scientist, “Safety Concepts, Safety Communication” section

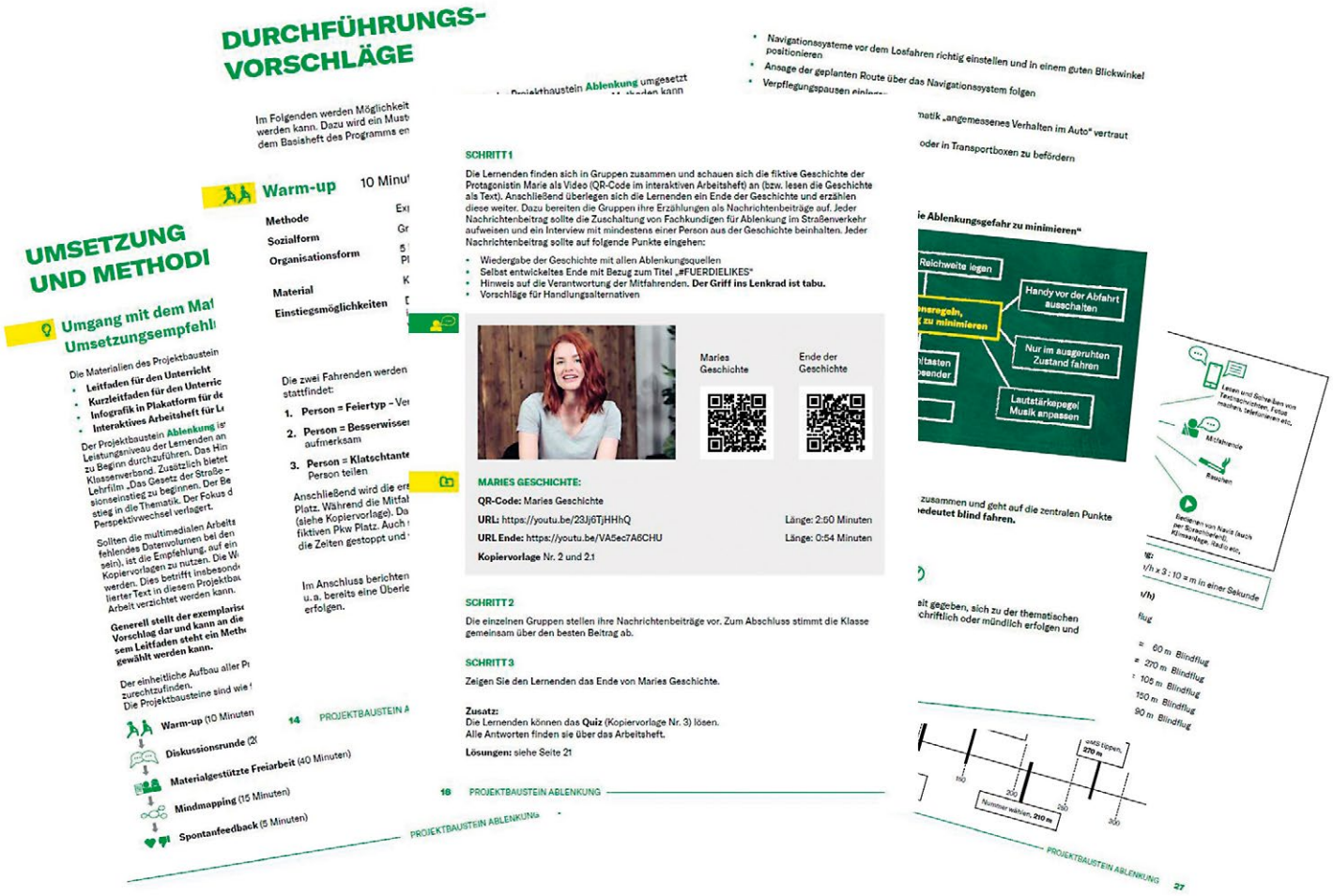
Revising a nation-wide target group programme for teenagers and young adults

With its “Young Drivers Campaign” programme, the German Accident Prevention Organisation (DVW) has been addressing the issue that accidents by young drivers are more frequent due to their lack of driving experience or risk-prone behaviour since 1984.

In the scope of the programme, local accident prevention organisations are responsible for events that are primarily held at schools. They consist of project modules on specific topics and Road Safety Days. The project modules deal with target group-specific topics in a classroom format. Various activity elements are deployed, such as an obstacle course wearing drunk goggles and driving simulators.

The programmes were evaluated in 2016 and 2018 in the version as it existed at the time. As a consequence, they were restructured and renamed. A steering committee consisting of representatives from the Federal Ministry of Transport and Digital Infrastructure and BASt, founded for the purpose, identified work packages and distributed the work among DVW and BASt. BASt took over the revision of the project modules. In the future, these will be presented by volunteer members of DVW and (as a new feature) also by teachers at the schools in a standardised format. It is intended to use them to develop target group-specific topics and prepare Road Safety Days. They are designed for an ex-

Each project module consists of a guidance document, quick reference guide, workbook and a classroom poster; interested parties can also gain an understanding of the entire programme from the main manual



Each project module includes a proposed design for a double class period – here an excerpt from the "Distracted drivers" project module

emplary double class period (90 minutes).

The intense 2019-2020 work phase included many milestones on the path towards finalising the development of up-to-date and media-supported teaching materials and teacher guides. Recommendations from specialist consultants for mobility education and road safety education at Länder level, detailed suggestions from many BASt researchers and didactic comments from teachers were taken into account. This gave rise to the new "YOUNG+SAFE+READY TO GO" target group programme which grew out of the old "Young Drivers Campaign" programme.

Project modules

The following project modules can be ordered from the DVW online shop, starting in spring 2021:

- Alcohol and drugs
- Distracted drivers
- Human behaviour as a risk factor
- Vehicle safety – automotive engineering
- Road accidents and their consequences

Each of the 5 project modules consists of a detailed manual containing examples of lesson formats and extensive background knowledge, a quick reference guide for teaching activities, a classroom poster and a workbook for students.

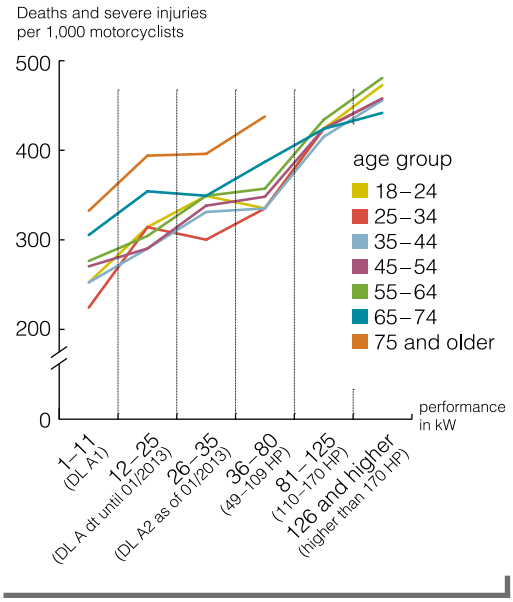
The volunteer trainers and school teachers can quickly find their way through the materials thanks to their uniform layout, and they can use the collection of methods to adapt their classes to the situation in the double class period. Besides conventional templates for trainers to copy, the trainers will also find QR codes for working with the social media platform YouTube, in order to live up to the spirit of the times and enable students to work with their own mobile devices. 5 protagonists were cast especially as consultants in producing subject-specific experience reports to be used as an introduction to the project modules. ■

Performance or recklessness – risk factors in motorcycle traffic

Martin Pöppel-Decker, mechanical engineer, “Accident Statistics, Accident Analytics” section

The following findings are based on an evaluation of two-wheel motorcycles with vehicle registration numbers which were registered by the police from 2008 to 2017 in the scope of the official statistics on road accidents. On average, there were nearly 28,000 motorcycle accidents per year that resulted in personal injuries. 579 motorcyclists were killed in 2017, 9,555 were severely injured and another 18,554 sustained minor injuries. The numbers of motorcyclists killed and of motorcyclists with minor injuries from accidents have been declining over time: -11 per cent deaths and -9 per cent slightly injured persons.

By contrast, the number of severely injured motorcyclists is at a nearly constant high level. The trend continued downward in 2019: 530 motorcyclists were killed, 9,000 were severely injured and about 18,000 were slightly injured. Specific structural parameters which only change relatively slowly over time will be outlined below.



Ratio of motorcyclists with severe personal injuries (deaths and severe injuries per 1,000 motorcyclists) by motorcycle capacity and age of motorcyclists in the 2008 to 2017 period

At 57 per cent, most of the motorcycle accidents resulting in personal injuries were recorded in built-up areas. However, an increasing shift towards rural roads can be observed. While in 2008 34 per cent of these accidents happened on rural roads, in 2017 it had increased to 40 per cent. The accidents on rural roads lead to the most severe consequences. In 2017, 74 per cent of the motorcyclists killed and 54 per cent of those severely injured had accidents on rural roads.

Single-vehicle accidents of motorcyclists have gained in significance: in 2017, they accounted for 31 per cent of motorcycle accidents resulting in personal injuries. This needs to be seen in the context of accidents shifting towards rural roads, because almost half of all the motorcyclists involved in accidents on rural roads had single-vehicle accidents (46 per cent).

Single-vehicle accidents involving motorcycles are typically characterised by motorcyclists losing control over their vehicles. This is the cause for more than 80 per cent of the single-accident accidents involving motorcyclists below the age of 45. In the majority of cases, they sway off the lane to the left or to the right. This is particularly true for the 18-24 age group and the 25-34 age group, having swayed off the lane in 65 per cent of the single-vehicle accidents. The root cause mentioned most frequently in the case of single-vehicle accidents is “inappropriate speed”, at 54 per cent.

In 33 per cent of the accidents involving more than one road user, motorcyclists are considered to be the main cause for the accident. Among these accidents, “insufficient safety distance” ranks highest, at more than 32 per cent. This usually results in rear-end collisions. The share of rear-end collisions involving motorcyclists aged 16-17 is as high as 42 per cent. “Insufficient safety distance” and “inappropriate speed” are thus the main driver-related causes of accidents.

No limit on performance?

Selected vehicle engineering data is recorded in the official road accident statistics about the vehicles involved in accidents, such as performance and engine capacity. The Federal Motor Transport Authority (KBA) has been adding this piece of information since 1995 based on the vehicle’s licence plate and the date of the accident.

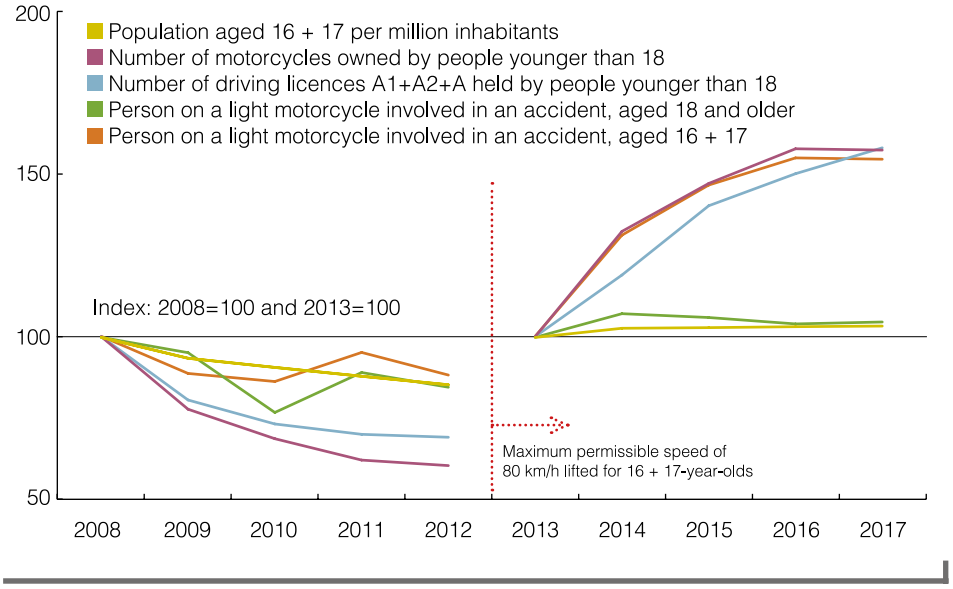
High-performance motorcycles with more than 81 kW/110 HP capacity make up about 17 per cent of the motorcycles involved in accidents. Their share in the portfolio of existing motorcycles is slightly lower at 13 per cent. The development in the number of people involved in accidents by their motorcycle’s capacity results in a heterogeneous picture. Effects related to the transposition of the third EU Directive on driving

licences have become particularly visible. Against the backdrop of a slightly lower rate of motorcycles involved in accidents than in 2008 (- 6 per cent), the number of motorcycles of up to 11 kW capacity – these are usually light motorcycles – has increased by about 4 per cent.

An above-average increase of 145 per cent has been shown for motorcycles with a 26 to 36 kW capacity (driving licence category A2) involved in accidents. The share of motorcycles of the 12 to 25 kW category (previously driving licence category A downtuned) has significantly decreased due to the reform. Strong increases of 12 and 20 per cent respectively have been observed since 2008 among high-performance motorcycles of an 81 to 125 kW capacity and of 126 kW and higher capacity. Motorcycles of this performance category have for the most part only been on the road since 1995. Before that, there was a voluntary commitment by the motorcycle industry and retailers to downtune the motorcycles and not launch them into the market. The portfolio of existing motorcycles of the 81 kW and higher category has even increased by 68 per cent since 2010.

The parameter "Drivers killed or severely injured in relation to the number of drivers involved in accidents" – severe personal injury (SP) per 1,000 drivers – shows how strongly a motorcycle's performance influences the consequences of an accident. The graph illustrates this parameter depending on motorcycle performance and motorcyclist age.

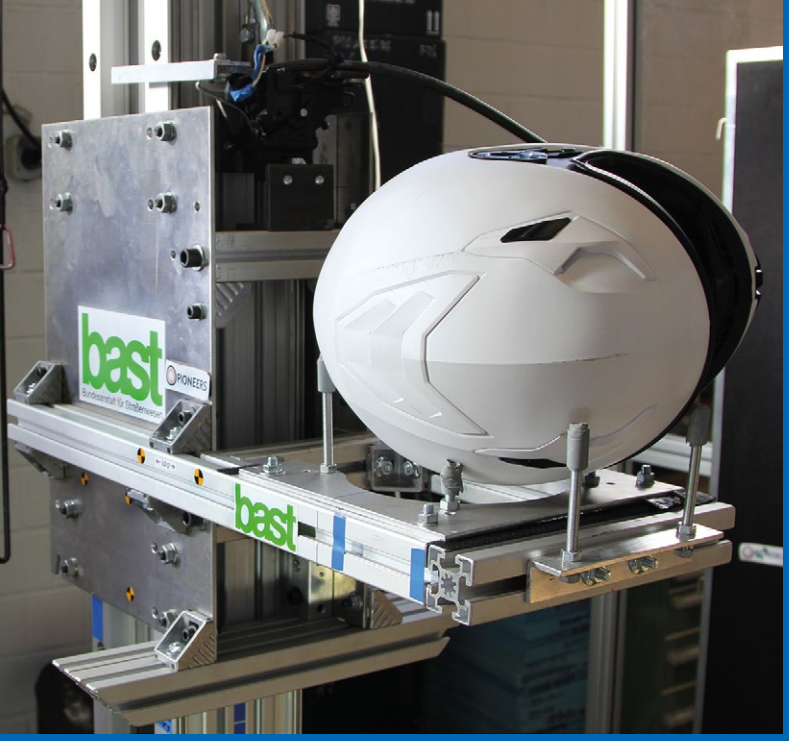
The consequences for motorcyclists become significantly more severe with increased motorcycle performance. Drivers of 126 kW motorcycles are shown to have twice as high a risk of being severely injured in case of an accident compared to drivers of 11 kW motorcycles (473 SP per 1,000 drivers vis-a-vis 263 SP per 1,000 drivers). Performance thus has a stronger impact on the severity of an accident than age-related risk components. The analysis of the correlated, technical features maximum speed and specific capacity shows a similar picture.



Index illustration 2008=100 and 2013=100 of persons younger than 18: Number of persons involved in accidents resulting in personal injury, population and number of light motorcycles and number of driving licences

In the scope of transposing the third EU Directive on driving licences (EU 2006, starting in 01/2013), the maximum permissible speed restriction of 80 kilometres per hour for drivers younger than 18 was lifted in the light motorcycles category (L3e-B). In its place, a maximum performance weight of 0.1 kW per kilogramme was introduced. Starting in January 2013, these light motorcycles may or can reach a maximum speed of about 130 kilometres per hour. Lifting the restriction has led to a substantial increase in the number of 16-17-year-old drivers of light motorcycles involved in accidents. This increase is almost exclusively based on light motorcycles with a maximum speed of more than 80 kilometres per hour and corresponds almost exactly to the increase in the numbers of motorcycles and driving licences. Though the structure of accidents has only changed marginally, the severity of the accidents in young drivers rose from a lower level (231 SP per 1,000 drivers of downtuned light motorcycles) to the level of drivers older than 18 (259 SP per 1,000 drivers on regular light motorcycles).

The examples of light motorcycles and motorcycles of the A2 driving licence category showed clearly how well-received (new) attractive vehicles are in the individual user groups. In both cases, the users of faster and more powerful motorcycles are affected by the increase in severity of accidents involving these vehicle groups. ■



Automotive Engineering

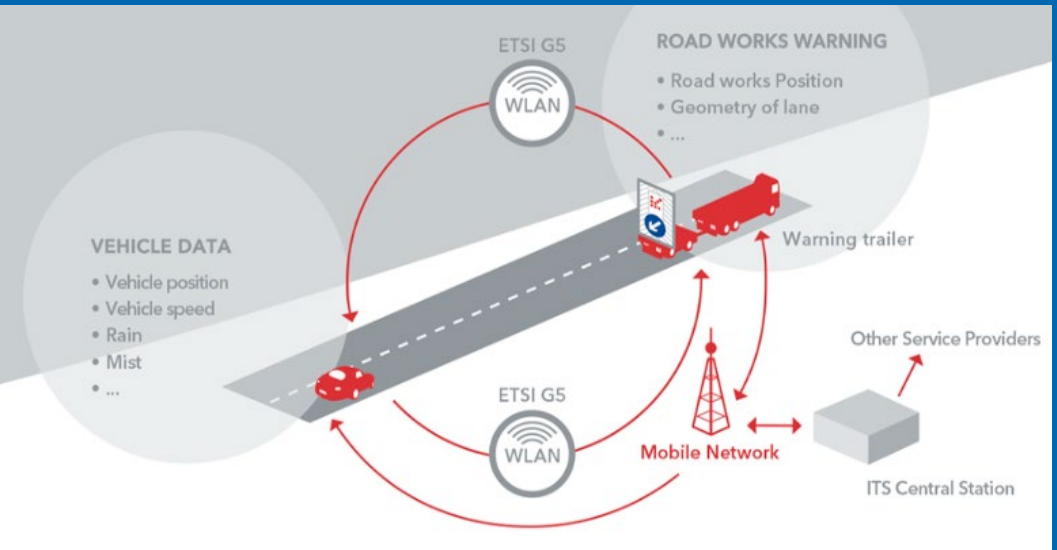
Roadworks are learning to speak – from idea to reality

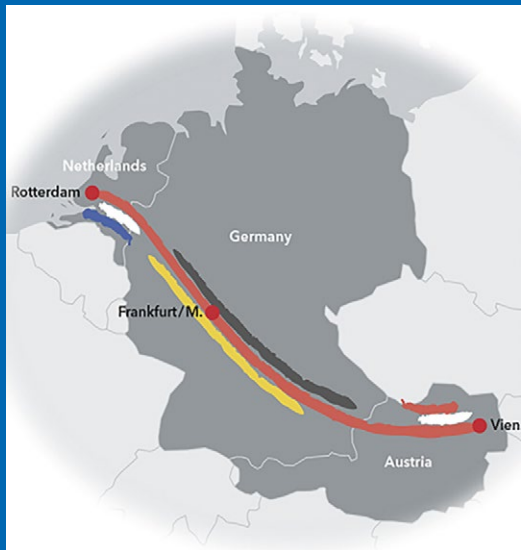
Communication of automated vehicles with non-automated road users

Euro NCAP tests on the active safety of light vans

Airbag safety systems for cyclists

Innovative drop test to assess protective gear






EURO NCAP
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Roadworks are learning to speak – from idea to reality

Sandro Berndt-Tolzmann, physicist, and Dr Lutz Rittershaus, physicist and engineer, head of "Connected Mobility" section, Ralf Meschede, electrical engineer, deputy head of section, and Karen Scharnigg, civil engineer, „Traffic Management and Road Maintenance Services" section

Becoming aware of obstacles on the road before seeing them. Recognising hazards before they turn into a threat. This vision of safe and intelligent mobility can be achieved by connecting vehicles and infrastructure. Cooperative systems – also known as C2X communication for car-to-car and car-to-infrastructure communication or as C-ITS for Cooperative Intelligent Transport Systems – are the technology with which this is possible. They enable direct communication between the road infrastructure and vehicles.

The nation-wide launch of initial cooperative services was prepared by 2020 by using mobile roadworks safety trailers (aka warning trailers), equipped with C-ITS technology, on the C-ITS Corridor Rotterdam – Frankfurt/Main – Vienna. This was done in a close cooperation between the Netherlands, Germany and Austria. The developments in the corridor have been coordinated with the automotive industry, and, with the Golf 8 series, cars with mass-produced C2X technology have been driving on German roads since 2020.

While the first cooperative roadworks warning signs were developed and put into operation by Hessen Mobil, BASt has developed key components of the overall architecture, the security and data privacy concept, and is responsible for accompanying and evaluating the tests and field trials.

Economic viability of cooperative services

An economic assessment of cooperative mobile safety trailers was conducted in the scope of the scientific support for the Digital Test Bed Motorway. The aim was to determine whether the introduction of cooperative roadworks safety trailers is economically reasonable and what benefit it can generate versus the costs involved. Changes in the consumption of resources, for example, accident-, time- and fuel-related costs, were identified and monetised, and compared with the additional costs incurred by retrofitting existing safety trailers and operating them as cooperative trailers. The costs and benefits were projected up until the year 2032.

The positive effects of the cooperative safety trailers are based primarily on their capability to warn road users at an earlier stage and more clearly about imminent hazards, such as short-term roadwork sites. An accident prevention potential of about 30 per cent was calculated for comparable applications: that has also been used as an assumption for this assessment. Individual cost and benefit components were taken into account for further analysis.

The cost components describe the costs to be expected for installing and operating cooperative safety trailers at the national level. The essential economic benefit of such trailers results from increased road safety in combination with the associated reduction in accident-related costs, as well as the reduction in lost time due to traffic congestion as a consequence of accidents. The researchers analysed various scenarios of vehicle equipment standards to compare costs and benefits. The accident cost unit rates of the Federal Transport Infrastructure Plan as well as from BASt research were used to calculate accident-related costs.

The result showed that cooperative safety trailers are economically viable in all scenarios. Even in the least favourable scenario, economic viability is expected to be achieved as of 2022 applying Federal Transport Infrastructure Plan's accident costs and as of 2025 in accordance with BASt accident costs.

Development, test, operation

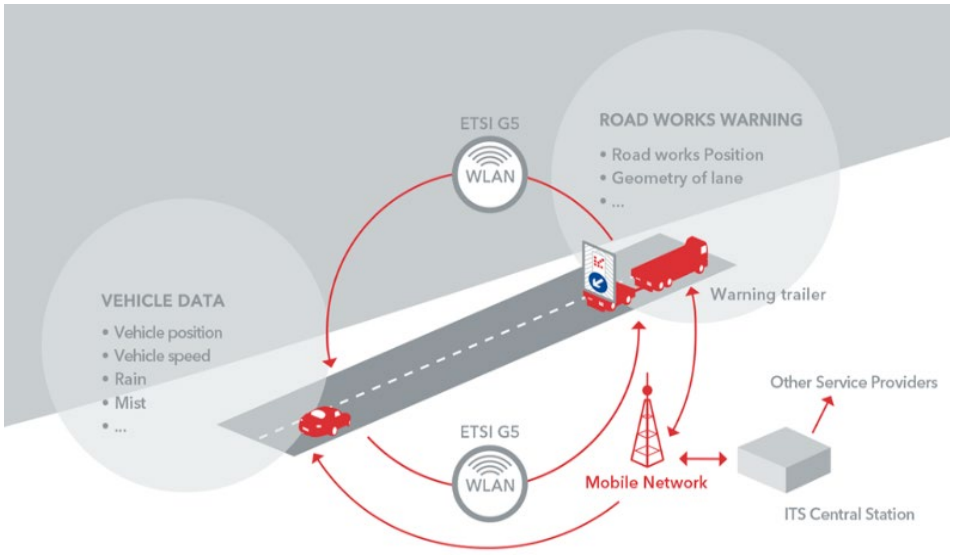
An extensive testing programme was established at the same time as the development activities to enable as trouble-free operations as possible. Selected test scenarios were defined in the run-up to the tests, based on the system requirements and in close coordination with the development partners in infrastructure and the automotive industry. As in the system development programme, the tests were divided into 5 phases to identify conflicts early

on and then be able to resolve them at the development stage. During the test phases at the Drive Centre Hessen, all the developers participating in the project were able to test their cooperative systems against each other and immediately analyse deviations from expected behaviour. In conclusion, cross-border tests were conducted between the systems from the 3 partner states that had already been involved in the previous test phases.

Once the development was completed, the entire system was tested in a 6-month trial operation, including comprehensive tests of operational processes as well as the functionality of the "roadworks warning" and "monitoring traffic conditions" services under real-life conditions. The researchers defined use cases for the functional tests with which they were able to systematically test the different scenarios presented by short-term roadworks on motorways. Data privacy issues were also addressed, besides preparatory work on the architecture, technical implementation and associated tests and a suitable organisational framework.

Outlook

The aspects covered so far and mentioned above brought the introduction of cooperative systems closer to the threshold of regular operation. But in addition to that, it will be necessary to continue fine-tuning important factors:



The 2 cooperative services in the C-ITS Corridor

- To comply with data privacy requirements pursuant to the General Data Protection Regulation, a corresponding adaptation of the German Traffic Act has been initiated.
- At the technical level, comprehensive tests are being prepared in the scope of the C-Roads project to ensure, for a wide range of EU Member States, the interoperability of the implementations and the cooperative services based on them.
- At the organisational level, suitable committees and framework conditions need to be determined and the necessary processes established for the changes required in the existing implementations and the future development. These collaborations and the necessary change management across many organisations need to include European road operators, global car manufacturers and automotive companies, as well as relevant legislators.

This selection of future challenges shows that extending cooperative systems remains an exciting field of action, even though a very viable foundation has already been laid by the C-ITS Corridor, enabling a smart connection between vehicles and infrastructure. ■

Communication of automated vehicles with non-automated road users

Dr Heike Hoffmann, psychologist, and Roland Schindhelm, mechanical engineer, deputy head of the "Automated Driving" section

Can contemporary forms of communication be transferred to the mixed traffic of the future?

The communication among road users plays an important role in today's road traffic. The non-verbal exchange of information, for instance by hand gestures or eye contact, makes it possible to clarify traffic situations and to assess and predict the behaviour of other road users. Communication thus serves road safety and the flow of traffic.

The planned introduction of automated driving gives rise to the question of how self-driving vehicles will communicate with non-automated road users in the mixed traffic expected in the future. After handing over the control of the vehicle to a self-driving system of the SAE automation Level 3 or higher, human drivers have the possibility to turn their attention away from the driving task and engage in non-driving-related activities. During an automated drive, the human drivers are thus not available or available only to a significantly lower extent for communication with other road users.

Research project and approach

BASt commissioned an analysis of the changes to be expected in the communication between an autonomously driving passenger car and non-automated road users – pedestrians, cyclists, passenger cars – and what requirements arise from these changes for the external communication of automated vehicles [1].

The methodological approach used in the project was based on a theoretical analysis, which first reviewed the communication means available to car drivers in today's road traffic. Besides the signalling devices in a vehicle, for example, headlight flasher, indicators, brake lights, including the vehicle dynamics, such as changes in speed, were taken into account in the field of technology-based means of communication. In terms of communication based on human signalling, the analysis included the drivers' body language (hand gestures) and eye contact. The next step in the project was to compile a catalogue of traffic scenarios in which road users interact with each other and exchange information using standard communication means that are currently available. For further analysis, those traffic/interaction scenarios were selected which were considered relevant with regard to their influence on road safety, flow of traffic or road user culture in today's road traffic.

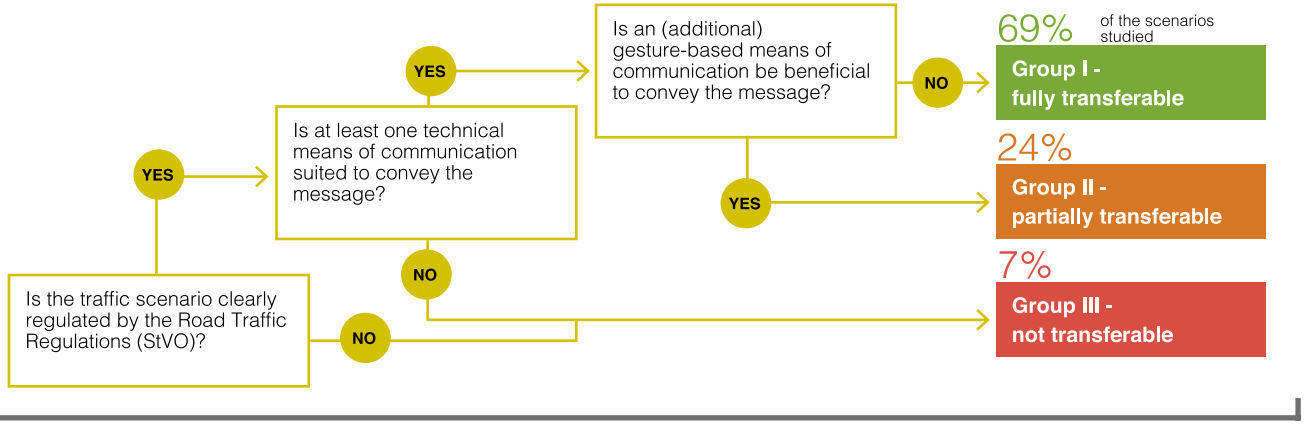
The project focused on assessing the transferability of the scenarios to future mixed traffic. On the basis of theoretical considerations and findings from empirical studies, the scenarios were reviewed to see whether the communication means traditionally deployed by a conventional car can also be used by an autonomously driving car in mixed traffic. The question whether new communication concepts would be necessary as a consequence of increasing vehicle automation, and if so what concepts, was a subject of discussion at the concluding expert workshop.

Results

Overall, 127 relevant interaction scenarios were included in the catalogue of scenarios for traffic constellations in urban traffic, on non-built-up roads and on motorways. As expected, the majority of scenarios concern traffic in built-up areas.

A number of conditions were combined to evaluate the transferability of the scenarios to future mixed traffic. On this basis, the scenarios were evaluated in reference to whether a regulation exists in the German Road Traffic Regulations (StVO), whether suitable, technology-based means of communication are available and whether additional, gesture-based communication is necessary and what its benefit is.

The evaluation showed that more than 2 thirds of the traffic/interaction scenarios studied are transferable to future mixed traffic with automated vehicles (group I). Clearly, the regulations of the StVO apply to these scenarios, and the traffic partners do not deviate from the standards there. Additionally, the assumption is that traditional, technology-based signalling devices will still be available in an automated vehicle. In the scenarios of group I, these signalling devices are suited to convey the specific message without the need for additional support from the



Evaluation of traffic/interaction scenarios with respect to their transferability to mixed traffic including automated passenger cars starting at SAE automation Level 3

human drivers' body language or eye contact.

About one quarter of the scenarios studied are only partially transferable to mixed traffic (group II). In the group II scenarios, additional gesture-based communication would be helpful, but human drivers will no longer be available for this starting at Level 3 automation.

Roughly 7 per cent of the scenarios studied (group III) were considered non-transferable to mixed traffic. These are scenarios that are either not clearly regulated in the StVO or those for which traditional technical signalling devices in the vehicle do not suffice to convey the necessary message. Interaction scenarios not transferable to mixed traffic include, for example, oncoming traffic situations at unregulated bottlenecks (risk of deadlock), getting into and out of parking spaces when more than one traffic partner is involved, or in the zone of influence of motorways.

Conclusion and outlook

The findings of the project have shown that the majority of the traffic scenarios analysed can be transferred to mixed traffic. In many of the transferable scenarios, the vehicle's driving behaviour (vehicle dynamics) is particularly decisive in conveying the relevant information to the surrounding road users.

There is a need for action for the group II and group III scenarios, however, to develop new communication schemes with which conflict situations arising from the scenarios can be solved. Requirements for new visual and acoustic signalling devices in automated vehicles starting at SAE automation Level 3 are already being discussed at the UNECE level: it is intended that they be incorporated into future type approval regulations. The information content is not, however, clear yet. The question is whether it is enough to mark the operating status during the automated driving mode or whether the automated vehicle should send out signals of intended action and requested action to the surrounding road users. This is also the subject of current research activities – besides questions concerning the impact on the behaviour of surrounding road users, ergonomic design of the interface with external communication devices and methods to evaluate them. ■

References

[1] SCHAARSCHMIDT, E., YEN, R., BOSCH, R., ZWICKER, L., SCHADE, J., PETZOLDT, T.: Fundamentals of communication between automated vehicles and road users Grundlagen zur Kommunikation zwischen automatisierten Kraftfahrzeugen und Verkehrsteilnehmern, Berichte der Bundesanstalt für Straßenwesen, Heft F 138, 2021

Euro NCAP tests on the active safety of light vans

Maxim Bierbach, mechanical engineer, and Adrian Hellmann, mechanical engineer,
"Active Vehicle Safety and Driver Assistance Systems" section

Driver assistance systems in light vans

Accidents involving both unprotected road users and other motor vehicles can be effectively prevented or reduced in severity by active safety systems. Active safety systems are systems that independently intervene in steering or braking the vehicle and, where necessary, also alert the driver by visual, acoustic or haptic warning signals. In particular, emergency braking and lane keeping assistance systems which are considered part of active vehicle safety, have been used, for example, for a number of years in the passenger car segment, successfully contributing to reducing the number of accidents. It is intended to transfer these successes to the light vans category to exploit a potential increase in safety.

To date, however, the selection that active safety systems manufacturers offer in the light vans segment is small. This is also due in part to the lower demand, as the customers' purchase decision is often characterised by high cost pressure, and optional extras are often turned down. These two aspects lead to a very low rate of assistance systems equipment in this vehicle category.

Euro NCAP's light vans campaign

This is why the European New Car Assessment Programme (Euro NCAP) has initiated a campaign: It will particularly award vehicles from the light vans segment that are equipped with safety systems that go beyond what is legally required. This is intended as an incentive to transfer the active safety equipment already well -established in the passenger car world to the light vans segment.

Euro NCAP, as a consumer protection organisation, enables an objective comparison of the vehicle manufacturers' different products with respect to active and passive vehicle safety. Standardised testing procedures are used that are derived from accident scenarios. Interested, safety-oriented car buyers will thus receive an objective overview.

The automotive industry uses these results as a promotional platform, where independent laboratories evaluate their products and award ratings.

To date, there has not been a specific Euro NCAP programme to regularly address the safety of light goods vehicles of the N1 category. A campaign was initiated in 2020 to enable an assessment of these vehicles with respect to their safety equipment. In the scope of the campaign, various laboratories tested a number of transport vans, primarily in terms of active vehicle safety. BASt tested 3 commercial vehicles as part of the campaign.

Test protocol developed in collaboration with BASt

It was necessary to develop a separate, pertinent test protocol to prepare the active vehicle safety tests of light commercial vehicles. To this end, representatives of BASt contributed their expertise in an international Euro NCAP working group to enable an assessment of the systems that are designed differently from those of passenger cars, and to optimise the testing procedures with respect to feasibility and material wear.

Besides sheer dimensions, the vehicles of the N1 category also differ significantly in weight from passenger cars. In this context, a maximum load capacity of up to 3.5 tonnes must be taken into account, as well as the relatively high position of the centre of gravity.

The testing regulations for passenger cars, version 2018/19, served as a basis to develop the test protocol for light commercial vehicles. The newly developed N1 test protocol includes test scenarios and tests for the emergency braking and steering assist systems: This led to the creation of tests for vehicle-vehicle rear-end collision scenarios and pedestrian-cyclist scenarios with mini vans crossing or driving parallel – weaker road users crossing or moving longitudinally.

Additionally, assistance systems for lane keeping and traffic sign recognition were evaluated. To simulate loading scenarios as they occur in practice, the vans are loaded for the tests based on half their payload. The load is positioned in such a way as to have the load's centre of gravity in the geometrical centre of the cargo space.

Testing the emergency braking assistance system to prevent or mitigate rear-end collisions

BASt test series on N1 vehicles

The following commercial vehicles from various manufacturers were tested: Ford Transit, Mercedes Vito and Volkswagen Transporter T6.1. The results of BASt's test series will be published by Euro NCAP together with those of other European test laboratories.

Though all vehicles used in the tests were top equipment level (maximum equipment) in terms of safety packages, the individual vehicle types tested varied significantly in their equipment with assistance systems, as did the performance of the built-in assistance systems. Furthermore, some models were equipped with all assist systems already in the basic version, whereas others had them only as optional extras for more money or were not available at all. Nonetheless, the campaign's test series clearly showed that it is possible to install modern and effective safety systems in light vans. ■

References

BASt Bericht 2020 F1: Euro NCAP tests on the active safety of light vans Euro NCAP-Tests zur aktiven Sicherheit von Kleintransportern

https://www.euroncap.com/en/ratings-rewards/commercial-van-ratings

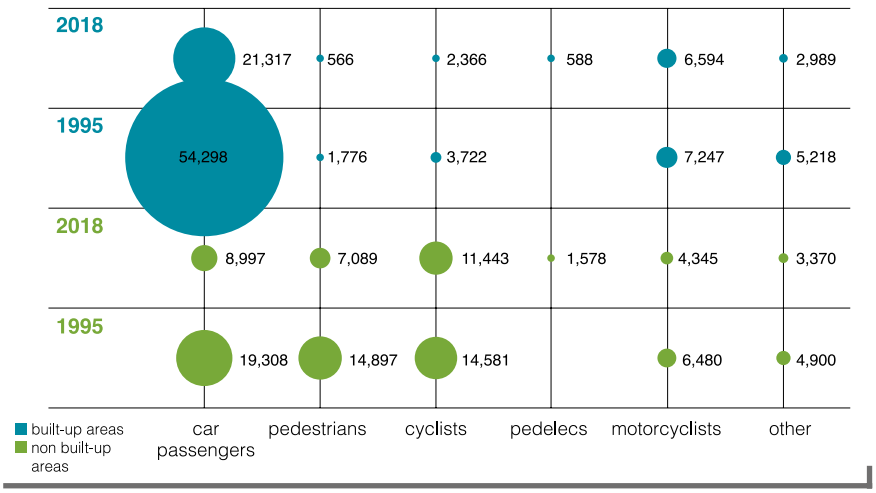
Airbag safety systems for cyclists

Daniel Huster, automotive engineer, and Oliver Zander, safety engineer, deputy head of the "Passive Vehicle Safety, Biomechanics" section

The development of accidents involving pedestrians and cyclists in Germany does not show a uniform picture. While a slight decline can be observed in the number of accidents involving pedestrians across all severity levels, the number of cyclists falling victim to an accident is rising continuously. In absolute terms, the number of cyclists killed in traffic in 2018 is close to the level of 2004. It is worth noting that, in the meantime, cyclists in built-up areas have become the largest group of road users killed or severely injured in accidents.

The situation is likely to be aggravated in the near future due to the continuous increase in the use of pedelecs. Most of the accidents involving cyclists are collisions with passenger cars – for the most part accidents at intersections – and single-vehicle accidents. These are also the accidents resulting in most of the fatal injuries. In terms of numbers, there are more injuries of the extremities and head injuries in cyclists than injuries of the thorax area, but the latter account for the highest share of severe and fatal injuries (AIS2+).

The question arises how to specifically respond to this development. Testing requirements have now been drafted for consumer protection and legislation, intended to be implemented in the next few years and to counter severe head injuries in cyclists. The other anatomical regions, however, – such as the thorax – will still not be taken into account in the foreseeable future. In the scope of the EU's SENIORS research project, BASt, together with additional partners in a consortium, has developed a testing procedure for components that is now being refined in the scope of a follow-up programme. As single-vehicle accidents will not, however, be considered at all in a potential future implementation, these need to be addressed by personal protective equipment. It is in this context that BASt has examined the protective potential of airbag safety systems for cyclists.



Road users killed or severely injured in accidents in Germany

System description

Basically, the protective potential of airbag-based safety systems can be determined as a function of total response time and dampening behaviour. The total response time is cumulatively composed of the sensor time (time the sensors need from detection to deployment) and the set-up time (time for inflating airbags). If the total response time is shorter than the time to impact, i.e., the period of time between the beginning of a critical incident to a crash into the anatomical region that is to be protected, the fully inflated airbag system can show its cushioning effect to the full extent.

The airbag vests examined are intended to mitigate impact on the thorax, back and throat/neck of the person on the bicycle after a corresponding detection phase in the event of an accident. 2 interacting sensors in the vest and on the bicycle are intended to detect sequences of movements and shocks typical for an accident. Depending on the bicycle's speed, they order the airbag vest to inflate using a CO_2 cartridge installed in the vest. According to the manufacturer, the deployment time is 80 milliseconds at an airbag pressure between 300 and 500 millibar.

Test programme

A test programme on BASt's vehicle engineering testing facility provided insights into the deployment of the airbag, the sensors' deployment algorithm, the cushioning properties

of the airbag and the effectiveness in real accident scenarios.

A full inflation of the airbag vest with CO_2 was achieved in a time window of less than 100 milliseconds during a stationary test with external deployment. The maximum load on the ribs of the THOR 50th percentile dummy was very low, and thus the associated risk of injury with a chest compression of 4 millimetres.

The sensing algorithm and the interaction between the 2 installed sensors were tested in proof-of-principle tests. BASt researchers determined that besides the low reproducibility of the sensing time and the time of deployment, though a coupling of the 2 sensors and carrying or mounting them on the bicycle is not necessarily required for deploying the airbags, it is still recommended, as this will lead to significantly increased reliability and a reduced total response time.

The shock-absorbing properties of the airbag vest were tested in various test constellations under 2 different speeds on a calibration bench, using a THOR 50th percentile dummy. In the tests, the deployment times of the vests triggered externally varied. The findings were compared with a vest that was statically inflated, and with an unprotected dummy. Loads on specific points were simulated using a calibration pendulum, and a flat crash into an obstacle was simulated. The result has shown that the shock-absorbing properties of the airbag vest are capable of limiting surface impacts on the chest area over a certain period of time. In contrast, very hard loads and loads on specific spots punched through the vest, as expected, and led to much more severe repercussions.

Single-vehicle accidents were simulated by Hybrid III 50th percentile dummies as cyclists crashing into various obstacles followed by them falling from the bicycle. After the dummies were thrown off and fell from the bicycle over the steering wheel, the airbag vest was astonishingly not deployed, though this would be expected given the impact on the saddle sensor.

Airbag vest in stationary test: undeployed and deployed

In conclusion, the researchers simulated 2 other accident scenarios that occur frequently: an accident at an intersection involving a bicycle (speed 20 kilometres per hour) and a crossing passenger car as the collision opponent, as well as a longitudinal scenario (passenger car driving 20 kilometres per hour crashes into a bicycle waiting at a traffic light). With a GPS signal available and interacting sensor units, the system works as intended. The sensors detect the collision in time and trigger a signal to the airbag vest, which is fully inflated prior to the collision of the person with the car (thorax against the edge of the car roof) and the impact on the thorax is significantly reduced. In the longitudinal scenario, however, the car's momentum does not suffice for the system's sensor algorithm to detect it as an accident. In this case, the vest inflates only during the secondary impact when the person hits the road surface.

Conclusion

The airbag vest for protection of the thorax, back and throat/neck of cyclists in case of an accident tested was only partially capable of mitigating the injuries that occurred. When a GPS signal is available, the combination of airbag and saddle sensors can detect a certain proportion of real-life accident scenarios, but the system's total response time may sometimes take too long to show the full extent of its shock-absorbing effect. Provided that the airbag vest is considered additional personal protective equipment, it can contribute to mitigating the consequences of a bicycle accident under certain constraints. It is recommended to also inform about this circumstance in the manual. ■

Innovative drop test to assess protective gear

Daniel Huster, automotive engineer, “Passive Vehicle Safety, Biomechanics“ section

In contrast to passengers in cars, riders of two-wheeled vehicles can hardly be protected by in-vehicle restraint and protection systems. In case of a collision with other road users or in single-vehicle accidents, riders of two-wheeled vehicles are basically dependent on the protective effects of their helmets and other elements of protective gear.

Protective gear for riders of two-wheeled vehicles consists primarily of a bicycle or motorcycle helmet. These 2 types need to undergo standardised component tests and show a minimum cushioning effect before they can be marketed as safety helmets. Other elements of protective gear – for example, back protectors – are also tested dynamically. Some dynamic component tests are enabled by drop tower test rigs with which a defined impact can be simulated, and the cushioning property of the protective gear determined using sensors. By further developing testing regulations to include more realistic test configurations, the protective potential of the protective gear can be increased, thus contributing to road safety.

FTVA’s drop tower test rig

General operating principle

A drop tower test rig uses gravity to accelerate a test specimen or impactor onto an anvil. In an exemplary test of a motorcycle helmet, a headform is equipped with the helmet to be tested. The helmeted headform is then positioned on a guide sled and elevated to the impact level defined earlier at the drop tower. When the free fall is triggered, the sled drives down the tower and guides the helmeted headform as to create an impact of the helmet on the anvil at the desired position – for example, the forehead or temple area. Sensors located at the headform’s centre of gravity measure the acceleration impact on the helmet to rate the helmet’s cushioning effect. As the helmeted headform is only loosely positioned on the guide sled, it separates from the sled as soon as it hits the anvil. In this way, drop tower test rigs enable a test specimen to crash freely into the anvil while expertly guiding the free fall at the same time. As an alternative, an impactor can also be used instead of the guide sled and accelerated towards the protective gear element to be tested. In that case, a back protector, for example, will be lying on the anvil and a defined impactor will exert such a load onto the protector that the cushioning effect can be determined at the anvil or the impactor.

Properties of BASt’s drop tower test rig

Drop tower test rigs are usually designed for a specific type of test. Despite having similar functions, there are drop tower test rigs for helmets, for protectors and other applications. A retrofitting of the test rig is often not envisaged or may be complicated due to space constraints.

BASt’s drop tower test rig is an innovative in-house development enabling a wider range of functions and can be adapted to experimental impact configurations. Dimensioning and the availability of space enable implementing new test set-ups and methods. A pole of 6 metres with 4 linear guide mechanisms enables using an effective drop height of up to 5 metres. The vertical velocity of up to 9 metres per second that can be achieved with it covers the relevant impact speeds in accident situations as well as the specifications of various testing regulations. A massive machine bed enables assembling and positioning different anvils and crash installations. This makes it possible also to conduct tests on an inclined anvil to simulate a tangential impact on a helmet.

Compared to an impact on a horizontal surface, which test regulations require in evaluations of helmets, this tangential impact is more realistic for the accident situations of riders of two-wheeled vehicles. The guide sled can be adapted individually to

enable testing various helmets and novel configurations. The drop tower is equipped with a remotely controlled rope winch and a laser-supported level measurement for the sled. When a test is conducted, the guide sled passes a highly precise light barrier to measure its speed immediately before the test specimen crashes into the anvil. After the test specimen has crashed and triggered the separation of the guide sled from the test specimen, the guide sled slows down by diving into a foam cushion. The crash area of the drop tower is encased in a 4 square metre housing with a door as protection against flying test specimens and debris.

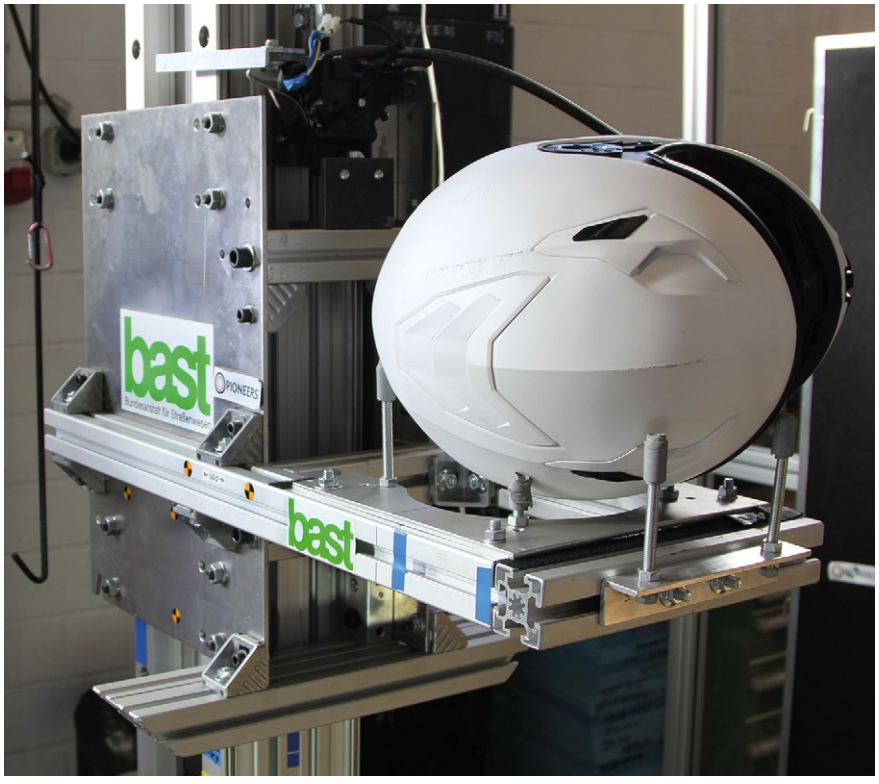
The headform with the helmet to be tested is positioned onto the guide sled for the test. The initial height of the free fall is calculated on the basis of the theoretical vertical velocity and existing low friction losses. The comparison between theoretical and actually measured speeds is repeated for each test conducted, enabling an increasingly precise estimate of the necessary initial height.

The guide sled is then dropped from the initial height as previously calculated to start the test. This is done by means of a purpose-built remote trigger which cuts the connection between rope winch and guide sled, releasing it.

The ensuing crash of the helmeted headform is recorded using measurement technology, enabling an analysis of the effective loads and the protective effect of the helmet. As the relevant time frame for the helmet crash is only 10 to 20 milliseconds, the measurements are performed at a correspondingly high scanning frequency of 20 kilohertz. High-speed images are usually recorded for further analysis, documenting the test with 1,000 pictures per second.

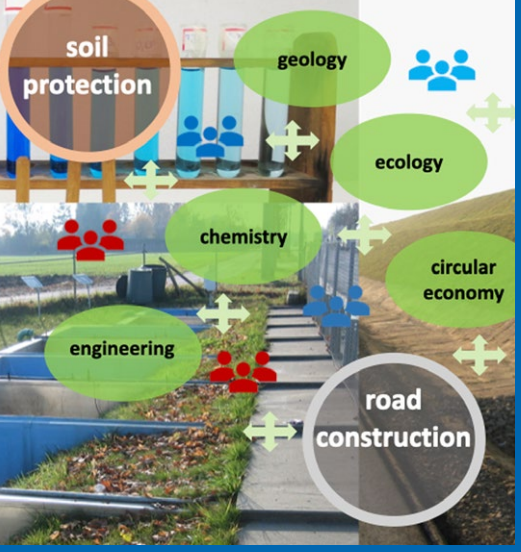
Utilisation of the drop tower test rig

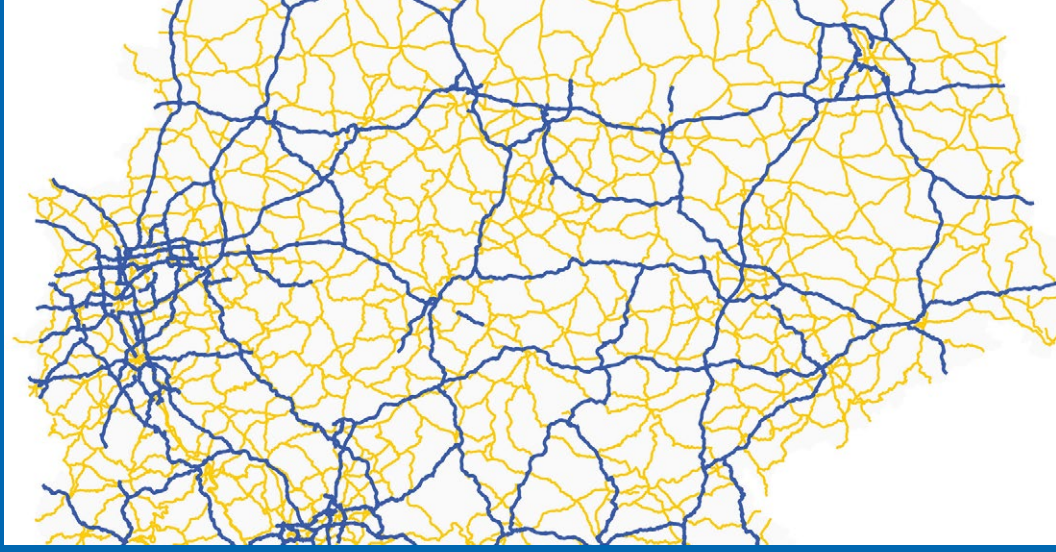
The drop tower test rig enables testing motorcycle and bicycle helmets in accordance with applicable regulations. The test rig can be variably retrofitted and expanded to test new or modified regulations. In this context, various crash configurations are being developed for motorcycle helmets in the scope of the EU's PIONEERS (Protective Innovations Of New Equipment for Enhanced Rider Safety) research programme. Findings from these tests will also be used in international regulations, such as the UN Regulation 22 for motorcycle helmets. The drop tower test rig is also used to develop future dynamic tests for cervical vertebra protectors for motorcyclists (neck braces). The variability of the test rig makes it possible to test differing concepts at short notice, cost-efficiently and under comparable conditions. ■



Guide sled with positioned helmet


bast





Traffic Engineering

Traffic barometer – traffic during the coronavirus pandemic

Drones measuring air pollutants

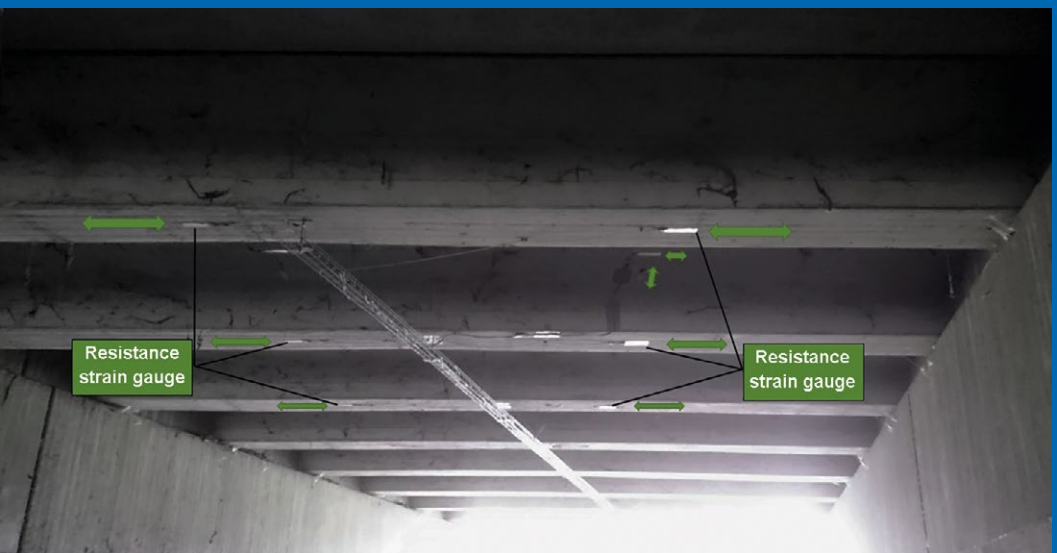
Bridges weighing vehicles

Technical developments to avoid road closures

How is the toll table actually developed?

Jointly analysing and protecting soil and water in the road environment

Safe rural roads with the help of suitable safety barriers



Traffic barometer – traffic during the pandemic

Anke Fitschen, surveying and real estate assessor, and Arnd Fitschen, surveying and real estate assessor, "Traffic Statistics" section

The traffic on German roads in 2020 was heavily influenced by the coronavirus pandemic. The drastic lockdown in spring led to free motorways (BAB). BASt monitored this development in real time in the form of a traffic barometer and provided regular information updates on the internet. The Federal Government's crisis management also benefited from these updates.

Traffic significantly declined as a consequence of the restrictions due to the coronavirus pandemic. Up until and including 21 July 2020, the developments on federal motorways were determined, using the existing data from axle load monitoring sites (AMS) and automatic permanent count sites (DZ), compared to the time period prior to the coronavirus pandemic (2 February to 7 March 2020).

Data from axle load monitoring sites

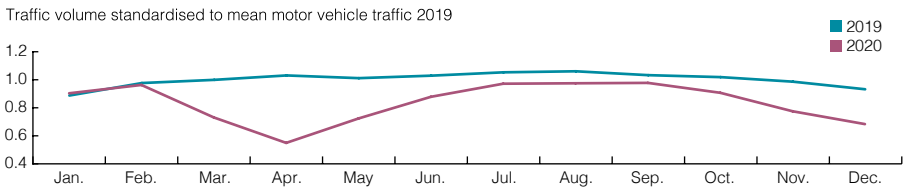
The data from about 2,000 permanent count sites is usually made available to BASt after quality controls in the highway authorities of the Länder as monthly files with a delay of several weeks, so that they were not timely enough for these real-time studies. In contrast, the data from axle load monitoring sites is available on a daily basis. The first traffic barometer was therefore compiled based only on axle load monitoring sites and published already on 2 April 2020, i.e., just 10 days after the comprehensive lockdown started in spring. In the 25-31 March 2020 period, the decline in motor vehicle traffic was shown to be -46 per cent. From calculations at a later stage, using 359 permanent count sites (including AMS), the decline was calculated to be -47 per cent for this time period, thereby confirming the value for the whole of Germany that was determined earlier on the basis of only 4 AMS in North-Rhine Westphalia.

Provisionally, the Länder provided the raw data from their permanent count sites already just a few days after the end of each month to enable using large data volumes to update the traffic barometer, which was compiled every 14 days after extensive calculations. Daily data from the axle load monitoring sites was used to calculate any development beyond the end of each month.

The sharpest decline was measured for the Easter weekend at -54 per cent, in heavy goods vehicle traffic at -44 per cent. Compared to the same public holidays in 2019, roughly 74 per cent fewer cars were on the roads on Good Friday, Easter Sunday and Easter Monday. Traffic then increased continuously due to the gradual lifting of coronavirus-related measures, until pre-pandemic levels were reached again in mid-July. However, the traffic in the 2 February to 7 March period cannot serve as a basis to compare the traffic volumes in summer times, as the normal graphical display of yearly traffic volumes shows that there is more motor vehicle traffic in summer than in winter.

Monthly development

The traffic barometer was restructured into a more practicable format to further study the developments in traffic. The normal supply of preliminary data from the permanent count sites of the Länder is now its basis. Monthly developments are described, comparing each month to the month before and to the same month of the previous year on both federal motorways and federal trunk roads. This has shown that the summer traffic has not yet reached 2019 levels and is running at about 8 per cent below the 2019 curve (-5 per cent in heavy goods vehicle traffic). The barometer will be updated on a monthly basis and will continue to provide reference values for current traffic developments in the future. ■



Traffic barometer – road traffic development on federal motorways by months – all motor vehicles

Drones measuring air pollutants

Dr Anja Baum, geophysicist, deputy head of section, Dr Julian Rüdiger, chemist,
and Rickmar Seldschopf, environmental engineer, “Environmental Protection“ section

It is important to know the concentration of pollutants – particulate matter, soot, ozone and nitrogen oxide – in the air to enable assessments of air quality. These concentrations are measured on site across Germany by Länder and federal authorities and projected using models. BASt too operates measuring stations at the A555 motorway near Wesseling and the A4 motorway near Bergisch Gladbach/Bensberg to determine pollutant concentrations in areas close to traffic. Stationary and continuous measurements enable monitoring the compliance with limit values, thereby ensuring and steadily improving the quality of people’s lives. Mobile measurements are, however, an important and crucial tool for a more comprehensive understanding of the pollutant levels in urban spaces. Using ambient air vehicles and even measurements by bicycle make it possible to review the air quality across Germany. There is, however, still a lack of information on the vertical distribution of pollutants, which is of great significance for transport and for modelling spatial distributions of pollutants.

Drones are closing the information gap

Using drones enables measuring the vertical profiles of pollutant loads at manageable costs. Since the performance of drones has continuously increased, they have been used in air quality measurements in numerous studies in recent years. The primary focus was on feasibility studies and experimental utilisation. The MesSBAR project aims to close the gap to routine measurements by drones. To do this, 3 automatically operating quadrocopters were developed that will measure air pollutants. The instruments used on drones are exposed to environmental influences to a greater extent than the instruments used in stationary measuring devices, which is why they need to be subject to extensive quality assurance. The drones’ sensors are operated and monitored in BASt measuring containers at the same time as other instruments that were tested for suitability. Initial measurements have been taken since July 2020 at BASt’s cross-section measuring station at the A4 motorway. The different measuring devices are being operated in various modes over a period of several months. Initial evaluations have shown that the data measured by mobile and stationary sensors is basically consistent, thereby confirming that the sensors are suitable for use on pollutant drones.

Takeoff in spring

Test flights are planned for the first drone prototypes to take place in spring 2021 at BASt’s measuring station at the A555 motorway near Wesseling. To this end, the partners in the project consortium – the Institute of Flight Guidance of the Technical University Braunschweig and the Leichtwerk Research company – will unite the custom-made drone body with the sensors. Sensors purpose-built by the Jülich Research Centre will be integrated alongside commercially available measuring devices. The Leibniz Institute for Tropospheric Research is providing scientific support for the particle sensors, and the National Metrology Institute (PTB) is ensuring the metrological traceability of the measurements. It is intended to compare modelling for pollutant distributions in the atmosphere conducted by the Jülich Research Centre to actual surveys of the vertical distribution in (near) real time. The Federal Environment Agency is providing emission registers to explore potential pollution from local and regional large-scale emitters at the local measuring stations. ■

Illustration of the pollutant drone prototype (Leichtwerk Research GmbH) at the A555 measuring station

Bridges weighing vehicles

Jens Dierke, civil engineer, and Ralf Meschede, electrical engineer, deputy head of the "Traffic Management and Road Maintenance Services" section, Anke Fitschen, surveying and real estate assessor, "Traffic Statistics" section, and Daniel Eickmeier, civil engineer, "Maintenance of Engineering Structures" section

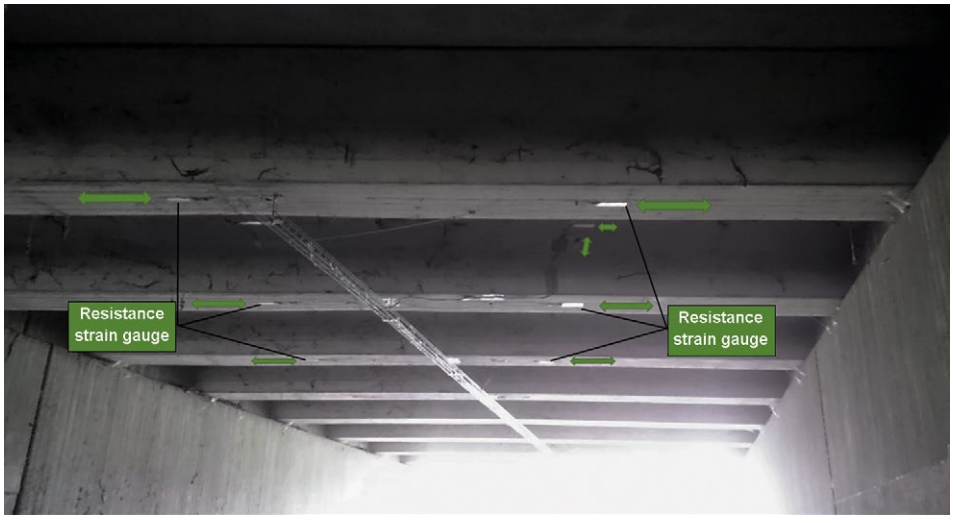
Testing Bridge WIM systems in Germany

Axle load monitoring sites form a network of measuring sites along German motorways (BAB) to record the weight of heavy goods vehicle traffic. Gross weights and axle loads can be weighed in motion with the help of sensors sunken into the carriageway. The data gathered continuously by these axle load monitoring sites is evaluated statistically by BASt and used as the basis for planning roads and bridges and managing their maintenance. Furthermore, the Federal Office for Goods Transport (BAG) uses some of the measuring sites to pre-select overloaded vehicles in controls.

The number of fixed axle load monitoring sites on federal motorways has been limited to the minimum necessary for network-wide load data due to the efforts and costs involved. Temporary measurements in individual sections would be very informative for certain more detailed assessments, for example, concerning specific network sections or bridges. For this reason, suitable mobile systems are sought with which these measurements can be conducted in a cost-effective way. Bridge WIM systems that can be mounted on bridge engineering structures were tested in a BASt pilot project for their suitability as measurement technology; operational and economic aspects were also analysed [1].

Pilot test on motorway A8

2 different Bridge WIM systems were installed under bridges in a test field on the A8 motorway near Rosenheim. According to the information provided by the system manufacturers, they appeared to be suitable in their geometry and structural properties. The picture shows the sensors installed on the underside of a bridge. The sensors measure the bridge's deflection that is caused by passing vehicles. The vehicles' weight is then determined using corresponding software of the Bridge WIM systems.



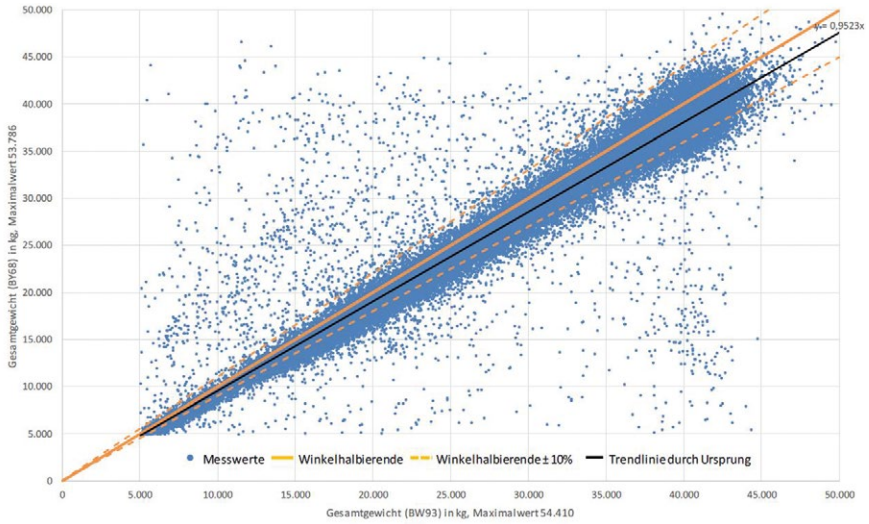
Motorway bridge with sensors to record weights of vehicles (Bridge WIM)

An existing control station with verified truck weighing scales was another element of the test field. It was operated jointly by BAG and the police and was downstream to an axle load monitoring site on the motorway. This enabled, on the one hand, establishing the actual weight of the vehicles, and on the other, comparing the Bridge WIM systems and the axle load measuring sites. The test team installed a vehicle identification system that generated anonymised vehicle codes, pursuant to data privacy regulations, to enable automated allocation of the data from the different measuring sites across the measuring field, which was about 11 kilometres long.

In a first step, the handling of the Bridge WIM systems was analysed, and the installation and dismantling by specialised companies was accompanied and documented in detail. The efforts for installing and later dismantling the system greatly depend on the set-up of the system (hardware and software) and local conditions.

In a standard environment, the system can be installed, including calibration, by a team of 2 people within one or 2 working days – this is relatively little effort. Dismantling takes about half a working day.

To determine the accuracy of the measurements, test drives using



Comparison gross weight Bridge WIM system (BW93) and axle load measuring site (BY68) for 188,924 vehicles (4 April to 31 August 2018)

test trucks were conducted following a test procedure that is well-established in reviewing calibrations and for the technical acceptance of permanent axle load measuring sites. In a supplementary step, comparative measurements were taken on trucks which were guided away from traffic and re-weighed in collaboration with BAG and the police. In addition to these tests, data from the Bridge WIM systems and from the existing axle weighing scales was measured continuously over a period of several months and evaluated as a reference system.

The evaluation of the vehicle tests showed that the Bridge WIM systems can fulfil the requirements concerning the accuracy of measurements in axle load measuring sites in terms of gross vehicle weight. Some restrictions were observed for other parameters, such as axle loads. The long-term comparison between a Bridge WIM system and an axle load measuring site illustrated in the picture, during which roughly 190,000 vehicles were weighed, shows an overall positive correlation in determining the gross weight of vehicles.

Conclusion and outlook

BASt's pilot project was able to show that the mobile use of Bridge WIM systems is possible at suitable bridges in the German roads network. The quality of the measurements of heavy goods transport vehicles was rated as good in the pilot project, particularly in terms of gross weights. The 2 systems tested showed differing restrictions for the other parameters. The systems ran stably without re-calibration (test vehicles roll-overs) throughout the test period of 6 months. The calibration should be scheduled as closely in time to the measuring period as possible to minimise the influence of temperature on the accuracy of the measurements.

Due to the positive results overall, a follow-up project is currently being prepared to develop a concept for a combined survey of axle loads (stationary axle load scales and temporary Bridge WIM systems). Differentiated surveys will be conducted to serve as examples at various sections where axle load monitoring sites are already in place and there are suitable bridges. The concept is intended to define the volume of additional measurements necessary and assess whether dividing the motorway network into defined sections, as is done, for example, for the traffic census, can also be an option in surveying axle loads, or whether a different type of division would be more reasonable. Furthermore, it is also expected to gain insights into how to use Bridge WIM systems in the second level network.

In the future, a surveying method would thus be available for a spatially differentiated database that would be expandable to other road categories, to be used both for planning roads and bridges in Germany and managing their maintenance. ■

References

[1] KATHMANN, T., SCOTTI, C., KUCERA, U.: Monitoring and evaluation of Bridge-WIM pilot test Bridge-WIM Pilotversuch – Begleitung und Auswertung, Berichte der Bundesanstalt für Straßenwesen, Heft V 337, 2020

Technical developments to avoid road closures

Andreas Coumanns, traffic engineer, "Highway Design, Traffic Flow, Traffic Control" section and
Johannes Thomé, vehicle engineer, "Highway Equipment" section

At roadwork sites, it is important to differentiate between the areas that continue to be available for public road traffic and others that are temporarily unavailable because of the ongoing construction activities: traffic zones and work zones. Different laws apply to the 2 zones. On the basis of the German Road Traffic Regulations (StVO), the "Guidelines for safety at roadwork sites" (RSA) define how traffic needs to be routed, restricted or banned, and what traffic signs and traffic installations need to be put up to ensure the safety and orderly flow of traffic and to avert roadworks-related risks. Their scope thus refers to the "traffic side". They are addressed to the authorities which, pursuant to the StVO, are in charge of placing traffic signs and installations. These authorities are responsible for separating work zones from traffic zones by defining the positions of traffic signs or traffic installations – for example, edge of carriageway markings or delineator posts.

Occupational health and safety

Regulations for the work zone can be found in the Workplaces Ordinance (ArbStättV). It stipulates what the employer needs to take into account with regard to employees' health and safety when setting up and operating workplaces. Besides employers, the ArbStättV is addressed to contracting authorities via the Construction Site Ordinance – in the case of road construction measures, this generally refers to the authority responsible for road construction and maintenance. The "Technical Rules for Workplaces, Volume Roadwork Sites" (ASR A5.2) are the basis for specifications in the ArbStättV, particularly to minimise the risks for employees at roadwork sites when working in spaces bordering the traffic zones. When ASR A5.2 was introduced, conflicts ensued with respect to the spaces required by each zone.

Tool kit

BASt developed the "tool kit for the interaction between RSA and ASR A5.2 in planning roadwork sites bordering road traffic" to explain the contents of the 2 regulations referred to in the title. The tool kit also suggests solutions for critical borderline cases that may arise with which to ensure maximum safety for both employees and road users. The road cross-section in question needs to be divided in an appropriate manner to take adequate account of both the needs of traffic – maintaining minimum availability and ensuring road safety – as well as of occupational health and safety – enough room for movement and protective measures.

The tool kit deliberately focuses on the planning phase. For example, a key item is that a signposting plan must have already been submitted to the contracting authority before the tendering process starts so that conflicts can be detected at an early stage. Traffic will initially be routed according to the traffic requirements that may exist for each specific case. On this basis, technical aids, processes and work flows need to be selected to make it possible to do the work necessary in the zone closed to traffic. Deploying employees in workplaces bordering traffic is of central significance in this context, as it requires complying with safety distances pursuant to ASR A5.2. This is not always possible, which is why a solution is aimed for already in the planning phase by designing

- work and manufacturing processes,
- work flow and working hours as well as
- how they interact.

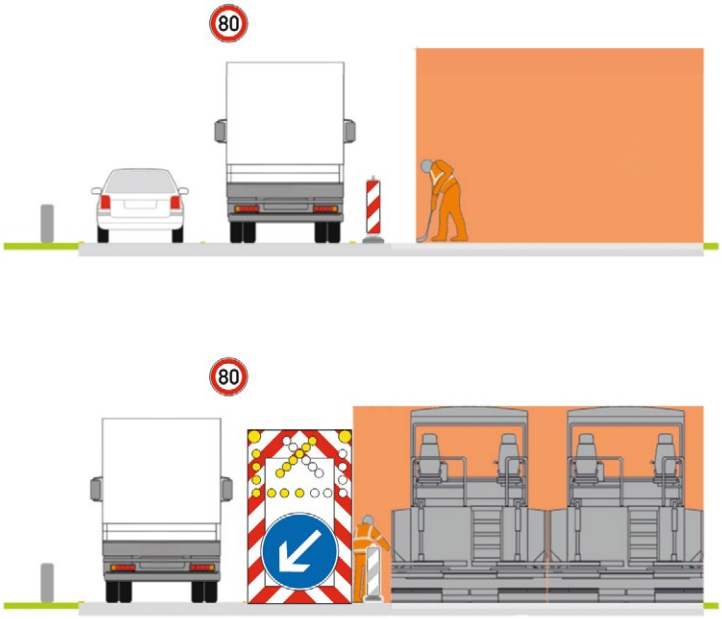
Besides further aspects, the Occupational Health and Safety Act specifically refers to risks for employees that arise from the 3 points mentioned above. In this context, these provisions are primarily addressed to the employer. The employer is obliged to compile a risk assessment and define appropriate measures. Narrow roads particularly make finding a solution more difficult.

The tool kit offers a modular system. It defines and combines traffic routing types and modular solutions. Depending on the type of roadworks and the expected traffic volume, these systems aim to make the best possible use of the widths available to render full closures unnecessary. The aim is to work with closing parts of the road – for example, individual lanes – and only fully close the road for traffic in emergencies. The magnitude and duration of the closure should always be reduced to the minimum necessary. On the one hand, the tool kit describes (temporary) traffic routing types with which to maintain traffic while doing the work. On the other hand, it outlines

how to avoid a temporal overlap of heavy traffic and space-intensive roadworks. Besides these purely organisational measures, the tool kit also calls for the development of new technical solutions to resolve space-related conflicts.

One of these approaches is to avoid work in areas bordering traffic – i.e., on the "edge" of the work zone that faces the traffic zone. If technical progress makes it possible to avoid deploying employees in these spots, work can still be done next to traffic even at narrow road widths. Employees will then perform their work from a safe distance by using machine-aided methods. The space saved can then be assigned to either the traffic or the work zone, depending on what is required. Additionally, to avoid disrupting traffic unnecessarily, compliance with safety distances is intended to be generally restricted to the point in time and duration of the actual work and to the areas where work is done. The picture shows how a targeted temporary closure of a temporary lane during times compatible with the flow of traffic can create spaces for employees as needed during the construction phases that involve activities under confined space conditions. Such traffic restrictions may be avoidable entirely in the future by means of technical solutions making it unnecessary for employees to be between the construction machine and traffic.

The tool kit is a means that can support finding a solution in the conflicting priorities of occupational health and safety and road safety, and it should be used already in the planning phase. It also offers a good overview of requirements from the different legal areas which need to be taken into account in this context, thereby contributing to mutual understanding and solution-oriented collaboration on the part of the individual stakeholders. Furthermore, this will clarify who needs to be included doing which task in which of the planning phases.



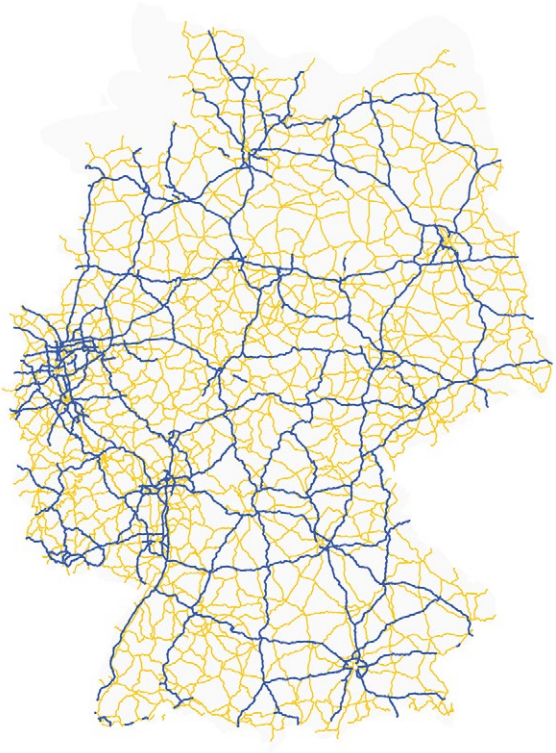
Excerpt showing traffic routing type "Vf24 80 1320 delineator post" top: Option 1 – below: Option 2

The call for such a document for critical borderline cases shows that it will be necessary to continuously improve the processes at roadwork sites and to find technical solutions with which the space requirements of the work zone can be reduced and the safety of everyone involved increased. For the time being, the tool kit, with its mainly organisational measures, describes what is currently possible. In the future, supplementary measures can, however, also be added and, in particular, technical developments, specifically in the field of construction machines, can be taken into account. ■

How is a toll table actually developed?

Marco Schmidt, spatial and environmental planner, and Ulrich Löhe, geographer, “Traffic Statistics” section

Pursuant to the German Federal Trunk Road Toll Act, there is an obligation to pay tolls for using federal motorways and federal highways with heavy goods transport vehicles with a minimum gross weight of 7.5 tonnes: the truck toll. Commissioned by the Federal Ministry of Transport and Digital Infrastructure (BMVI), BASt makes the tolled trunk road network available at regular intervals to the toll operator Toll Collect, using the Federal Information System Road (BISStra) as a basis to collect the truck toll. In accordance with the conventions of the Road Network Database Instructions (ASB) applicable for Germany’s road sector, the data is transmitted every 2 months: sector, from network node, to network node.



Tolled motorways (blue) and federal highways (yellow), last update: January 2021 (source: BISStra, processed with QGIS)

The size of the toll network

At the beginning of 2021, the tolled motorway network consists of more than 3,000 sections with a total length of roughly 13,200 kilometres. There are also the tolled federal highways with about 20,000 sections and a length of about 38,000 kilometres. Added together, this amounts to more than 50,000 kilometres of tolled roads. It is important to take into account that just a few motorway sections near international borders on the A5 (D - CH and D - FRA) and the A6 (D - FRA) are toll-free. According to the Federal Ministry of Transport and Digital Infrastructure, the revenues from the truck toll were about 7.3 billion euros in 2019.

As a next step in the process, BASt’s toll network is transferred into a toll table which includes all toll nodes and toll sections, in coordination with Toll Collect and the Federal Office for Goods Transport (BAG). In a concluding step, this table is published by BAG, including the toll rates relevant for billing.

BISStra

BASt continuously maintains the federal trunk road network in the BISStra system on the basis of the Länder’s quarterly supply of data. The data from the Länder illustrates the status of the road network at each specific date of reporting. As Toll Collect needs, however, a 2-month overview of the toll network, toll-relevant changes need to be anticipated at each data delivery – for example, changes due to roads opening to traffic, roads being dedicated as public roads or being downgraded in BISStra. An intensive exchange of information is needed with the Länder authorities responsible for road construction and traffic law-related decisions as well as with the department responsible for road-related legislation at the Federal Ministry of Transport and Digital Infrastructure. Official journals where dedication orders are announced are another important source of data.

Toll table working group

The competent committee for this topic is the “toll table working group”, chaired by the BAG. All toll-relevant issues are discussed in this committee. The web-based toll base data portal (MaBaDa), developed by Toll Collect, is an essential tool for the coordination process across authorities. Toll-relevant measures are individually entered, discussed and defined there. At the beginning of the year 2021 there will be some changes and new challenges in how the toll network is processed in BISStra: for example, the interval of data delivery to Toll Collect will be shortened from 2 to 1.5 months for reasons of international harmonisation. The Autobahn GmbH will also need to be included in updating the tolled federal trunk roads, as they will be responsible in the future for planning, building and operating motorways. ■

Jointly analysing and protecting soil and water in the road environment

Silke Sielaff, laboratory chemist, deputy head of the "Chemistry, Environmental Protection, Laboratory Services" section, Dr Birgit Kocher, geo-ecologist, "Environmental Protection" section and Tanja Marks, environmental engineer, "Earthworks, Mineral Aggregates" section

There is no shortage of questions in the field of environmental protection. Usually, each discipline only considers its own field – but what is important for soil protection may be counter-productive in water protection. BASt recognised the sign of the times early on. Already in 2002, an interdisciplinary working group was founded for soil and water protection – the "AG BoWaSch".

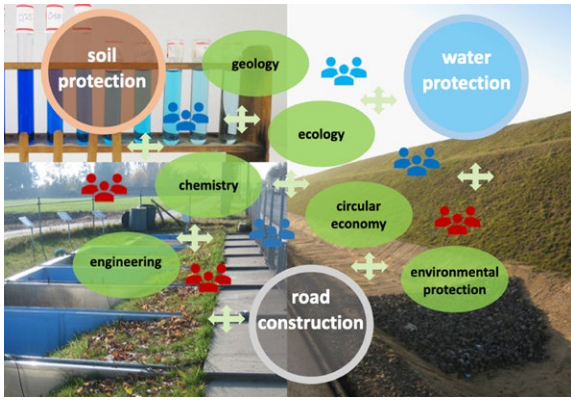
Its members' differing qualifications and work focus enable working on a broad spectrum of questions in a competent and coordinated manner and above all, not forgetting the practical requirements in road construction and road traffic. The questions range from "How many pollutants does road traffic discharge into soil and water bodies?" and "How can road construction material be reused in an environmentally compatible way?" to "Where do tyre abrasions go?"

Everything is connected. This is why it is important to understand and consider the mutual dependencies in nature associated with planning, building and operating roads. Not only road construction and road operation benefits from the competences bundled in the working group. The AG BoWaSch also supports the drafting of new regulations and laws in the fields of soil, water and waste. The disciplines represented – environmental engineering, geology, geo-ecology, civil engineering and a number of fields in the classical natural sciences – all use different strategies and processes. An exchange promotes creative approaches to finding solutions. This produces extensive ideas for research, expert reports and publications, which find their way into specialist literature and numerous sets of regulations and legislation.

Current main areas of work

Taking part in developing the overarching national legal framework called "Mantelverordnung", which consists of several chapters, is a characteristic example of the work of the AG BoWaSch. Nowadays, engineering structures are subject to life cycle assessments. Soil and water protection, ecology but also economics play an important role in road construction. The Mantelverordnung aims to specify for the first time nationally uniform, legally binding requirements in an ordinance on the production and installation of mineral secondary construction materials. It also contains new, adapted regulations in the fields of landfills and commercial waste, as well as a complete revision of the Federal Soil Protection and Contaminated Sites Ordinance.

The complex correlations between the requirements for soil and water protection and the impacts on the construction practice and transport structures of the regulations planned in the Mantelverodnung were intensively discussed in the scope of the working group and then addressed in research activities on a broad range of topics. The findings will also be used for further scientific deliberations and to implement the requirements in technical regulations on road construction. The different backgrounds of its members enable also unusual perspectives "outside the box".



At a time when resource efficiency and recycling are important factors, and environmental protection needs to be taken into account in its entirety, practicable regulations and compromises need to be presented in the Mantelverordnung. The AG BoWaSch has contributed its share to the different conferences and coordination processes by submitting opinions and participating in person, and is collaborating in the effort of translating topics such as soil and water protection into practice, including circular economy-related environmental issues. ■

Safe rural roads with the help of suitable safety barriers

Janine Kübler, civil engineer, head of section, and Susanne Schmitz, civil engineer, “Highway Equipment“ section

The characteristics of rural roads show many special features: besides sometimes having very narrow cross-sections, small radii and frequent junctions, there are often obstacles – for example, trees – very close to the edge of the road. This array of local constraints makes it harder to find a solution for suitable measures to increase road safety in practice. Annual accident statistics show there are many accidents that result in the severest consequences, in particular on rural roads. One third of the fatal accidents in 2019 were recorded on rural roads. Accidents involving crashing into a tree or into some other obstacle next to the road are often responsible for these deaths. One notable safety potential to be tapped into to prevent these accidents is the use of road restraint systems – in general, steel guard rails with corresponding front and end constructions.

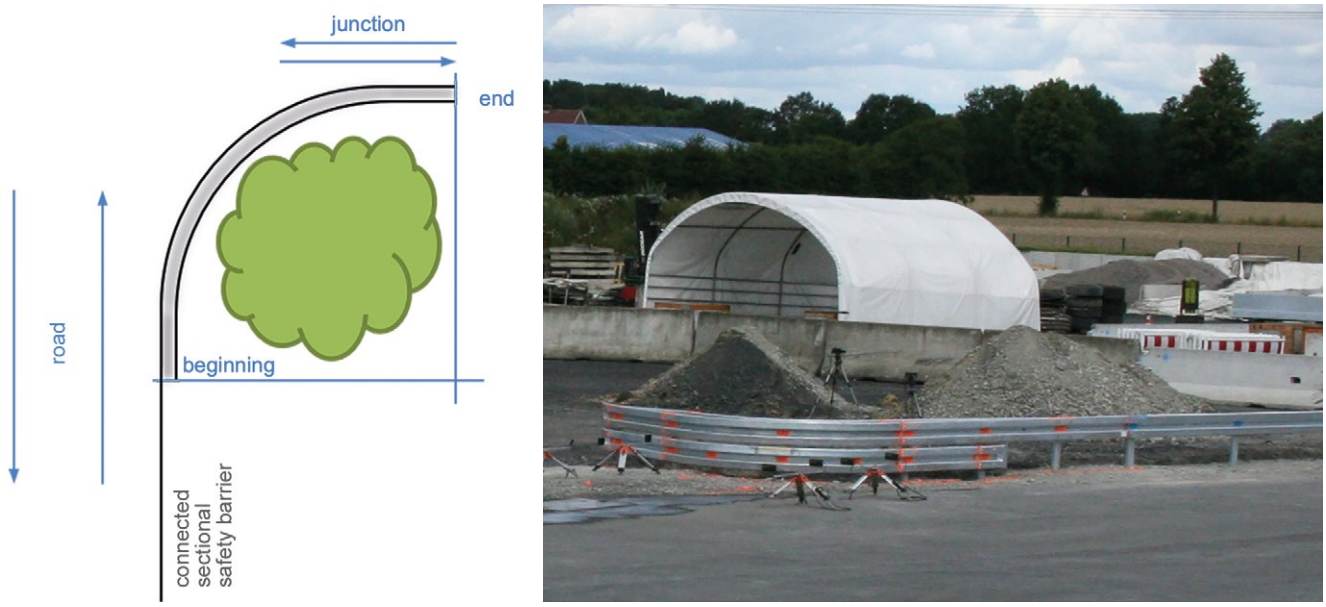
The Federal Ministry of Transport and Digital Infrastructure (BMVI) initiated a retrofitting programme for safety barriers on rural roads in 2017 to improve this situation and reduce the number of deaths and severity of injuries for persons involved in accidents. Since then, potential hazards on rural roads have been more intensely reviewed; they are then eliminated using appropriate solutions. Besides various other traffic-related and structural measures, retrofitting the safety barriers in front of obstacles near the edge of roads is an option to improve road safety. But the accident statistics also show that the safety barriers themselves can be a potential hazard, for example, for riders of two-wheeled vehicles. This is particularly true if they were not installed in a compliant or appropriate manner. For this reason, a comprehensive review of the possibilities to improve road safety should always be conducted before generally equipping road sections with safety barriers.

BASt is working on tasks to promote further developing improved safety barriers and implementing topical findings in the field.

Implementing solutions to improve road safety

In collaboration with the Federal Government-Länder working committee on safety barriers, BASt has developed “Guidelines for special solutions to protect trees and objects at rural roads” to prevent incorrectly using safety barriers under the highly multi-faceted and often narrow conditions found on rural roads, and to support Länder road construction authorities in implementing the retrofitting programme. These guidelines were updated in

Rural road before (left) and after (right) being secured with safety barriers



Sketch of a curved safety barrier for junctions (left) and prototype on a test field (right)

2020 to help practical implementation by sharing new insights and developments. The aim is to support planning and implementing authorities in their decision-making process to select the best possible system and implement it. For this purpose, the guidelines list typical constraints and aspects that may be relevant in selecting appropriate safeguarding measures at danger spots in the form of suitable safety barriers. Another aim of the guidelines is to promote uniform solutions for similar conditions and to prevent deficient applications. An extensive collection of examples shows how the theoretical regulatory requirements can be practically implemented.

A corresponding study to test the effectiveness of retrofitting safety barriers on accident situations on rural roads has already been initiated.

Promoting the development of improved constructions

The intensified process of the past 3 years of retrofitting safety barriers at rural roads has shown that commercially available safety barriers are not yet sufficient in providing optimum safety for all the conditions and constraints on rural roads. Cases in point are obstacles and trees in the immediate junction area at access roads or certain individual obstacles which, pursuant to current legislation, need to be secured with a safety barrier of a minimum of about 60 metres length. By defining the requirements for performance- and construction-related properties of curved safety barriers at junction areas and short safety barriers with integrated front and end constructions, it was possible to create uniform overall conditions to develop new safe constructions at these particular places. This was done together with representatives of the Federal Government-Länder working committee on safety barriers and in coordination with the industry.

Initial new developments of such constructions have already been tested by the industry in the crash tests required. BASt will have direct access to the outcomes of these tests and can gain important insights about how to use the new constructions for other use cases in the future and what their limitations are so as to use this knowledge in updating corresponding regulations. ■

Bridges and Structural Technology

Using digital technologies for engineering structures

Resilient road tunnels using the RITUN guidelines

Is innovative replacement construction of concrete bridges sustainable?

Collaborative research on intelligent bridges – OSIMAB and BrAssMan

Narrow expansion joints made of asphalt in practice

Innovations for tunnel safety and security

Verbundprojekt RITUN

Leitfaden zur Verbesserung der Resilienz von Straßentunneln

RITUN
RESILIENTE TUNNEL

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

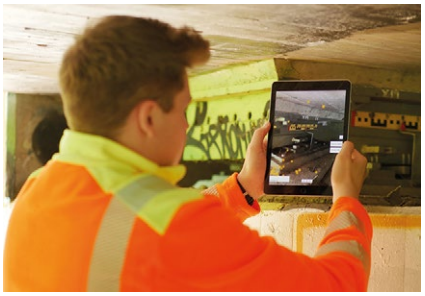
Using digital technologies for engineering structures

Sonja Neumann, machine engineer, “Maintenance of Engineering Structures“ section

Federal trunk roads are currently facing challenges: due to continuously rising traffic volumes, the road infrastructure is exposed to increasing loads. Additionally, the ageing of the engineering structures and the effects of climate change have made it necessary to implement a significant number of maintenance measures. Structural inspectors are responsible for monitoring and inspecting the engineering structures. They detect and assess defects and damages at regular intervals to ensure the structural stability, durability and road safety of engineering structures. To do so, they need to include a multitude of information about the structure and its damages, for example, from previous inspections. This requires a lot of financial resources and effort. Digital technologies with a potential to collect and retain data in a uniform, localised and clear manner offer support.

Structural inspections using digital technologies

This is the context of BASt’s ongoing research project “Structural inspections using 3D models and augmented/virtual reality”. The project analyses and demonstrates to what extent digital solutions can support the process of inspecting engineering structures. The basis is a 3D model of the structure, which is the result of applying the Building Information Modeling (BIM) method to combine relevant structural information from the existing portfolio, the manual inspection process and the monitoring of the structure [1]. Combining them with elements of virtual and augmented reality (VR and AR) enables those involved in the process to use these pieces of information digitally. When inspecting an engineering structure, the inspectors can be equipped with a tablet or AR-enabled goggles [1]. Areas to be inspected can be immediately identified and compared to documents from previous inspections and associated photo documentation. This is made possible by AR technology which extends the reality the inspector sees by superimposing digital information. The information can then be directly integrated into the decision making, and the findings of the inspection can be added to the 3D model with the help of the system. Furthermore, VR elements make it possible to analyse the 3D model virtually at the office and look at interlinked findings in the scope of preparing or following up on inspections. In addition, using remote communication, the inspection on site can be connected to the office and to experts who are not on site. A prototype that is being developed at a bridge near Nuremberg in the scope of the project is to be used to illustrate the research findings.



Structural engineer with a tablet (picture: HHVISION)

Structural engineer wearing AR goggles (picture: HHVISION)

Potential for the future

These developments may potentially make a digital tool available which will contribute to optimum quality assurance and informed decisions in structural inspections. Additionally, the consistent and semantic collection, retention and illustration of data during structural inspections is an important precondition for further developments in the process of digital transformation. This includes, for example, forecasting damages with the help of artificial intelligence and using a digital twin of the engineering structure to initiate maintenance measures at an early stage. ■

References

[1] LIST Digital, HHVision, Fraunhofer FIT, Bochum University of Applied Science: Structural inspections using 3D models and augmented/virtual reality Bauwerksprüfung mittels 3D-Bauwerksmodellen und erweiterter/virtueller Realität, Zwischenbericht zum Forschungsprojekt 15.0666 im Auftrag der BASt, 2020, in Bearbeitung

Resilient road tunnels using the RITUN guidelines

Ulrich Bergerhausen, civil engineer, and Dr Selcuk Nisancioglu, civil engineer,
"Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section

The Resilient Road Tunnels project (RITUN), funded by the Federal Ministry of Education and Research (BMBF) in the scope of its initiative for innovative end-users "(Users-Innovative): Research for Civil Security", analysed possibilities to improve the resilience of tunnels to contribute in a structured way to maintaining their safety and availability. The project lasted for 2 years and was supported by the project executing organisation VDI Technologiezentrum GmbH. With BASt as the lead agency, the findings were compiled in close cooperation with ILF Beratende Ingenieure GmbH and the Central Office for Engineering Structures and Georisks at the Bavarian Building Authority.

The significance of resilience for road tunnels

The term resilience originates from the Latin verb resilire (leap back, rebound) and describes the physical ability of an object to rebound to its original shape after changing its shape. The term as well as the concept has become ubiquitous in the meantime and is used by various disciplines, for example, to describe ecosystems, in psychology, and nowadays also in engineering. Within the project, resilience was defined as the ability of road tunnels to prepare for disruptive incidents, to factor them in, to avert them, to cope with the consequences, to recover from them as quickly as possible and to adapt to them with increasing success [1]. The researchers identified measures with which to improve the robustness of tunnels vis-a-vis external influences – threats such as fire or extreme rainfall – and also to enable an accelerated return to full availability after such an incident occurs. The possibility to temporarily operate tunnels after such an incident while maintaining the safety levels required and thus to ensure partial availability was also studied. The "minimum operating conditions" developed for this purpose are a supplementary resilience measure for the phase after the occurrence of such an incident.

Outcomes achieved

The findings of the project were summarised in an application-oriented guidance document. It contains all the information and tools necessary for practical application to systematically improve the resilience of road tunnels. This includes an introduction to the concept of resilience for road tunnels, as well as information on how resilience measures work. Awareness of the potential threats is a precondition to determine and implement these measures. On the basis of an approach covering all threats, all relevant threats were assigned to the locations they may affect – tunnels, tunnel equipment, network elements, central systems such as tunnel control centres, operating buildings, energy supply. Damage scenarios were developed from this and made available as a threat-damage matrix for individual identification. Fact sheets that were additionally developed provided detailed information on the specific resilience measures. The compilation of "minimum operation conditions" makes it possible to safely continue to operate a tunnel after an incident has occurred by implementing compensatory measures.

The guidance document concludes with remarks on resilience that address aspects that go beyond the measures contained in the guidance document, such as establishing a resilience culture in highway authorities, encouraging those involved to explore these subjects further. All the findings are based on risk-analysis studies, traffic simulations and the cooperation with experts from research and practice. Before the findings were published, they were tested in practice with end users at a tunnel and an enclosure system. ■

References

[1] THOMA, K. (publisher): Resilience by design, Strategy for future technology topics Resilience-by-Design, Strategie für die technologischen Zukunftsthemen, acatech STUDIE, April 2014

www.bast.de/ritun-guidelines

Is innovative replacement construction of concrete bridges sustainable?

Dieter von Weschpfennig, civil engineer, “Concrete Structures“ section

Replacing road bridges is gaining in significance due to the ageing fabric of the structures, continuously increasing heavy goods vehicle traffic as well as deficits present in existing road bridges. Replacement structures within the existing road network will, however, cause disruptions to the traffic flow during the construction phase when the structures need to be fully or partially taken out of operation for a temporary period of time. Particularly for busy road stretches, methods need to be found with which to reduce both the necessary traffic disruptions and the construction time to a minimum, thus ensuring the structure’s availability.

Analytical method

On the basis of a depiction of the current approach in implementing replacement structures, BASt compiled innovative construction methods for substructures as well as superstructures at federal trunk roads using concrete or a combination of steel and concrete. Besides innovative construction methods, innovative construction procedures were also analysed with which it would be possible to build replacement structures laterally. The innovative approaches were compared to the current processes to demonstrate the reductions in construction time and traffic disruptions. Sustainability criteria already in place for bridge constructions were used as a basis to take into account and evaluate specific aspects of ecology and economics for the innovative construction methods and procedures developed.

Results

In the network of federal trunk roads, four load-carrying systems can be found most frequently in bridge structures:

- one-field systems with total lengths between 10 and 30 metres
- frame constructions with up to 30 metres of span length
- 2-field systems with total lengths of up to 70 metres
- 3-field systems with total lengths of up to 100 metres

Construction blueprints were developed for these on the basis of the innovative construction methods and procedures described above. The subsequent comparison with traditional processes for replacement structures showed a construction time reduction of up to 66 per cent. In analogy, there are also similarly significant reductions in disruptions to the traffic flow. Some aspects of the construction blueprints mentioned above need to be included in regulations for bridge construction; before this can happen, it is important to gain experience in practically implementing them. For them to be successfully implemented, the contracting authorities of the Länder and of the Federal Government for the federal motorways, planners and the construction industry need to undertake particular efforts to maintain not only the structural stability but also the durability and road safety of the bridges at the current levels.

The significant reduction in traffic disruptions and construction time offers high potential to reduce CO_2 emissions and macro-economic losses. Replacement structures for bridges can thus be built in a significantly more sustainable manner. ■

References

WIRKER, A., DONNER, R.: Innovative and sustainable replacement construction of concrete bridges Nachhaltiger und innovativer Ersatzneubau von Betonbrücken, Berichte der Bundesanstalt für Straßenwesen, Heft B 155, 2020

Overpass structure in modular design

Collaborative research on intelligent bridges – OSIMAB and BrAssMan

Andreas Socher, “Concrete Structures“ section

In the scope of the mFund (modernity fund) research initiative of the Federal Ministry of Transport and Digital Infrastructure (BMVI), 2 collaborative projects have been funded, in which BASt is participating. The projects basically deal with how to optimise and extend the prevailing maintenance management of road bridges.

OSIMAB – online safety management system for bridges

In the OSIMAB project, an integrated concept is being developed to monitor and assess the condition of existing road bridges. This is intended to lay the foundation for a predictive lifecycle management system. The project contains a modular-designed safety management and operates a real-life laboratory at the Sachsengraben viaduct on the A45 motorway, providing extensive measurement data with its 145 active sensors. This data is used to calibrate system models which, in combination with a smart data analysis, capture the condition of the structure and continuously show its development. The reliability analysis conducted based on this data then provides a safety-relevant evaluation to assess the risks thus identified, and to recommend actions.

BrAssMan – bridge asset management for road bridges

The follow-up project BrAssMan focuses on a data analysis (projection models, permanent measuring systems, key parameters) across the entire portfolio of bridges to create a basis for intelligent asset management using comparable parameters. Qualitative assessments are expected to be the result of an intensified overall analysis of the existing bridges at federal trunk roads to make the condition scores more objective. Representative bridges in the portfolio will be categorised, analysed and in specific cases equipped with measuring technology – 3 clusters with 3 to 5 bridge structures each. It is intended to derive standardised projection models and partially standardised (reduced) measuring concepts (global, local) that offer cost-saving solutions for optimised ways to survey and assess the condition of bridge structures and to enable predictive intelligent asset management.

The OSIMAB project was concluded at the end of 2020, the BrAssMan project is expected to conclude at the end of 2022. ■

Viaduct Sachsengraben A45

Narrow expansion joints made of asphalt in practice

Michael Staeck, corrosion protection technician, “Steel Structures, Corrosion Protection, Bridge Equipment“ section

Joints need to be placed between engineering structures and adjacent road surfaces to absorb the movements occurring in this area. These areas are usually covered by grouted joints at bridges with free expansion lengths of up to 12.5 metres – in practice, damages repeatedly occur in these spots. According to the regulations applicable, there is currently only the possibility to install expansion joints made of asphalt to prevent such damages. Their dimensions are, however, designed for bridges with free expansion lengths of up to 50 metres, and thus oversized for this use case. The plug expansion joints described below can be a useful supplementary tool.

The structure of the plug expansion joints is largely similar to that of expansion joints made of asphalt, but they are much narrower in width, usually between 7 and 30 centimetres. The joints are installed in the asphalt wearing course only, so the sealing layer in place cannot be damaged. Since 2008, plug expansion joints have primarily been used in the Baden-Württemberg region.

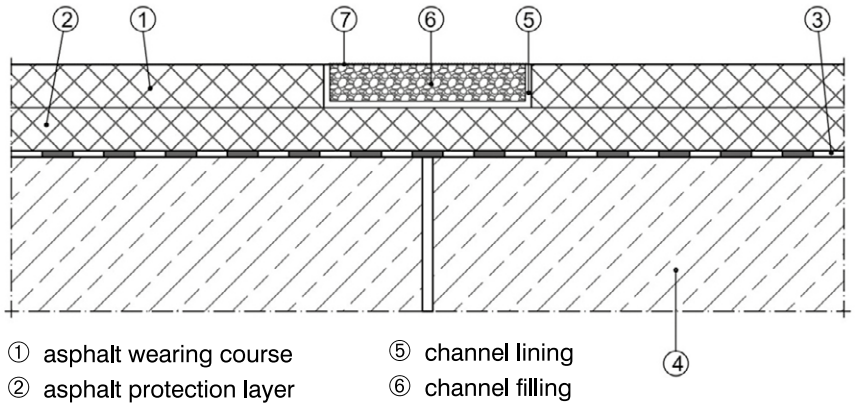
Collection of case studies

Data from 56 bridge structures with a total of 146 plug expansion joints and several years of traffic loads was evaluated in the scope of collecting case studies. About 15 per cent of the plug expansion joints examined showed damages in the form of debonding at the channel edges, but such debonding was limited to localised spots. Most of the plug expansion joints were, in contrast, free of damages even after up to 9 years under traffic. One notable feature was that most of the damages were detected at plug expansion joints at roundabouts. In these cases, the joints are usually at the transition of the asphalt pavement of the open-air section to the concrete pavement of the roundabout section. About 27 per cent of the 75 plug expansion joints examined showed delaminations at the edges. For the most part, these delaminations were found between the plug expansion joint and the concrete pavement. The concrete surface appears to be a particularly critical contact surface for the plug expansion joints’ bonding agent. Additional pressure arises from the impact of motor vehicles braking and accelerating. Furthermore, leaked amounts of binders were found in the wheel paths at about 19 per cent of the plug expansion joints at roundabouts. So far, these amounts do not, however, impair the function of the joints.

Positive experiences on bridges – no rutting

More positive experiences were shown when these joints replaced grouted joints between bridge structures and road surfaces as well as along bridge caps. 97 per cent of the 69 plug expansion points on bridges showed no edge delaminations or leaking binders. In these cases, no deformed plug expansion joints were found in the wheel paths, which are sometimes a problem in expansion joints made of asphalt.

Plug expansion joints are thus a promising alternative as a replacement for grouted joints which have reached the limits of their performance capability. When used in roundabout scenarios with a concrete pavement, measures should be defined to improve the joints’ bonding with the concrete layer; particular care should be applied during their installation. ■



① asphalt wearing course
② asphalt protection layer
③ sealing layer
④ bridge deck
⑤ channel lining
⑥ channel filling
⑦ surface finish

Innovations for tunnel safety and security

Christof Sistenich, mining engineer, deputy head of section, and Felix Wawrzyniak, physics laboratory technician, "Tunnel and Foundation Engineering, Tunnel Operation, Civil Security" section

Optimising safety technology by using a model tunnel

A holistic analysis is required to assess a tunnel's safety and security, comprising the system that is formed by the tunnel users, infrastructure, tunnel operation and vehicles and the interplay of a wide range of individual components. Tunnel ventilation and its design is a vital equipment detail when tunnel users need to save themselves and be successfully evacuated in the case of a fire. The aim of using the model tunnel is to create experiment-based reliable assessments, particularly in situations when there is a complex tunnel ventilation system, as well as to make input data available for numerical methods.

The model tunnel

Since 2016, BASt has had a model tunnel at its disposal as a tool to recreate even more complex tunnel geometries at a 1:18 scale and to analyse them as regards ventilation technology issues.

The model tunnel in its modular design currently offers the possibility to recreate tunnels of a length of up to 790 metres. The horizontal and vertical alignment and cross-section, longitudinal and transverse gradient, ventilation specifications, special geometrical features and other operational installations can all be defined.

Method

Particle image velocimetry is available in the model tunnel as an innovative measuring procedure. In this procedure, powerful lasers illuminate particles which were released into the tunnel earlier, and their position is determined using highly sensitive cameras. This enables high-definition, two-dimensional and three-dimensional depictions of the flow distribution in the tunnel's cross-section. Helium is injected into the tunnel to create the upward lift resulting from higher temperatures in the event of a real fire.

Transferring the model tunnel into a numerical model at the same time is intended to be used for purposes such as further developing existing smoke propagation models and making available empirically-determined initial and boundary conditions for numerical calculation models.

Current status

It only makes sense to conduct experimental studies at a small-scale model tunnel if there is a similarity between the reduced-size model and the actual size in terms of flow mechanics. A set of similarity conditions derived from theoretical analyses has been successfully validated for fires when large-scale fire tests were recreated in the model tunnel; results of the real-life scenario and the model scenario were highly consistent. The results of an innovative measuring system capturing the flow conditions of a real-scale tunnel cross-section, which was developed at the same time as the model tunnel, are used to validate the similarity conditions.

Simulation of large-scale fire tests in the model tunnel

Future

A successful outcome of the validation is a first step in the practical applicability of the model tunnel to both conduct flow-related optimisation studies and use the findings in numerical models. Future research will continue to focus on model-type studies of flow distributions in a tunnel's cross-section that are induced by moving traffic but cannot be captured in large-scale scenarios, as well as on variably placing and designing ventilation systems for subsequent flow optimisations. ■


VÖGELE


TRANSPORTE

Highway Construction

Transnational research collaboration

Occupational health and safety requires and promotes innovations

Cold recycling technology using foam bitumen

From laboratory to road – the new mobile PWS

3D radar to determine the layer thickness of bridge surfacing

Contactless skid resistance measurement

Transparent bitumen

Concrete Pavement 4.0

infra 4D future

Transnational research collaboration

Ursula Blume, geologist, and Bernard Gyergyay, MSc in Transport and Business Management,
“International Road Construction Research Tasks“ section

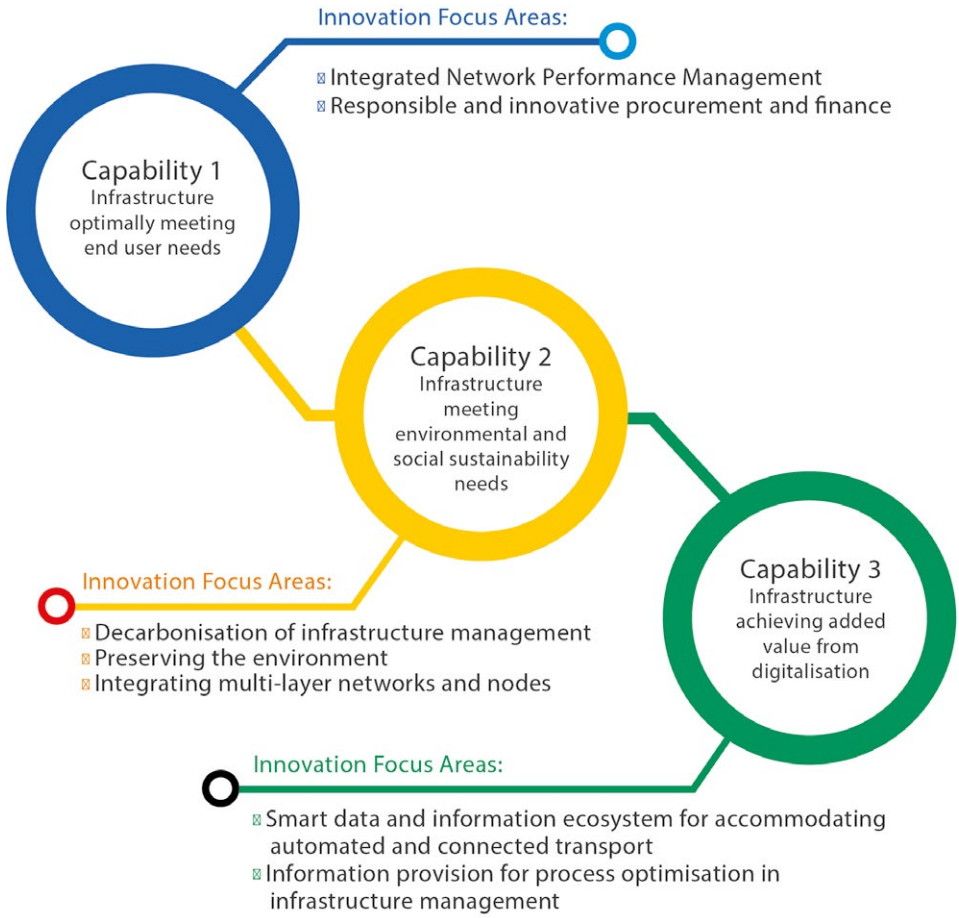
The need for innovations in the regional transport infrastructure sectors and the European transport infrastructure sector as a whole is multi-faceted and will grow continuously for the unforeseeable future due to ever increasing user requirements as well as environmental compatibility and digitalisation. At the same time, as the transport infrastructure has a relatively long service life and is thus seldomly replaced by the latest generation, the innovation processes are time- and cost-intensive and require versatile and continuous scientific support. This is increasingly impossible to accomplish solely at the national level.

Since the initial approaches of a transnational transport infrastructure research, developed with BASt’s decisive cooperation in the scope of the “ERA-NET Road” project (2008-2011), BASt has established a multi-layered, institutional knowledge base, enabling efficient and targeted participation in transnational research collaborations. BASt, together with its international cooperation partners, is continuously developing the necessary models further to respond with effective tools to the national need for innovations on joint research issues.

infra4Dfuture

In the EU project infra4Dfuture (i4Df), running from 2018 to 2020, 17 national transport infrastructure authorities jointly developed foundations for a new inter-modal cooperation model to shorten the paths to implementing innovations in the transport infrastructure.

There are 7 innovation focus areas (IFAs) in the cooperation model. An expert group, headed by transport infrastructure authorities, is evaluating the inter-modal need for innovations (with a focus on inland transport modes) in each of these focus



Overview of the 7 i4Df innovation focus areas (IFAs) and overarching capabilities

areas in a continuous process. This will be continuously reviewed and further developed in a structured dialogue with research providers and industrial partners. The large-scale European conferences on the topic of transport, taking place every 2 years, are the platform for a structured dialogue and exchange between the individual IFA groups – Transport Research Arena (TRA) and TEN-T Days. BASt was instrumental in developing the tools for the processes and is coordinating the IFA group on “Decarbonisation of infrastructure management”.

D-A-CH cooperation in transport infrastructure research

As a supplement to the cooperation models at the European level developed in the scope of i4Df, the European transport infrastructure sector is also characterised by European regional research collaborations, for example, NordFoU for the Nordic countries and the Baltic Road Association for the Baltic countries. Joint research at the multi-lateral and regional levels enables a targeted assessment of the need for innovations in a highly user-specific manner.

D-A-CH stands for the cooperation in the common economic region of the German-speaking regions of Germany, Austria and Switzerland (Confoederatio Helvetica in Latin). This cooperation aims to address research issues that are subject to comparable circumstances and underlying conditions in all 3 countries.

The common language and similar structures in transport infrastructure research enable effectively working on common research issues to streamline research, avoid duplications in research and to bundle human and financial resources.

The research findings from the D-A-CH cooperation show a high degree of implementation when implementing research findings in practice. The success can be explained by a common understanding of the country-specific circumstances and is supported by applying agile, tried and tested processes to bring about highly efficient programme management. Since the cooperation started in 2016, 17 projects have already been funded with an annual tendering budget of roughly 2 million euros. ■

Members of the D-A-CH steering advisory council
top from left: Andreas Blust, BMK, Austria; Thomas Greiner, ASFiNAG, Austria; Bernard Gyergyay, BASt, Germany, bottom: Raphael Kästli, ASTRA, Switzerland; Christian Pecharda, FFG, Austria; Peter Schmitz, BMVI, Germany

Occupational health and safety requires and promotes innovations

Franz Bommert, civil engineer, “Asphalt Pavements“ section

Reducing fumes and aerosols in asphalt road construction

An innovation becomes widely accepted when it offers competitive advantages in the market. Besides price, these advantages for a successful participation in the market can also consist of preserving resources or contributing to environmental protection and occupational health and safety.

Asphalt is a mixture of aggregates and bitumen that is produced at temperatures of 170 to 190 degrees Celsius and processed – i.e., installed – at slightly lower temperatures. Hot processing of asphalt generates fumes and aerosols, for which limit values have been defined by relevant committees of occupational health and safety to preclude health hazards for asphalt workers. Asphalt is produced in largely automated mixing facilities where the workers’ exposure at the asphalt mixing facility has been identified as low. Hot asphalt mixtures are mechanically processed at construction sites using asphalt pavers. This process is not automated for the most part, and at the same time it is labour-intensive and requires a lot of manpower. Several asphalt workers are needed at construction sites to control the delivery and handover of the mixture and to control and steer the asphalt paver and the compacting. Measurements of the asphalt workers’ exposure to fumes and aerosols from hot asphalt at the Werte construction site have shown values that by far exceed the occupational exposure limit values, which were drastically lowered in autumn 2019. Action needs to be taken in the field of road construction using asphalt, a tried and tested construction material.

The basic correlation between asphalt temperature and the amount of fumes and aerosols is known. By adding waxes, paraffins or zeolites, the production and processing temperatures of asphalt can be reduced by about 20 Kelvin, which in turn reduces the generation of fumes and aerosols. Over the past 20 years, low-temperature asphalt has been tested and integrated into road construction regulations with key participation of BASt. Unlike in neighbouring European countries and the United States of America, this construction method is still not applied in Germany in a universal, nationwide approach, because there are reservations as to the durability of the low-temperature asphalt. The newly revised occupational exposure limit values return attention to this innovation and, in addition, call for a continuation of the innovation process. The deployment of low-temperature asphalt alone does not suffice to comply with occupational health and safety requirements. Additional measures are necessary, such as additional aeration or closing off work zones.

BASt is substantially involved in shaping several research projects funded by the Federal Ministry of Transport and Digital Infrastructure to continue the innovation process: updating the experiences of applying low-temperature asphalt after a long utilisation period, quantifying other essential factors for the generation of fumes and aerosols, examining and testing other technical measures, for example, air extraction in the work zone around the asphalt pavers. A solution is being developed here with technical expertise from BASt in the innovation process concerning low-temperature asphalts which had stalled earlier on. ■

Cold recycling technology using foam bitumen

Dr Dirk Jansen, civil engineer, head of section and Mehdi Kalantari, civil engineer, „Design and Structure of Pavements“ section

The increasing demand for more sustainability in the transport infrastructure sector has had an impact on various branches of this large economic sector, which also includes road construction and road maintenance. Recycling technologies are one of the sustainable measures known to reduce adverse environmental effects. Asphalt recycling procedures can be divided into the two overarching categories of hot and cold procedures. The main difference between the 2 procedures is the envisaged temperature of the asphalt mixture. The aggregate materials are not heated in a cold recycling process (KRC) which is performed under ambient temperatures. This is why energy consumption and emissions are correspondingly lower than in hot recycling processes. There is also the added potential of using higher rates of recycled material than in hot recycling.

Compared to other countries, cold recycling is used only to a limited extent in Germany. Reservations concerning this construction method with regard to the durability of the layers of the pavement structure are the main reason for this. As a consequence, there is a lack of performance data and empirical values concerning the behaviour of such recycled material at the national level. Driven by environmental awareness, various laboratory and field tests were conducted over the last decade to assess and further develop this technology. The results of these tests in combination with positive international experiences have led to an increasing interest in this technology in Germany. A collaborative research project was defined together with Wirtgen GmbH in 2018 to systematically collect further data and experience.

It is necessary to reduce the viscosity of bitumen to be able to mix it with aggregates or asphalt granulate, either by suspending bitumen droplets in water (bitumen emulsion) or by foaming bitumen. A small amount of water is injected into the hot bitumen to foam it. The water droplets evaporate immediately and form a foam within the bitumen which, though it only lasts for a few seconds, holds for a sufficient amount of time to use it and mix it with cold and wet asphalt granulate. Besides bitumen, cement or hydrated lime can be added as the second binding material to increase the humidity resistance of the recycled material. The compacted mixture gains in strength and rigidity over time, mainly due to evaporating water and cement hydration.

A mixture containing 75 per cent of recycled asphalt was defined in the scope of the project. The cold-recycled surface was applied to 2 thirds of a 100-metre-long section of the duraBASt premises, while a reference road surface material was used for the remaining one third. The reference surface material was a standardised pavement of a low load category using hot asphalt in accordance with the guidelines for the standardisation of road surface structures (RStO 12). The cold-recycled section was designed in its dimension for the same load.

The load was applied using the MLS30 simulator, which simulates a real-life truck wheel load of 50 kilonewtons at a speed of 6,000 roll-overs per hour. The loads on the surfaces varied from week to week to enable comparable conditions to as great an extent as possible with respect to prevailing temperatures. This was accompanied by non-destructive tests, core extractions and sensor-based measurements. The cross-section of the road pavement was captured, among other parameters, to assess permanent deformations (rutting) under load conditions. Permanent deformation is the primary failure mode of cold-recycled road surfaces with low bitumen and cement contents, in particular, in case of thin asphalt pavements. Based on the measurements, the rutting showed a size of about 2 millimetres in both the cold-recycled section and on the reference section after one million roll-overs with a 10-tonne axle load. This is significantly lower than the point of failure at 10 millimetres. ■

From laboratory to road – the new mobile PWS

Gudrun Golkowski, civil engineer, deputy head of section, and Kirsten Kunz, civil engineer,
"Earthworks and Mineral Aggregates" section

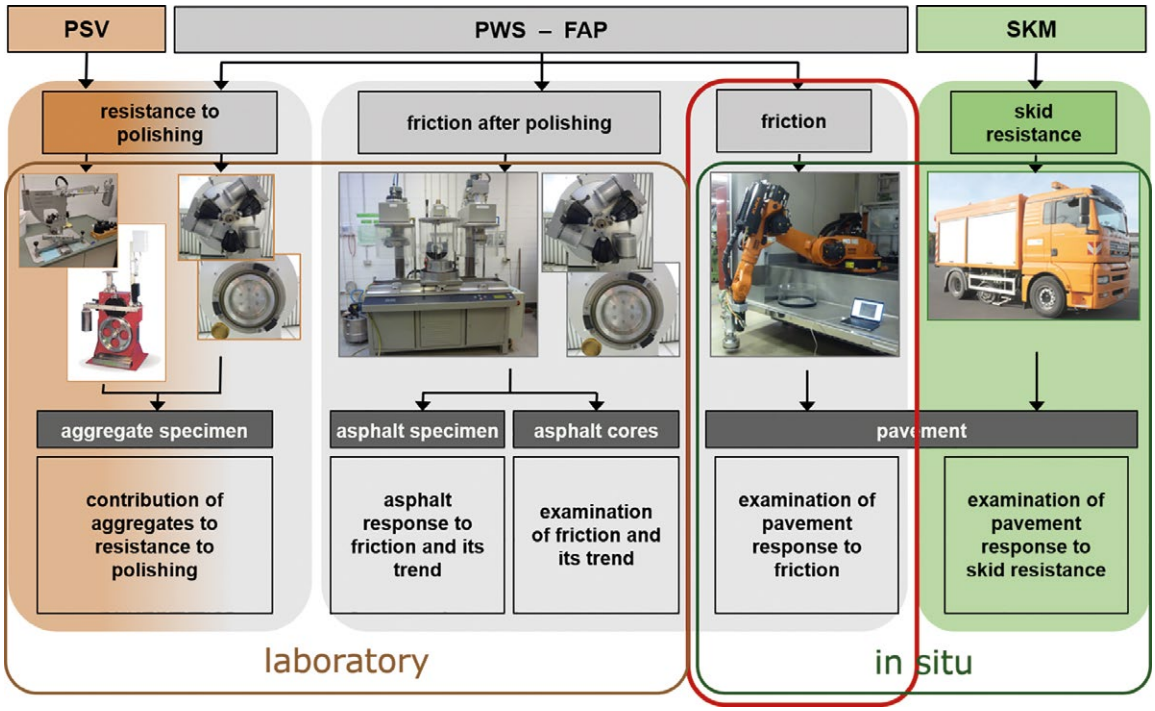
Skid resistance describes the level of frictional resistance and is an essential parameter for road safety as it determines the power transmission from the tyre to the road surface. Therefore, it is important to predict the skid resistance to be achieved after installation already at the development stage of material mixtures for the construction of road surfaces.

To date, this has been done by determining the Polish Stone Value (PSV) of the pure aggregate pursuant to DIN EN 1097-8. The procedure "Determining skid resistance after polishing according to Wehner/Schulze – Friction after Polishing (FAP) pursuant to DIN EN 12697-49" as a performance-oriented test procedure for asphalt and concrete mixtures is a more expedient method. This method makes it possible to measure the frictional resistance of laboratory test specimens and asphalt cores and project future skid resistance development.

It is necessary to focus the projections on the requirements already at the laboratory stage in order to assess what skid resistance newly developed mixtures of construction material will have in practice. With the new mobile testing equipment PWS, the Wehner/Schulze method can now also be used to measure the skid resistance on the road surface itself. These tests can thus validate the results of the laboratory measurements with respect to the skid resistance achieved in situ. It is intended to develop a new assessment procedure on this basis to determine skid resistance potential.

A look into the mobile PWS measuring system

To measure skid resistance on road surfaces in situ, the sensor head of the stationary PWS laboratory testing equipment was reconstructed and mounted onto an industrial robot that can independently target measuring points from the measuring vehicle and conduct the measurements. The sensor head needed to be adapted to the measuring conditions on the road. Water supply was implemented through the sensor head to have water available both for cleaning the area to be tested and as test water to determine the frictional resistance. Furthermore, a method had to be devised for positioning the sensor head parallel to the road surface for the measurements. An additional measuring probe was installed for this purpose. Prior to the measurements, the measuring probe defines a test area using 3 measuring points; the measuring head is then positioned correspondingly. A new measuring method was developed and applied to determine the friction coefficient, because in the laboratory PWS equipment the measuring sensor is located below the test area. In the mobile PWS, the friction coefficient is now determined with the help of a sensor when it comes



Robot in the measuring vehicle

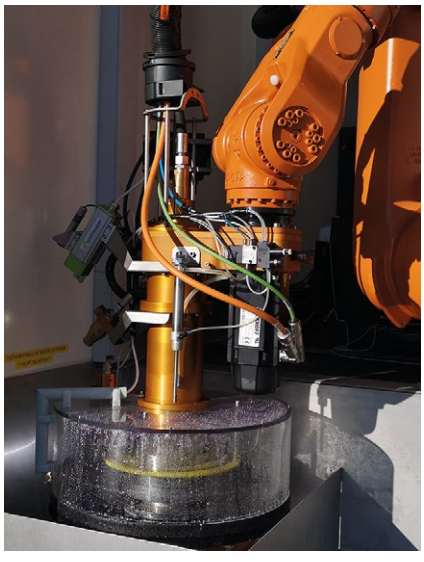
to measuring the angular velocity as the measuring head decelerates onto the test surface. Another built-in sensor eliminates outer impacting factors, such as the inclination of the measuring head.

Functionality of the measuring robot of the mobile PWS

The mobile PWS consists of the measuring head and the industrial robot to reach the measuring points, 2 additional measuring stations for test specimens in the vehicle, the main water tank and the cooling tank, as well as the control cabinets holding the measuring and controlling technology. The entire measuring apparatus is stored in the cargo space of a small truck. The robot's control is divided into individual steps for each measurement. The measurement is operated in an automated manner using an external control unit.

Basically, 3 measuring positions – right, centre and left – can be differentiated on the road surface and targeted separately behind the carrier vehicle. The measuring positions are designed in such a way that the industrial robot with the measuring head does not protrude over the dimensions of the carrier vehicle. Additionally, 2 measuring positions have been established in the vehicle itself: a reference plate made of glass with a textured surface is installed at the "calibration" measuring position. This will be targeted as a control measurement before and after each measurement. A torque transducer to record the measured value is installed below the reference plate – in a set-up identical to the laboratory PWS. At the other measuring position, there is the possibility to mount laboratory test specimens or asphalt cores into a sample holder in the carrier vehicle as in the laboratory PWS to then test them.

The measurements using the mobile PWS are conducted in a stationary mode. The individual steps of a measurement are: driving to the measuring position, cleaning the test area, scanning the measurement area, directing the measuring head and conducting the measurement. The test consists of a control measurement on the glass plate in the vehicle, and the measurement at the measuring point on the road surface. After the measurement at the measuring point, there is another control measurement on the glass plate. The measured values are saved in a file and can be accessed directly on site on the external control unit.



Measuring head

Outlook research

The polishing resistance of the aggregate contributes decisively to the skid resistance of road surfaces, but there is no established correlation between the polishing resistance of aggregates and the skid resistance in situ on road surfaces. The tests to determine the skid resistance potential aim to: create an assessment background, validate test results and derive an assessment method with which in the future the skid resistance potential of road surfaces can already be determined during the planning phase at the test specimens of the construction material mix, using the FAP laboratory test procedure.

Using the mobile PWS equipment helps to derive a reliable assessment background as a necessary and decisive link between laboratory and in situ conditions. The new procedure to determine the skid resistance potential will be used based on FAP tests to ensure that the construction material mix selected reliably complies with the minimum requirements for skid resistance in situ. These are determined by measurements using the sideway force method (SKM). It is intended to use this method instead of the previously deployed method of determining the polishing resistance of the aggregate by using PSV to test the sheer properties of the rocks used. ■

3D radar to determine the layer thickness of bridge surfacing

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

The advantage of non-destructive procedures is mainly that a multitude of data can be collected at a manageable cost and effort to describe structural conditions. This is true, in particular, for the georadar method, which can provide data on a bridge's structure and condition at speeds customary for local traffic. Conventional georadar systems collect data from one profile line per measurement. When a 3D radar is used, up to 25 profile lines can be measured in one roll-over. Two-dimensional and three-dimensional assessments can be generated from this density of information – for example, to calculate virtual cross-sections and depth sections.

In georadar procedures, radar waves are transmitted by an antenna into the subsoil, partially reflected there and then detected again by the antenna. The thickness of layers can be derived from a long-term interpretation of the signals received, and larger inhomogeneities can be detected – such as installations, obstructive objects and hollow spaces.

BASt's 3D georadar system in operation

Using the 3D radar at the Ahrtal bridge

The motorway institute of the Rhineland-Palatinate Mobility Agency needed area-wide assessments of the present layer thickness to plan maintenance measures for the asphalt surfacing of the Ahrtal bridge on the A61 motorway in Rhineland-Palatinate. Such information is usually only available as planning data for the construction or from spot sampling, and is thus subject to considerable uncertainty. This is why the Mobility Agency responsible decided to use 3D radar technology for the survey. BASt was commissioned to conduct the measurements, while an engineering office was to interpret the data.

A width of roughly 1.9 metres was captured per roll-over at measurements at speeds of about 65 kilometres per hour. Partially overlapping roll-overs were employed for an area-wide data collection, covering all lanes, including hard shoulder and marginal strip. The bridge surfacing with a length of about 1.52 kilometres and a width of about 24 metres was measured in 46 roll-overs, which lasted only a few hours, including turning vehicles around, and did not cause traffic disruptions.

The transition to the concrete bridge deck that can be clearly seen in the data, and the clearly distinguishable concrete reinforcement were taken as the determining boundary of the layer in evaluating the data. It is not, however, possible to use the measurement technology to further differentiate the multi-layer structure of the mastic asphalt surface. This is why for all the lanes measured, the lower edge of the mastic asphalt structure or the sealing were extracted from the measured data. The conversion of the run-over times into layer thicknesses was validated using already available core data against appropriate assumptions.

In total, about 6.9 million measured values were calculated and evaluated statistically. The findings were processed into graphical illustrations and were handed over as a digital set for further use.

Conclusion

The use of state-of-the-art non-destructive measurement technology made it possible to provide the authority responsible for road construction and maintenance with detailed and, in particular, area-wide illustrations of the thickness of the asphalt surfacing. It was possible to conduct the measurements during flowing traffic without disrupting it. The findings will be further used in the detailed planning of maintenance measures. ■

Contactless skid resistance measurement

Christian Gottaut, civil engineer, and André Meyer, civil engineer,
“Surface Characteristics, Evaluation and Maintenance of Roads“ section

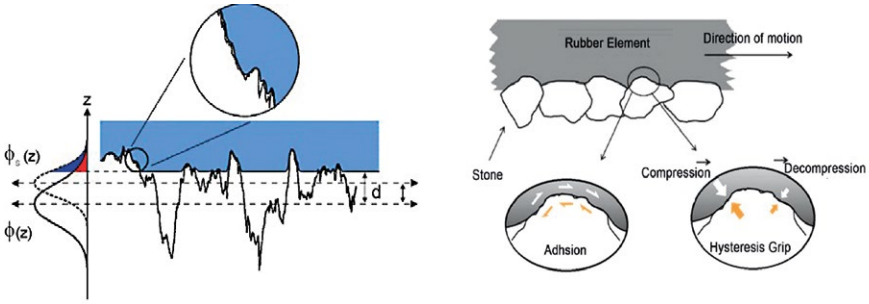
Skid resistance is one of the key properties of a road surface, as it is directly linked to road safety. Currently, skid resistance is measured and evaluated using the sideway force method (SKM), during which a test tyre is drawn over a previously wetted road surface at an angle under defined marginal conditions. BASt is responsible for the quality assurance of the method, thus ensuring a constantly high level of measurement quality. Though the SKM method provides reliable data on the level of skid resistance, it still has deficits with respect to economic viability and limitations in utilisation: it is necessary to bring along a large water tank and the test tyres are subject to excessive wear and tear. Furthermore, it is not possible to measure in narrow curves and the test sections are relatively long.

The contactless skid resistance measurement method

Contactless skid resistance measurement could be an innovative alternative to the SKM method. The basic idea behind this approach is that the texture of a road surface contains all the information necessary to determine the grip between tyre and road if surveyed with appropriate sensors using imaging with sufficient resolution. Based on highly-precise texture data from the road surface, numerical models can be used, for example, to calculate the friction coefficient of the road surface. The sensor could be mounted onto measuring systems that are already currently being used to survey the evenness and material features (surface) in the structural condition survey and assessment of road surfaces (ZEB). As a consequence, only one roll-over would be necessary to capture all relevant properties of the road surface. Additional benefits include that the measurement causes as little wear as possible and that the method can be used for a wider range of applications.

Funding in the “Innovation Programme for Roads”

Though research of the past 20 years has already generated promising approaches in this direction, it has not yet been possible to further develop the procedure and convert it from laboratory scale to practical implementation in a measuring vehicle. In the scope of the 9th publication of the “Innovation Programme for Roads” funding programme, BASt has awarded contracts for 2 research projects on “contactless skid resistance measurement of road surfaces” to close this gap. The 2 projects pursue different approaches, both in the sensor technology used to collect texture data and in how the friction coefficient is calculated.



Determining friction coefficient by modelling a tyre’s contact with the road surface, using the theory of rubber friction

BASt is closely accompanying the projects. Measurements that were conducted on the duraBASt premises using fast-moving vehicles equipped with the newly developed sensors are a case in point. In the ongoing final stages of the project activities, additional measurements are being conducted in real traffic on different road surfaces to, for example, test the robustness of the sensors and optimise the calculation algorithms. ■

Transparent bitumen

Dr Volker Hirsch, chemist, head of section, and Adrian Rink, chemical laboratory technician,
"Chemistry, Environmental Protection Issues, Laboratory Services" section

The physical properties of bitumen are determined by its chemical composition. This is true not only in terms of rheological properties, but specifically also with regard to its adhesive property and the sensitivity to oxidation from atmospheric oxygen. Time-consuming and complicated methods of analysis need to be employed to fully capture the chemical composition of bitumen. These methods require expert handling by specially trained staff. It is important to check whether the chemical composition of the bitumen available is suited to the modification selected, in particular, when it comes to producing modified bitumen or bitumen emulsions. A simple and cost-efficient rapid method is helpful for these use cases to ensure that the composition of the bitumen envisaged to be used for the production fits the purpose. The use of spreading tests offers such a possibility.

Spreading is a phenomenon in surface physics that was already used by Benjamin Franklin, US natural scientist, publisher and politician (1706-1790). He poured a teaspoon of oil onto the surface of a quiet lake. The oil then formed a visible monomolecular layer on the water's surface. A simple way to calculate the molecular size is to measure the area of the oily film spread and the amount of oil dropped.

Bitumen was used in spreading experiments as early as 1952 to test, for example, the compatibility of bitumen and tar [1]. A spreading experiment with bitumen suspended in cyclohexane leads to an interesting observation: the solution does not spread into a homogeneous layer but shows a characteristic, bitumen-specific distribution pattern.

What is spreading about?

The bitumen suspended in cyclohexane has only low surface tension and spreads very quickly due to the high surface tension of water. As the solvent evaporates, the bitumen components that are difficult to dissolve agglomerate. The agglomerates correspond to the dark areas of the spreading pattern and mainly consist of asphaltenes and polar compounds of higher molecular weight. The lighter-weight soluble bitumen parts, consisting for the most part of polyaromatics, come together around these areas, forming a semi-transparent phase. In contrast, the transparent phase consists primarily of aliphatic and aromatic compounds.

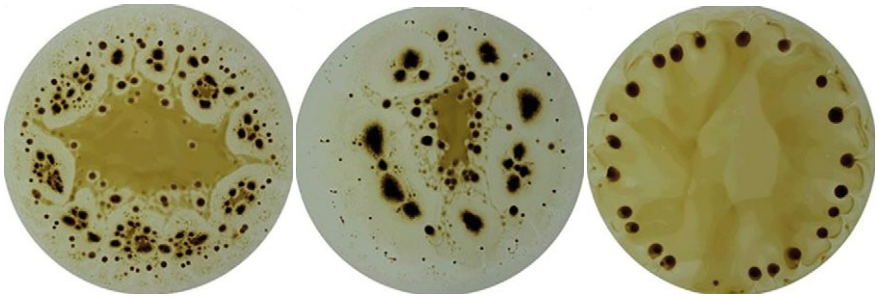
The spreading process by no means constitutes a chemical separation, during which a complex mix of organic compounds is broken down into individual components. Instead, it is a form of self-organisation that is mainly but not exclusively determined by the chemical composition.

There are other impacting factors, such as temperature of the water bath, bitumen concentration, type of solvent, test duration. These parameters need to be kept stable to obtain reproducable spreading patterns.

How is it done?

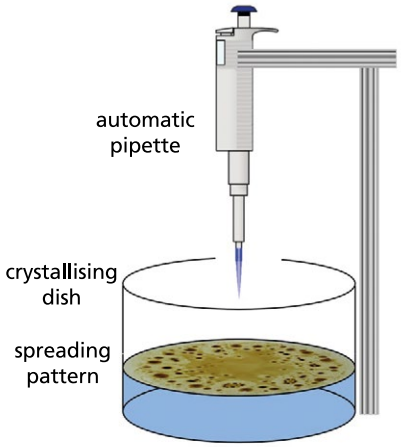
The test is simple to conduct. It only requires a crystallising dish filled with water and an automatic pipette with which to apply the bitumen solution in a precise and reproducible manner. The spreading pattern that is generated is photographed using a digital camera. The crystallising dish is placed on a light table to ensure even lighting.

The spreading patterns of one and the same bitumen sample are not always fully identical, but are surprisingly similar. This is why a visual evaluation of the spreading pattern already leads to good results. But it is crucial for a measuring procedure to be traced back to objective parameters. Modern image analysis tools offer a simple possibility to evaluate image information available in a digital format on the basis of various criteria, and to derive key characteristics from this.

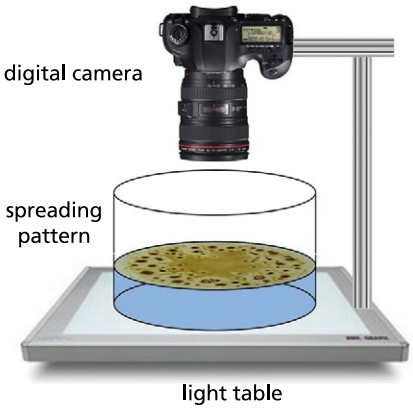


Russian Export Blend *Venezuela* *Kuwait*

Petroleum provenance of bitumen 70/100



Applying samples



Photographic documentation

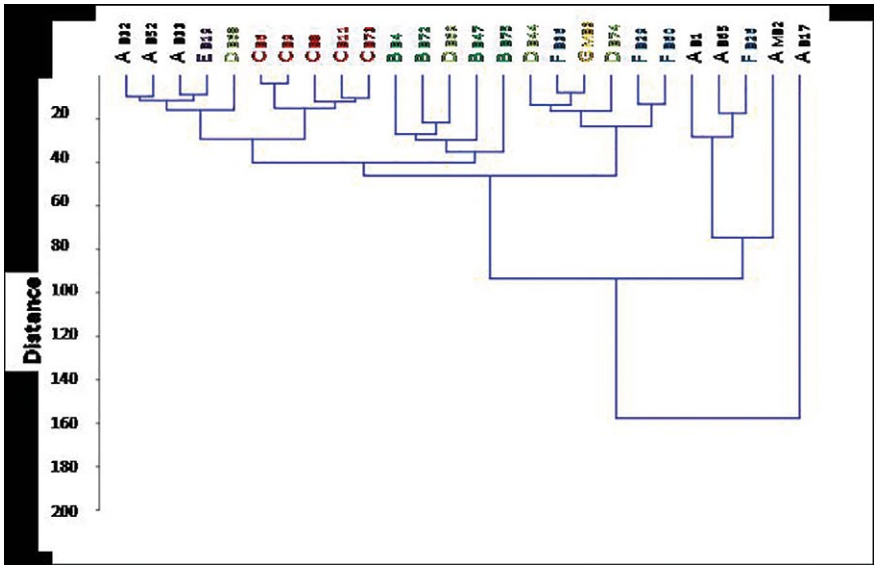
In the most basic case, it suffices to determine the transparent, semi-transparent and the dark parts of the area to come up with key characteristics for a subsequent statistical cluster analysis.

The graphical illustration shows the test results of 26 bitumen samples of the 70/100 type of known origin in the form of a dendogram. This clearly shows how similar the samples are to one another. The more similar the spreading patterns, the closer and the shorter the branches will be. The chemical composition depends on the petroleum provenance and the manufacturing conditions in the refinery. This, in turn, means that the spreading pattern can be seen as an indicator for the petroleum provenance and the manufacturing conditions.

What is the benefit?

A spreading pattern is a chemical identification feature (fingerprint). This aspect can otherwise only be obtained using complex testing methods. It is, however, impossible to determine the exact chemical composition from the spreading pattern. The method is thus primarily a useful option as a rapid test to control the samples used when it is important that the product properties remain constant in the process from the refinery to the product's installation. Furthermore, additional applications are possible to, for example, understand the influence of additives and rejuvenators on bitumen or to make ageing-related changes visible.

The steps needed in the evaluation of this procedure are simple and can be automated. In the future, even more simplifications can be achieved by using progressive methods of artificial pattern recognition. ■



Dendogram of bitumen 70/100 from different refineries

References

[1] LETTERS, K.: Tests to review bituminous binders in thin spreading layers, in bitumen-tar-asphaltene-pitches and related substances Versuche zur Prüfung von bituminösen Bindemitteln in dünnen Spreitschichten, in Bitumen-Teere-Asphalte-Peche und verwandte Stoffe, 3, 1956

Concrete Pavement 4.0

Barbara Jungen, civil engineer, and Dr Marko Wieland, civil engineer, head of "Concrete Structures" section
(at BASt until December 2020)

Increasing traffic loads, projected to grow further in the future, the increasing scarcity of resources and enhanced wear as a consequence of climate changes shift the focus to durability requirements for roads. Research also focuses on the aspects of the availability and long-term performance of the road infrastructure. This is why the process steps in road construction require stringent and quality-assured structuring to achieve the goals for roads in terms of evenness, skid resistance, noise and substance.

The Concrete Pavement 4.0 collaborative project intends to improve the process and production qualities of the pavement through systematic analysis and subsequent optimisation of the process chain. It is expected that translating research findings into practice will lead to a significant increase in the service life span of roads, combined with a decrease in life cycle costs.

Process steps

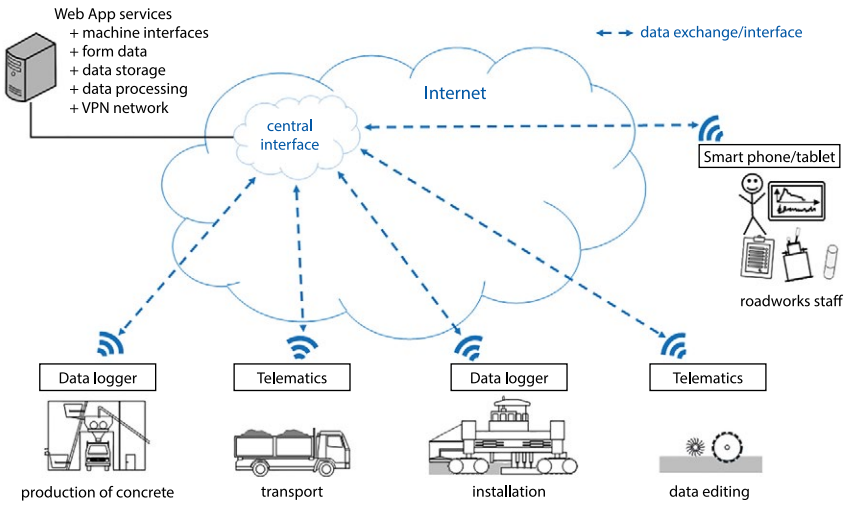
As part of the project, the individual steps in the process chain of building conventional concrete roads will be analysed with regard to their robustness and process reliability. Quality controls for compliance with the relevant requirements for the surfaces call for, among other factors, a meticulous control of the wide range of process steps within the overall production process. Digitalisation helps to collect data using measurement technology concerning the relevant parameters in the fields of wet concrete, construction, hardened concrete and surfaces, and to integrate them into the regulation and control processes. Directly controlling or regulating the individual processes is necessary, for example, to adapt them to the conditions and constraints on a given day, such as weather conditions, material parameters. By doing so, it will become possible to better ensure compliance with the later-stage requirements for the surface properties of the finished road product.

One basic component for this is, in particular, to further develop mixing technologies in terms of a rheology-aided control of the mixing process to make homogeneous wet concrete available for the bottom and top concrete layers of the road, also against the backdrop of the usual fluctuating properties of the input material. The reliable production of the concrete quality required has a major impact on the installation capability, compactibility and evenness. The continuous control of the properties of wet concrete is of specific significance in this context,

Installing a concrete pavement (picture: Schnorpfeil)

as this is where corrective concrete technology-related measures can be derived at one of the key interfaces for quality detection.

This requires measuring systems and tools that determine the specific parameter not only with sufficiently high accuracy but also within a short period of time. Should there be a deviation between the planned and the actual values, it is then possible to respond quickly by adapting the concrete production process.



Concept data structure Concrete Pavement 4.0
(picture: Institute for System Dynamics, University of Stuttgart)

New measurement concepts

In the scope of systematically analysing the process chain it has become clear that it is necessary to improve existing testing procedures and to develop entirely novel measuring concepts.

Developing and integrating a technology to be implemented in the paver to analyse and control the evenness of the finished road surface is also part of the project. The quality of this on-board evenness measurement will be reviewed and further developed with a separate high-resolution 3D laser scan system. Improving the basic evenness of the one- or two-layer concrete pavement at a wavelength area between ca. 0.5 and 50 metres will thus contribute to directly controlling evenness.

The development of innovative sensor concepts to capture rheological properties of concrete for pavements also includes measuring the hardening process of the installed concrete using non-destructive testing methods. Measuring the hardening process of the concrete using ultrasound measuring devices makes it possible, for example, to determine the best possible time for arranging joints, brushing or grinding the concrete without depending on subjective estimations, thus contributing to a robust production process.

Electronic measuring and controlling components need to be integrated to digitally connect all process steps and to enable a process-based continuous control and adaptation of the work flow in each individual process step. This will enable continuously surveying and evaluating the work of each tool and system. This is why the collaborative project also focuses on the implementation of Industry 4.0 concepts, besides technological developments. Combining objective and quantifiable parameters in one overarching control unit will enable the best possible organisation to produce concrete pavements. In the context of integrating Industry 4.0 elements into the production chain, the potential offered by digitalisation can be tapped to improve process reliability.

As a result, it is intended to enable a targeted adaptation and control of the process quality with the help of the optimisation approaches described above. Due to the immediate correlation between product quality and performance characteristics such as function and service life, the potential available can be verified and systematically utilised, in terms of a sustainability approach. ■

BMVI Network of Experts

Joint research for the German transport sector

Increasing the reliability of transport infrastructures

Joint research for the German transport sector

Teresa Wagner, political scientist, “Adaptation to Climate Change” section

The departmental research institutions of the Federal Ministry of Transport and Digital Infrastructure (BMVI) support the ministry in shaping the technological and societal change processes of the 21st century, confronting the associated challenges and making use of the opportunities that arise. Since 2016, they have been doing so in the scope of an inter-modal BMVI Network of Experts – under the slogan “making the transport system resilient and environmentally compatible”. At the conclusion of the first research phase of the BMVI Network of Experts in 2019, BASt and 6 other BMVI federal authorities have made important contributions to shaping a future transport system. This was enabled by a close collaboration between the departmental research institutions and specialist authorities and the BMVI as the initiator of the research network.

Besides scientific findings, the first research phase of the BMVI Network of Experts (2016 - 2019) also brought about the organisational preconditions for the cooperation across authorities. The authorities hired qualified staff and established a network across all stakeholders. Communication and a common understanding of the goals to be achieved were the key elements in this process. During the set-up phase, BASt was responsible for the overall coordination of the BMVI Network of Experts. A scientific task force provided technical and organisational support for both the research activities and the transfer of knowledge and technology.

Research findings exchanged with practitioners

Research within the BMVI Network of Experts is divided into 6 topics. BASt is participating in all of them and, in addition, coordinated the topic of “Increasing the reliability of transport infrastructures” during the first research phase. BASt employees developed and implemented research projects in a user-oriented manner, as the findings should be used to support a viable future transport system as directly as possible, addressing problems in practice.

These are examples of BASt highlights in the scope of the first research phase of the BMVI Network of Experts:

- hazard maps for the federal trunk road network arising from flooding, gravitational mass movements and stormy weather
- guidelines on “procedures to mitigate noise in cumulation periods”
- methods for an automated, drone-based assessment of the condition of engineering structures
- analysis and evaluation of technological developments – such as virtual reality and augmented reality (VR/AR) – and their utilisation potential in operating infrastructure
- concepts to cover the need for (heat) energy of motorway maintenance depots from renewable energy sources.

These and many other research findings of the BMVI Network of Experts provide immediate support to the work of practitioners, such as structural engineering companies and the Länder highway authorities.

Asphalt motorway bridge with electronic toll point (© am/Fotolia)

Sharing findings achieved in the set-up phase and following up on previous successes

It was possible to make innovative concepts and products, developed through user-oriented research and an intensive dialogue with users, available already in the identification and set-up phase. The reports on the findings of the topics 1-5 offer a more detailed insight into the research of the BMVI Network of Experts. The results described there are a valuable basis for further research processes focusing on data products and processes ready to be applied, management systems, and translating the progress into pertinent regulations and practical measures.

BMVI Network of Experts online – research findings at a glance

An online event on 19 January 2021 provided insights into selected research findings of the BMVI Network of Experts Knowledge – Ability – Action.

BASt president Stefan Strick represented BASt during this event with his keynote speech: “Research and Practice – hand in hand”. Sonja Neumann presented the topic “Authorities and digital transformation! Technology trends and data processing”, Dr Fabio Strigari the topic: “Less noisy and more environmentally friendly – transport infrastructure of the future”.

A recording of the event can be watched on the Network of Expert’s website. ■

https://www.bmvi-expertennetzwerk.de/EN/Publications/Publications_node.html

Road closure because of flooding (© DOC RABE Media/Fotolia)

Increasing the reliability of transport infrastructures

Dr Iris Hindersmann, geographer, and Ulrich Schmelter, civil engineer, “Concrete Structures“ section, Dr Kalliopi Anastassiadou, mining engineer, “Tunnel and Foundation Engineering, Tunnel Operation, Civil Security” section, Dr Martin Friese, civil engineer (at BASt until December 2020), Sonja Neumann, mechanical engineer, and Stefan Staub, geographer, “Maintenance of Engineering Structures“ section

Selected findings from the 2016 - 2019 research phase

The unfavourable age structure of engineering structures, the projected increase in goods traffic and the rise in disruptive events – such as flooding or cyber attacks – require solutions to ensure the reliability and resilience of the transport infrastructure. Additional efforts need to be taken to capture current and future conditions, to maintain, strengthen or replace the infrastructure in an optimum, coordinated manner while maintaining traffic.

Targeted research to continue ensuring the safety, security and reliability of the infrastructure and to prioritise existing resources and use them highly efficiently becomes a necessity to confront these challenges and answer urgent future transport-related questions. BASt’s bridges and engineering structures department worked on the following topics during the first 2016 - 2019 funding phase of the Network of Experts.

Lifecycle management

Lifecycle management pools data from the entire lifecycle of an engineering structure, derives indicators and analyses specific engineering structures in the context of the overall network. This enables standardising processes, reducing costs, increasing the availability of engineering structures and preparing the path towards predictive maintenance management. A rough concept for an inter-modal, indicator-based lifecycle management was developed in the scope of the activities during the first funding phase.

Status assessment

Knowledge of the portfolio of engineering structures enables planned maintenance; regular structural inspections at touching distance are the most important source of information. Innovative approaches were studied to provide additional information and to optimise the gathering of information by, for example, flying UAS (unmanned aerial systems) over bridge structures, besides AI-aided damage detection. In addition to monitoring procedures and non-destructive inspections, tests were conducted for quality assurance and assessing the economic viability and for quantifying the increase in safety. Their results will be processed into manuals and guidelines in a user-oriented manner.

Motorway bridge neçar Leverkusen (picture: poinz/Fotolia)

Resilience assessment

The owners and operators of road infrastructures will be given tool kits to help assess the resilience of engineering structures. The concept of resilience assesses the road infrastructure with respect to its capability to cope with damages after disruptive incidents and to quickly be returned to service. Procedures and models were developed to quantify the availability and safety of engineering structures in case of exceptional events, and the response and recovery processes in place for the road infrastructure after disruptive incidents were tested.

Construction while in service

When innovative and sustainable construction procedures for replacement structures were analysed, the focus was on minimising the construction time and reducing disruptions of traffic. In the meantime, pilot projects have already been carried out implementing a number of the construction methods examined. This resulted in a significant reduction in construction time compared to conventional construction procedures.

Digital technologies

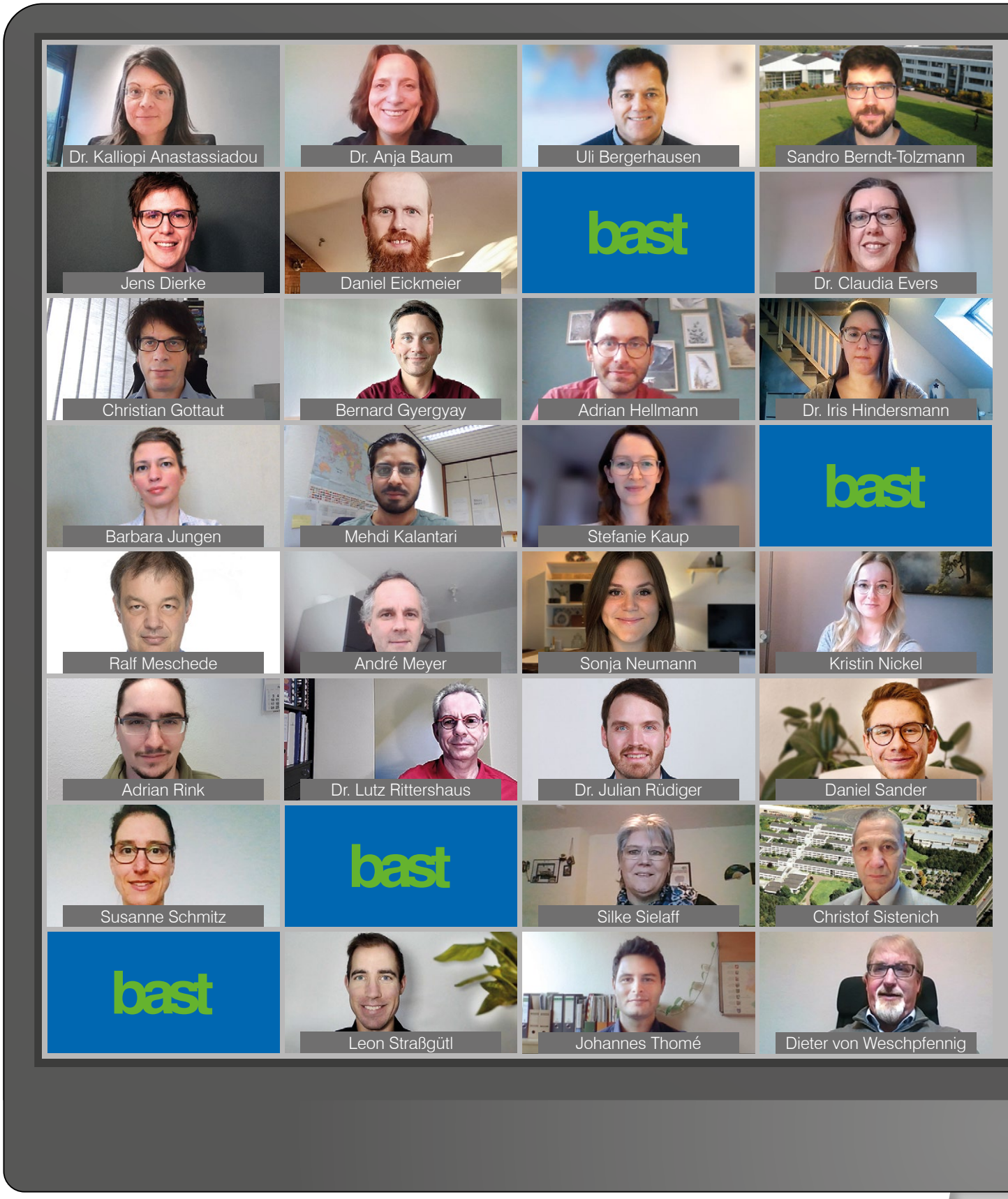
An important task in the digital transformation process is to identify relevant digital technologies, including the opportunities and risks they entail, at an early stage and assess their usefulness in finding answers to current problems. In this context, virtual reality and augmented reality were identified as digital technologies with a potential to be used by owners and operators of traffic infrastructures in maintaining the engineering structures. It is intended to carry out pilot projects to test the digital technologies specifically in the specialist application scenario of structural inspections and to show their potential.

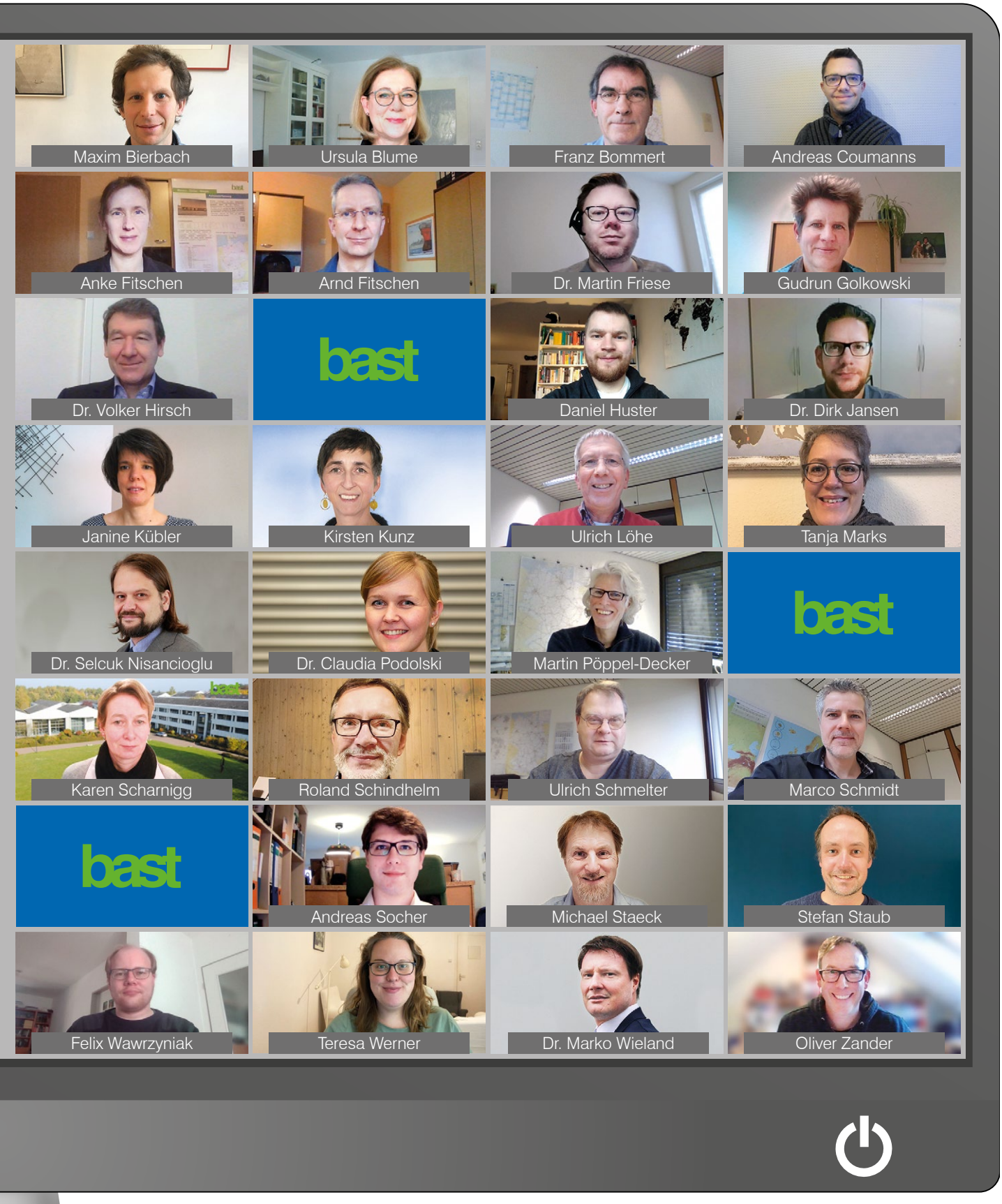
Funding phases

Various aspects of increasing the availability of engineering structures were examined in the first funding phase. In doing so, state-of-the-art technical developments and methods were developed and deployed. The projects have shown that the concept of inter-modal cooperation across different authorities leads to developing joint solutions to improve the availability of traffic infrastructures, and that it provides very good results.

The second funding phase of the BMVI Network of Experts, from 2020 to 2025, will focus on intensifying the cooperation with users and on further developing the topics and approaches to date. For this purpose, concepts for user dialogues are now being developed, such as questionnaires to interview experts. The aim is to enhance the exchange with the owners and operators of bridges and engineering structures. The concepts and procedures already developed will be implemented, further developed and optimised in pilot projects. ■

Authors of the articles

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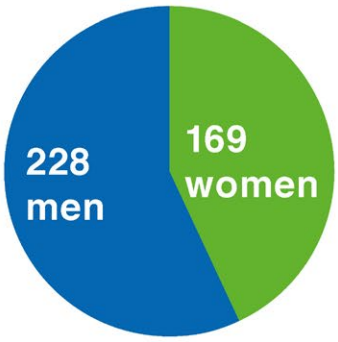
BASt Facts and Figures 2020



397
employees

52
reports
in our own publication series

scientists

12
lecturer positions at universities

average age of employees

participation in

749 committees

international

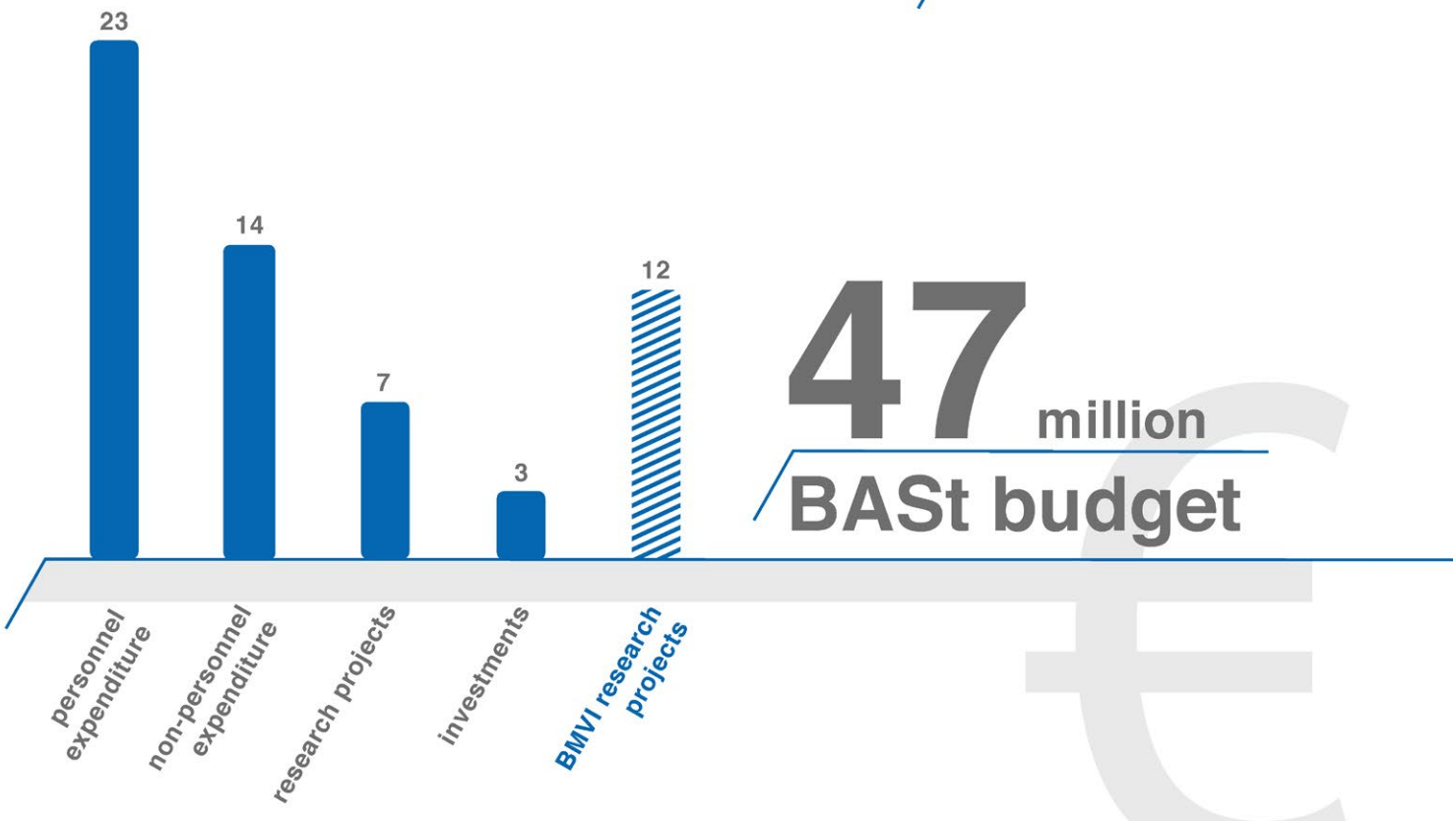
national

around 200 research projects of our own

16 international projects

with staff costs of more than one million euros

working on close to 300 external projects



47 million BASt budget

Teaching assignments and PhDs

PhDs and selected teaching assignments at a variety of universities and faculties also show how successful BASt employees were in 2020.

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

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

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

Dr Ferdinand Farwick zum Hagen: received his PhD in natural sciences at the Bergische University of Wuppertal.

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

Ralph Holst: teaching assignment in "Inspection and Management of Engineering Structures" at the Bauhaus University Weimar.

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

Bernhard Kollmus: teaching assignment in "Road Safety in Planning, Drafting Roads" at the Technical University Dresden.

Dr Mahdi Rahimi Nahoujy: received his doctorate in engineering at the Ruhr University Bochum.

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

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

Elisabeth Shi: teaching assignment in psychology and business psychology on statistics and methodology at the Rheinische University of Applied Science in Cologne.

Dr Marko Wieland (employed at BASt until December 2020): lecturer at the University Stuttgart, lectures at the Bavarian Bau-Akademie Feucht-wangen, the ABZ Mellendorf and the BFW Bau Sachsen in Dresden in the scope of “Concrete Technology Education”.

André Wiggerich: teaching assignment in psychology on methodology at the Rheinische University of Applied Science in Cologne.

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

BASt Organisational Structure