Embark on new Path!

Competence in transport infrastructure and beyond

STUVA

RESEARCH ▪ DEVELOPMENT ▪ SUPERVISION ▪ CONSULTING

Index

STUVA –
Research Association for Underground Transportation Facilities

Mathias-Brüggen-Str. 41
50827 Cologne, GERMANY

Phone: +49 221 5 97 95-0
Fax: +49 221 5 97 95-50

info@stuva.de
www.stuva.de

Our experience guaranties your success

Testing facilities unique in the world and decades of experience are only a few attributes of STUVA. Your tasks will be solved by our dynamic team with spirit of innovation and reliability.

The Research Association for Underground Transportation Facilities – STUVA – is an internationally renowned research institute and has today about 250 international corporate members. All industries, cities, transportation companies, consulting engineers, university institutes of distinction are represented.

STUVA mainly develops new products or methods in the field of producing transport infrastructures in conjunction with industrial partners. Additionally, STUVA undertakes multifaceted tasks in supervision and consulting.

The company is divided into the two units

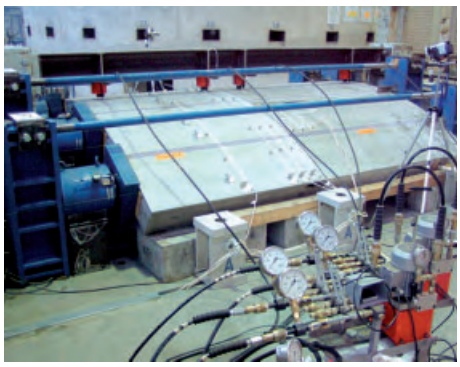
- Tunnelling & Construction Technology
- Transport & Environment.

Expanded consultancy services, for instance in the fields of fire protection design or industrial contract research, are processed by STUVAtec.

Specialties of STUVA are large scale testing facilities. Some of our installations are with regard to combination of dimensions and operational parameters unique in the world. Three test halls with a floor space of 2,000 m² are available at STUVA headquarters.

Obtain an insight of our extensive range of services on the following pages. Take advantage of our experience to assure your success!

Dr.-Ing. Roland Leucker
Managing Director



Segments without faults

Fine-tuned design details based on load capacity tests

Load tests are the most reliable variant to evaluate the bearing capacity of tunnel linings. By using them, structures can be optimised when calculative approaches are insufficient.

For a reliable evaluation of the bearing capacity of segmental tunnel linings in the erection phase, during tunnel driving and in the final state, load tests on parts of segments, whole segments or even segment rings can be required. As a result, the segment design with regard to positioning of reinforcement or other details can be optimised. For these special tests, tailor-made hydraulic testing facilities and measuring systems are available at STUVA headquarters.

- In **segment load bearing tests** the ultimate bearing capacity under vertical load can be quantified. This type of test is often also performed in the course of regular quality control over the whole construction period.
- With **torsional rigidity** tests the restoring torque depending on ring normal force can be determined. This also allows conclusions on damage-free rotation capacity of the joints to be drawn.
- **Diaphragm load** tests deliver information on acceptable forces of the TBM's thrust jacks. Consequently, the unevenness of the ring joints due to erection inaccuracy can be considered.
- **Shearing tests** serve for determining of the ultimate bearing capacity of coupling devices and for the optimisation of positioning reinforcement in this area.
- By means of **flaking tests** possible damage to concrete in the course of segment erection is investigated. Furthermore, influences of the circumferential gasket on flaking behaviour of concrete edges can be verified.
- With **friction tests** load transmission in the ring joints is covered. In that way, weak points like insufficient strong hardboard sheets or glue that plastifies under load can be identified.
- In **complex large scale tests** with partly multiple complete segment rings, the deformation behaviour of the total system under load in interaction with bedding forces can be investigated.

Amsterdam Metro (Netherlands)

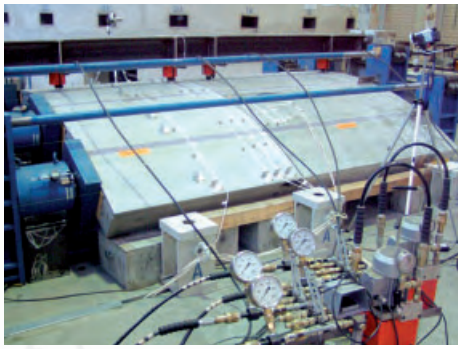
The new North South Line will link in the near future the stations "Zuid/WTC", "Centraal" and "Buikslotermeer". On behalf on the client, flaking tests were conducted in order to check the influence of cross joints of tunnel segment gaskets. Through this, evidence was provided that concrete and tunnel segment gaskets are attuned in the right way for this project.

Bosporus Tunnel "Marmaray" (Turkey)

The railway tunnel "Marmaray" represents the first direct standard gauge connection between Europe and Asia. This consists of an immersed tunnel under the Bospurus and is connected with the mainland by two shield tunnels. By means of torsional rigidity tests, the acceptable joint opening was verified in advance for the segments lying 60 m below sea level.

Sofia Metro (Bulgaria)

In the course of the extension of the metro system in the capital of Bulgaria, 3.7 km of tunnel for Line 2 was excavated with an EPB shield. Also because of the good segment design a top performance of 220 m in one week was reached. By means of diaphragm load tests, in advance the acceptable tunnelling thrust force under consideration of an eccentric offset was determined..

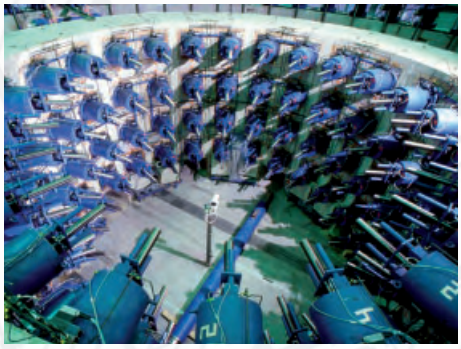


TUNCONSTRUCT (Europe)

In the scope of the research project TUNCONSTRUCT funded by the European Commission, together with industrial partners, new and innovative construction materials for tunnel linings were tested. By means of torsional rigidity as well as load bearing and diaphragm load tests the applicability of self-compacting, fibre reinforced and ultra-high performance concrete for segments was proved.

4th tube of the Elbtunnel (Germany)

For the 4th tube of the Elbtunnel in Hamburg two segment rings with a diameter of about 14 m and a height of 4 m were loaded via 96 hydraulic jacks. The resulting displacements were recorded continuously at 192 measuring points. For the very first time the transferability of calculative approaches from superstructure works on tunnels was proved on such a scale.



Safety underground

Fire protection concepts for tunnels and metro stations

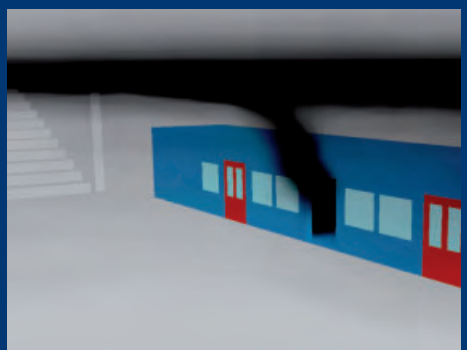
Modern traffic infrastructure is increasingly located in underground space. The advantage of invisibility in the urban and rural landscape faces the disadvantage of higher exposure of users in the event of fire.

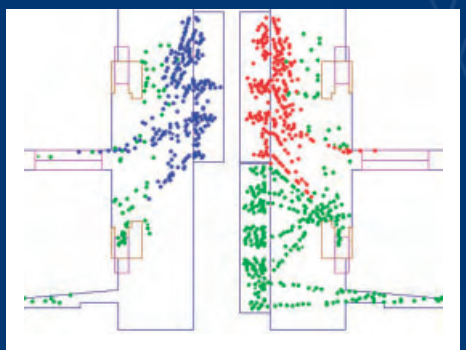
Fires in tunnels, metro stations and other underground structures are rare, but cannot be completely ruled out. But whatever might happen, people must have the opportunity to reach a safe place in time. Due to the fact that escape routes are often longer than those in ordinary high rise buildings and that hot and toxic smoke rises upwards – in other words in the direction of escape in metro systems. Hence, for these types of structures individual holistic fire protection concepts have to be developed.

STUVA possesses expert knowledge and decades of experience in this field. Aspects of construction and personal safety according to the latest state of technology are always considered in a generalized context. This means, for example, that the requirements for open architectural design are considered. Special customer requests such as fire-resistant glazing and water mist systems can also be integrated in our concepts.

We are your competent partner for:

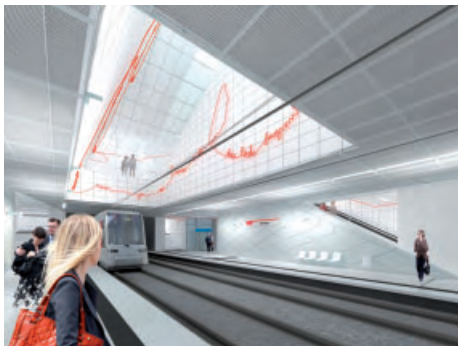
- Compilation of holistic fire protection concepts for underground structures such as tunnels, metro stations and caverns
- CFD calculations for determination of time-dependent spreading of fumes, temperature and toxic gases
- Numerical simulations of evacuation scenarios on the basis of an individual continuous model and analytical calculations according to different accredited procedures (NFPA etc.)
- Planning, consulting and performing of fire and smoke tests for acceptance of structures and check of technical equipment
- Evacuation tests with people on site
- Independent reviewing of safety concepts
- National and international research projects
- Providing expert opinions





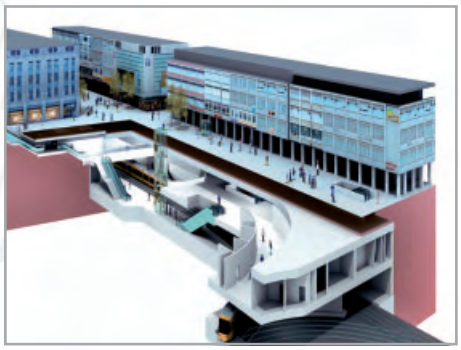
Wehrhahn Line Düsseldorf (Germany)

The Wehrhahn line is the second largest metro stretch of North Rhine-Westphalia's regional capital. It is over 3.4 km long and comprises six underground stations. These are designed to invite visitors to linger and are intended to be an integral part of the cityscape of Düsseldorf: cosmopolitan, innovative and creative. And thus the sophisticated architectural design was incorporated in planning fire protection.



Combined Solution Karlsruhe (Germany)

Hitherto, on average, at peak periods every minute a tram runs in each direction along the above-ground main axis in the city centre of Karlsruhe. The total of seven underground stations and 3.4 km of tunnel will create a high-quality urban space as of 2017. For the total system a holistic fire safety concept has been developed.

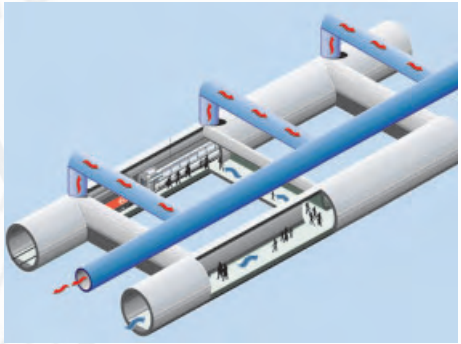


North-South Line Cologne (Germany)

The North-South Light Railway Line will significantly reduce the travel time from the southern parts of Cologne to the city centre as of 2019. The seven underground stations are designed in a modern way for which the use of fireproof glazing was reviewed. Furthermore, CFD-based calculations of smoke and evacuation simulations were carried out and construction-related consultancy services offered.

Gotthard Base Tunnel (Switzerland)

The Gotthard Base Tunnel in Switzerland with two tubes each 57 km in length will be the longest railway tunnel in the world after its completion in 2016. In case of fire the high speed trains enter an emergency station where better survival and rescue conditions prevail than in the running tunnel. In this context extensive fire and smoke simulations were also performed.



Mount Markus Tunnel (Luxemburg)

The Mount Markus Tunnel has connected Luxembourg and Germany since 2003. Before opening, for a final check of the technical safety equipment some smoke tests on site were required by road authorities. Thereby it could be shown that ventilation systems act as specified and air flow can change its direction in a sufficiently short time.

Barrier-free design

Concepts for accessible infrastructures

The demands of people with reduced mobility are to be put into practice with the design of built infrastructures. In many cases partly contradictory needs of users represent a major challenge.

Accessibility of built infrastructures plays an important role for sustainable building and mobility – in everyday as well as in emergency situations. People with reduced mobility (PRM) include disabled people as well as children and elderly people or people with prams et cetera.

Considering the needs of PRM is becoming more and more important, because the number of PRM will constantly rise in the near future. In some countries the share of the population of PRM is more than 30 % and will continue rising in the years ahead. Considering the needs of e. g. physically and sensorially disabled people at an early stage of design is generally beneficial and reduces costs. From many national and international projects and research STUVA has many years of in-depth knowledge regarding barrier-free design of the built environment and needs of disabled and handicapped people.

We offer competence in the field of barrier-free design with

- Consultancy services on planning and design
- Practical tests and workshops
- Second opinion and review of concepts
- Expert knowledge from national and international research projects
- Providing expert opinions

STUVA has been dealing with the needs of people with reduced mobility for over 30 years. We work towards a consistent but economic and balanced implementation of the Design for All-principle and invite those affected to participate.

Benefit from our knowledge from numerous working groups and committees in the course of your planning and design tasks:

- Road and Transportation Research Assn. (FGSV)
- German Institute for Standardization (DIN)
- Federal Working Group on Rehabilitation (BAR)
- European Institute Design for ALL in Germany (EDAD)

Crossings at urban main roads

In the project "Barrier-free crossings of main roads – Design of lowered kerbs and tactile ground indicators in detail" (2011–2013) extensive empirical tests are performed. These shall show, for instance, how kerb edges have to be designed to help people with visual impairments to detect them in a safe way and to help people with walkers or wheelchairs to easily cross them.

Barrier-free solutions in public transport

Within the scope of "Analysis of the state of development of barrier-free solutions in public transport for people with reduced mobility" (2011–2012) best practice and new solutions were collected. The richly illustrated documentation is published in the bilingual book (German and English) "Barrierefreier ÖPNV in Deutschland/Barrier-free public transport in Germany" (2nd ED, 2012).

Emergency exit doors in road tunnels

The project "Improving means of opening emergency exit doors in road tunnels" (2010–2011) shows the difficulties of PRM to escape from the tunnel in case of an emergency. Despite physical-effort, one third of the test persons could not open the emergency door. Based on this result, a wide range of possible improvement measures was developed.

PRM in emergency situations in buildings

From 2009–2011 STUVA worked on the project "Measures for managing emergency situations involving PRM in high-rise buildings". Besides reviewing the requirements and given national framework of barrier-free design in high-rise and public buildings the main task of this project was the systematic review and presentation of feasible technical and organisational improvements.

Improving safety of PRM in road tunnels

For different emergency scenarios, in the project "Consideration of the needs of disabled persons in relation to equipment and operation of road tunnels" (2008–2009) possibilities for the improvement of self- and external rescue were identified.
Now, many of these are to be found in technical guidelines and standard drawings that deal with new and existing tunnels.

Waterproofing

Basis for unlimited use of structures

Water ingress into structures is often the outcome of poor design or sub-standard execution. A variety of requirements have to be considered for securing the desired usability.

Often clients are not aware how important effective waterproofing is for underground structures. This especially applies due to the fact that these are very difficult to access – if at all – after completion. Therefore, in design and construction specific constraints have to be taken into account. These include:

- Chemical and mechanical exposure
- Conformity with the geometry of the structure
- Environmental compatibility and workability
- Testability of functioning

STUVA has been dealing with all kinds of questions relating to waterproofing for over 40 years regarding:

- Tunnels
- Dams
- Underground garages and basement levels
- Landfills
- Parking levels and bridge decks

Many findings have already been introduced in practice and regulations (e. g. DIN 18195, Ril 853).

We are your competent partner for:

- Consulting and supervision on-site of watertight concrete and waterproofing materials
- Review of design documents such as shop drawings and quality management handbook
- Identification on-site of causes of damage
- Conception of refurbishments
- Practice-oriented tightness tests on
  - Waterstops
  - Membranes
- Special fields
  - Gaskets for segemental tunnel lining
  - Umbrella waterproofing
  - Injections and grouting
  - Joint refurbishment
- Drafting of recommendations
- National and international research
- Providing expert opinions

Merowe Dam (Sudan)

The Merowe Dam at Nile River North of Khartoum is an impressive 9.3 km long and up to 74 m high. It provides 60 % of Sudan's consumption of electricity and serves, at the same time, for irrigation and flood protection. After flooding in 2009, extensive consultancy services were provided by STUVA. These aimed to optimise water tightness of the dam.

Sewer Tunnel "Emisor Oriente" (Mexico)

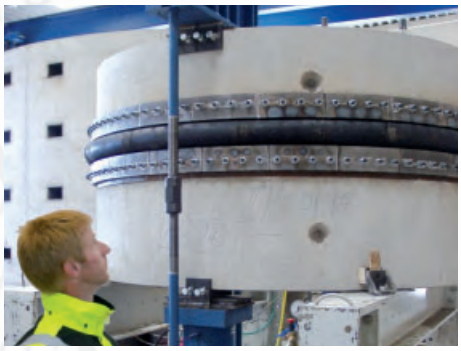
The 62 km long tunnel "Emisor Oriente" with a diameter of 8.70 m ranks among the world's largest sewer projects. It serves for flood protection of Mexico City and discharges up to 150 m^3 of water per second. Before construction, STUVA performed water tightness tests under consideration of the extreme loading on tunnel lining segments and gaskets.

Rail project "Stuttgart 21" (Germany)

The core of "Stuttgart 21" is the reorganisation of the central dead-end railway station "Stuttgart" into a high-performance through station underground. Furthermore, it represents an important urban development project. It links up with the new high-speed railway link Stuttgart-Wendlingen. STUVA has been entrusted with consultancy services on all waterproofing aspects.

Emscher Sewer Tunnel (Germany)

In future, the wastewater in the region of the Emscher River will be discharged through closed sewers and the river itself will be renaturalised. In this way, over a length of 51 km the world's most modern wastewater system will become reality. In order to ensure long-term tightness, tests on original jacking pipes under real loads as in the construction phase were performed.



Lefortowo Tunnel (Russia)

The 2.2 km long Lefortowo Tunnel under the Jausa River fills a gap in Moscow's third motorway ring road. In order to route the traffic on two levels on top of each other, the tunnel diameter amounts to over 14 m. In advance suitability tests on tunnel segment gaskets were performed by STUVA according to their internationally accepted guidelines.

Durable traffic routes

Time lapse on the testing circuit

By means of STUVA's testing circuit, extreme loading on pavements, tracks and installations can be simulated. The significant results enable a reliable evaluation of innovative designs.

The latest forecasts assume an increase of heavy goods traffic on Europe's roads of about 40 % by the year 2025. This will lead to a significantly stronger impact on road structures. As a result, higher requirements for the building materials asphalt and concrete are to be expected. Innovative technologies such as low-noise asphalt and white topping or new installations for drainage and joints shall also contribute towards protection of environment and resources.

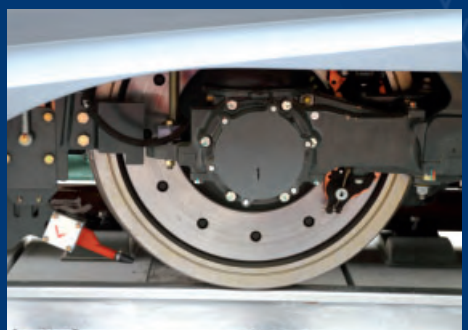
In order to make these solutions economic and sustainable under tough prevailing conditions, it has to be verified in advance that their life cycle costs are not higher than in the case of established measures. This applies especially if verified theoretical models are absent. In order to simulate, on the one hand, a wide range of parameters and, on the other, realistic boundary conditions, accelerated pavement testing (APT) is an interesting alternative.

By means of STUVA's testing circuit, within a few weeks the effects of loading extending over a roughly 15 year period can be represented in real terms. In this regard seasonal temperature fluctuations – extreme frost and heat – can also be taken into account. The results are almost as significant as from a pilot route; however, costs are much lower.

The variety of combinations of extreme conditions is unique in Europe's testing facilities:

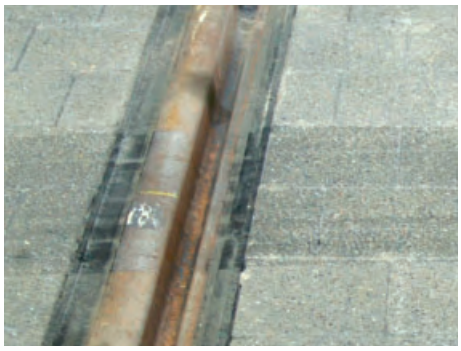
- Velocity: up to 100 km/h
- Axle load: up to 10 t
- Temperature: –30 °C to +60 °C
- Circuit length: over 30 m

Due to the modular design of the facility, components can be exchanged easily. In this way, for instance, also systematic tests on wheel-rail systems with regard to durability and/or vibration emissions are also possible. This applies to parts of the vehicles as well as to the track.



Urban Track

Within the scope of the research project "Urban Track", funded by the European Commission, in cooperation with several industrial partners rail fastening devices for use in road pavements were tested. In this way particularly suitable designs and building materials like jointing compounds could be identified.



Low-noise asphalt

On behalf of the Technical University of Delft (Netherlands), in cooperation with the Institute of Road and Traffic Engineering (isac) of RWTH Aachen University tests on so-called low-noise asphalt were performed. These were aimed to detect grain break-outs from the top layer. The frequent texture measurements were carried out by the Federal Highway Research Institute (BASt).

Joint systems for parking levels

In coordination with the German Institute for Building Technology (DIBt) and the North Rhine-Westphalia Materials Testing Office (MPA-NRW) joint constructions for parking decks were investigated. Because of the successfully passed tests the DIBt agreed to grant a General Test Certificate of the Building Authority (abP).

Asphalts for extremely heavy loads

Funded by the Consortium of Industrial Research (AiF) and the German Asphalt Institute, comparative tests on asphalt constructions for extremely heavy loads were performed. To sum up, for certain material combinations a strong increase of rut formation could be registered for certain material combinations.

Asphalt expansion joints

A test series on traversable asphalt expansion joints in the course of tunnels and trough structures was financed by the Federal Ministry of Transport, Building and Urban Development (BMVBS). The results were used by the involved industry to improve details of these joint constructions.

Fatigue Strength

Relevant testing of superstructure components

A high-grade superstructure results from the selection of its individual components. Efficient tests represent an essential requirement for determining the characteristics that apply.

A perfect superstructure represents an important prerequisite for reliable and economic rail traffic. In some cases for safety reasons, speed restriction sections have to be set up owing to shortcomings. Delays and diminished popularity of the affected links are the outcome. Furthermore the costs for maintenance must not be underestimated. Apart from the functional aspect other considerations such as noise and vibration emissions have a significant role to play.

In order to be able to assess different designs either the technical parameters of tracks have to be explicitly established or comparative examinations of a number of variants undertaken. These first and foremost relate to:

- Fatigue strength,
- Static and dynamic stiffnesses,
- Settlement and deformation behaviour.

A hydropulser is available at STUVA for the practice-oriented and meaningful determination of the properties of superstructure components.

This is a hydraulic testing device, which can produce static, cyclic and dynamic loads either force or path-controlled. Thanks to the additional possibility of introducing an inclined load, tests according to DIN 45673 can be carried out on the test stand.

Technical details of the test stand:

- max. static force: F_{stat} = 160 kN
- max. dynamic force: F_{dyn} = 120 kN
- max. frequency: f = 60 Hz
- max. amplitude: A = ± 50 mm

Fields of application are for instance:

- Rail fastener,
- Sub-ballast mats,
- Track foaming,
- Plastic coatings for steel parts.

Rail fasteners

Rail fasteners must on the one hand be soft so that only low noise and vibration emissions occur. On the other hand they must also be stiff enough to ensure suitable positioning of the track. Corresponding stiffness values can be determined by means of hydropulsers. It is also possible to predict the insertion loss on this basis. ,

Sub-ballast mats

Sub-ballast mats are applied for reducing vibrations. Cyclic loads produced by a load plate can determine the stiffness of the system in the ballast box as well as whether ballast stones harm the surface of the mats. This could lead to complete destruction of the mat in situ thus neutralising its effect.

Track foaming

Foaming the ballast leads to stable, sustainable track positioning. In this way tamping and aligning are avoided. Furthermore the noise and vibration emissions are expected to drop as a consequence. Thanks to comparative tests the deformation behaviour of ballast with and without foaming after a permanent load is established.

Optimising superstructures

Thanks to comparative measurements on samples it is possible to attain optimised superstructures both with regard to the construction cycle as well as constructive design. In this connection the deformation behaviour and the fatigue strength must be taken into consideration as essential parameters. These can be checked using deformation and stress measurements by means of DMS.

Urban Track

Within the scope of the „Urban Track" research project funded by the EU samples of different rail bed structures for use in road areas were industrially produced and tested. In this way it was possible to identify particularly suitable designs and construction materials. These results formed the basis for the resultant field tests.

Quiet rail traffic

Protection from noise and vibrations

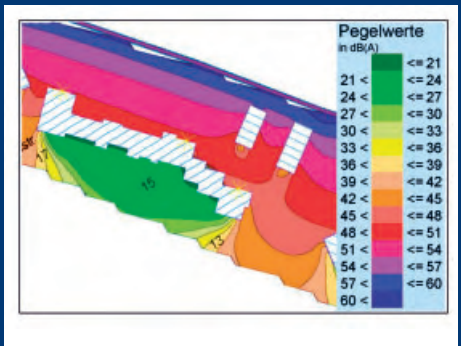
Traffic noise is often the cause of stress and sleeplessness. For the improvement of quality of life next to railways, effective and economic measures are to be newly developed.

Noise and vibrations have negative impact on people's quality of life. In severe cases, they can even make them ill. Protection from these effects is a fundamental mission of health care. Hence, these topics are also focussed by the public, research and legislation. Consequently, protective measures for existing and new railways induce high costs. Thus it is necessary to develop innovative measures for railway traffic that is quit as well as low in vibrations. Additionally, these must be effective and economic.

STUVA has been carrying out investigations in this field for almost 40 years and has accompanied new developments since that time. Our specialties in this regard are large scale testing facilities. In this connection, all possibilities for reducing noise and vibrations are taken into account: at the source, in the dissipation area and the immission area. Many of the results have already been implemented in practice and in regulations.

We are your competent partner for:

- Measuring, analysing and visualisation of
  - Air-borne noise as well as ground-borne noise and vibration
  - Transmission of vibrations in tracks, tunnels, ground and buildings
  - Natural vibrations of vehicle, track and building components
- Calculation and evaluation of noise emission and immission according to regulations
- Prediction of ground-borne noise and vibration
- Conception of measures at vehicles and tracks for reduction of vibration and curve noise emission
- Testing of vibration behaviour and endurance strength of track components via
  - Hydropulser according to DIN 45673
  - Testing circuit
- Providing expert opinions



STUVA Conference

The International Family Get-Together for Tunnellers

Every two years the STUVA Conference is held together with the STUVA Expo occupying several thousand square meters. It is a regular meeting place for roughly 1,500 members of the international tunnelling family.

For over 45 years the STUVA Conference has been recognized as a premier forum for all fields of underground construction. With 1,500 professionals from more than 20 countries it is one of the world's leading and largest events in the tunnelling sector. STUVA Conference is held late November/early December in odd years.

Conference

The presentations will be given bilingually (simultaneous interpretation English/German) covering main topics of underground construction:

- Most recent technical developments
- Major international projects
- Safety during construction and operation of tunnels
- Design/construction/refurbishment/upgrading/research
- Mechanised and conventional tunnelling
- Sustainability and efficient use of energy
- Economics/contractual issues/financing

STUVA Expo – The Exhibition of Underground Construction

With growth figures increasing all the time, the accompanying exhibition STUVA Expo will be taking place directly related to the conference. More than 140 well-known national and international exhibitors are taking advantage of this professional marketing platform and presenting their products and services in the fields of machinery and equipment, material and supplies, planning and consulting, and construction.

Make use of this opportunity to discuss a common strategy for the future with exhibitors and colleagues. The combination of conference and trade show offers a unique international platform for sharing experiences with national and international tunnelling experts.

Welcome!