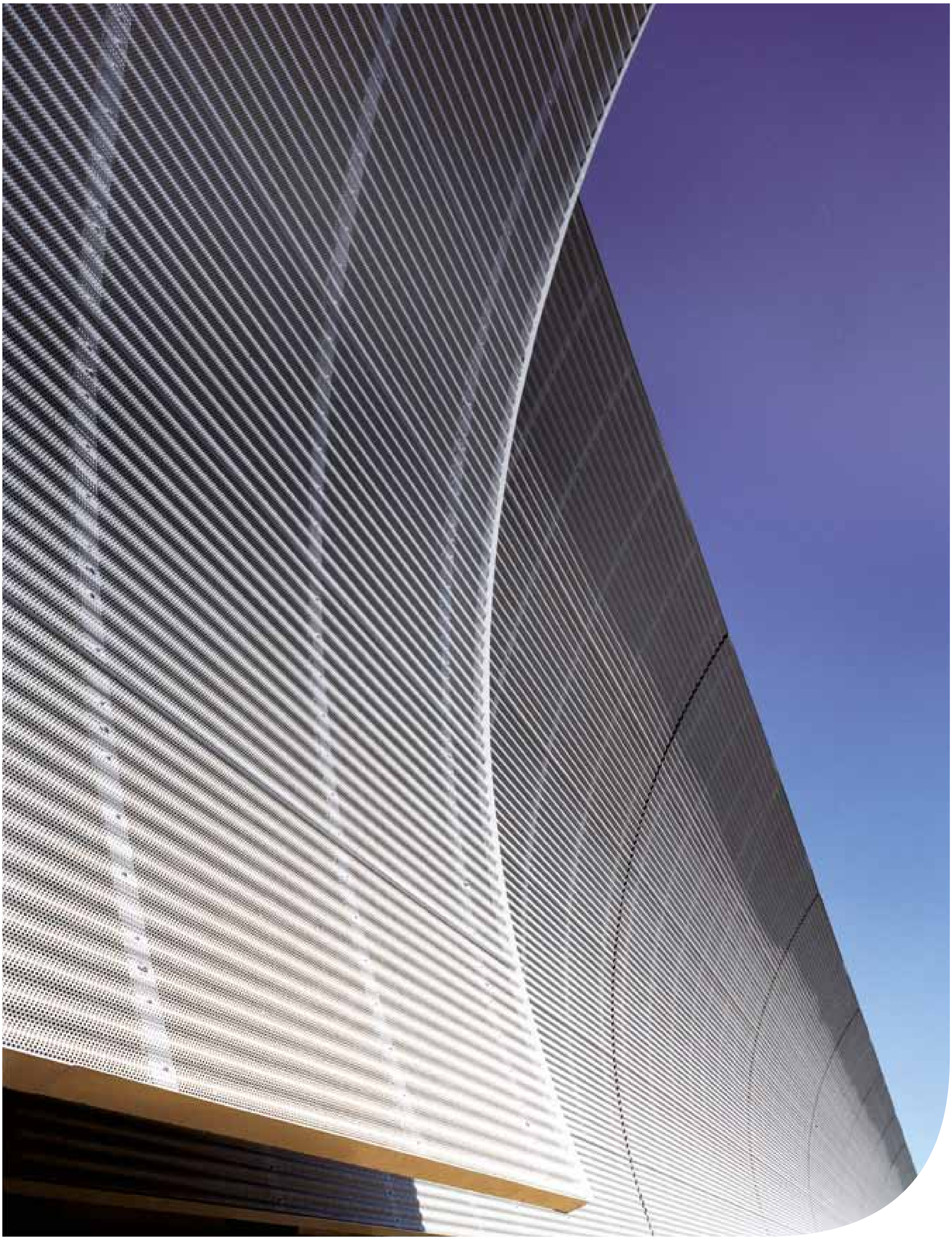
Planning and design of noise barriers

SSF Ingenieure



Noise protection – in service of the environment and well being

Introduction

Noise barriers have been constructed in Germany for about 35 years. Extending and adapting the traffic infrastructure to the growing demands of a functioning economic and cultural region would be simply inconceivable without structural noise protection. Traffic noise is a form of environmental pollu-tion that has to be taken seriously.

In the context of approval procedures for implementing construction projects, the German Federal Immission Control Act stipulates binding limit values at the immission sites along new and improved roads which result in the need to construct noise protection systems. An impact analysis is followed by weighing up the protection aims to be achieved as primary cover with structural so-called active noise protection measures. Here there is a choice between noise barriers, noisereducing asphalt surfaces and noise reduction tunnels. For reasons of economic efficiency, under consideration of capital expenditure entailed in construction and maintenance together with capitalization for replacing the corresponding installation, noise barriers, also in combination with open-pore asphalt surfaces, are usually preferred for installation. Noise reduction tunnels are used mainly in conurbation areas. Additional measures which may be required in order to achieve the protection targets such as the installation of noise protection windows in combination with ventilation systems are so-called passive protection measures. The extent of passive measures should be kept to an absolute minimum in the interests of those in need of protection. Passive measures should only be used when obtaining noise protection by constructional measures is out of all proportion to the expenditure involved.

In all countries, it was possible to observe a pragmatic approach at the start of all efforts towards structural noise protection, limited solely to satisfying the demands for noise protection. Design aspects were rarely involved. State building authorities such as South Bavaria Motorway Authority, responsible among others also for a large number of noise barriers, recognised early on that these systems which in part can achieve a considerable size, have a major impact on the adjoining surroundings, and that good design can be seen as a chance to improve the traffic route.

The noise barrier is all the car driver sees along extensive stretches of road. Its design quality should therefore compensate for the inability to see the environment. As far as residents on the other side of the barriers are concerned, subtle design ideas should counteract the inherent impact of the structures. As with other public building structures, the quality and variety of noise barriers also have to fulfil high design demands. After all, a society is also defined by the way it deals with such structures in highly exposed positions. Noise barriers are also part of the building culture of their times. The monotony of standard barriers can be relieved by simple means with many interesting structures that harmonise with their surroundings.

Most erected noise barriers are standard barriers as defined early on in the regulations. For the most part, cassette-type wall elements are fitted between steel posts in a grid of 4 – 6 m. These structurally and economically optimised panels dominate our current picture of noise barriers; and thus even slight variations in style are seen as a welcome change.

In the course of our many years of experience in designing noise barriers, also in dialogue with architects, the following design principles have emerged and proven successful. Design is always based on subjective perceptions. The suggestions described below should not be seen as doctrine: on the contrary, they are to be taken as a contribution to improving design quality of engineering structures and should stimulate discussion on this issue.

The way we see it, design develops out of the choice of suitable constructions, and not just from playing around with colours and surfaces.

This article only makes marginal reference to the structural and constructional demands and requirements involved in operation. We hence refer to the comprehensive standards and regulations.

Concrete shells with aluminium cover; porous concrete – A9
Munich-Freimann

Design principles

In principle, noise barriers must not be too high, particularly in urban contexts. In addition to the already existing physical divide brought about by the traffic route, it is important to avoid imposing extreme optical barriers within a town area. Many road users and pedestrians in the town will perceive the barriers mostly on a subconscious level. The structures therefore also have the role of being a self-confident representative of the area they are protecting.

Noise barriers should generally be no higher than 9 m or at maximum 6 m when installed on embankments. There must always be a balanced height ratio between embankment and barrier, with the em-bankment higher than the barrier.

On the side of the barrier facing the road – given the relative speed with which road users drive past – a relatively calm barrier surface should be chosen. Avoiding vertical elements in the structure results in a desirable optical elongation of the barrier, making it seem lower and more dynamic.

On the residents' side, the noise barrier is viewed on a more stationary level, so that greater structuring is desired. Together with horizontal elements e.g. for fastening climbing aids, vertical elements can also be used and be in a geometrically balanced ratio to the barrier height or to the horizontal barrier sections.

Specific vegetation along the noise barriers is desirable on both sides. It is important that this does not lead to overgrowth: instead, the barriers should be enhanced by suitable plants at deliberately chosen intervals. Vegetation must not impair maintenance of the barrier; in addition, the overall visual effect should be of a well-tended system.

The height of many noise barriers is often an exact reflection of the results obtained from the acoustic calculations. These frequently result in a highly varied range of heights which should certainly not be implemented in the actual structure. The many corners and edges lead to surfaces appearing arbitrary and elusive. Changes in height should be kept to a minimum and designed with great care. It is most favourable to generate calm and self-contained barrier sections with constant height. Coupling elements for these barrier sections are for example short slide-over shear panels set in front of the basic layout and connected to the barrier section with transparent cross bulkheads. An optical separation of sections of different height can be obtained by transparent coupling elements.

A suitable geometry is also important in the basic layout. The aim must be for the noise barrier to run parallel to the roadway as far as possible. Changes in axis should be produced by transparent cross bulkheads for example, rather than twisting the barrier itself.

On bridges, transparent elements should be used as much as possible so that the outer effects of the bridge design are not unnecessarily weakened by the attached noise barrier. A smaller grid is required when anchoring the posts on the bridge structure compared to the open road, which also fits in when rating the dimensions of the transparent materials.

Designs

Noise barriers on the road side up to 6 m in height

In addition to cassette-shaped or large-scale aluminium panels, noise barrier elements can also consist of reinforced concrete slabs, which can be produced as precast parts with quality control and are very economical. Another advantage is the high mass of such elements which effectively counteracts the passage of sound. Concrete is a well tested durable material frequently used in road structures that copes extremely well with the aggressive ambient conditions.

Standard construction methods consist of sliding the individual elements into position between steel posts. The surface of the smooth concrete initially reflects the sound. The high absorption level the surface is expected to fulfil and the poor design quality in this state require screening of the wall. Among others, this can consist of aluminium front-mounting elements that also cover the posts.

As an alternative, it is also possible to use concrete slabs with an integrated front-mounted shell made of porous or timber-concrete composite, which satisfies the acoustic requirements. In this case, it also helps to position the elements over the posts as well, at least on the road side of the barrier. On the other side, the visible posts are not a hindrance and tend to lend a structure to the wall, as long as there is a balanced width-to-height ratio.

For low barrier heights of up to approx. 4 m, it is possible to manage completely without steel posts when using concrete slabs. The individual elements are positioned directly next to each other. Their connection reinforcements at the end of the slabs are embedded in the receptacles of the steel piles. The neighbouring elements are each connected at their base points, resulting in a cohesive barrier where shrinkage and temperature effects have to be verified also in longitudinal direction. Joints therefore have to be provided in the barrier at certain intervals. Meticulous design and precise verification of the base points are vital prerequisites for the durability of these structures.

Noise protection barriers can be structured easily by offsetting the steel posts from the barrier surface. This results in varied physical structures on one side, with calm continuous surfaces on the other.

Meanwhile, aluminium elements are available with a smooth and corrugated surface, also offering highly absorbent characteristics. State-of-the-art for many manufacturers is to slide the outer screening over the posts. Many structures have also been reinforced to cope with the snow thrown up by snow ploughs in the winter months. The numerous new products offer a wide range of good design possibilities.

Noise barriers on embankments

On embankments it makes sense to screen the concrete elements with picket fencing. Here the wooden parts are not exposed to constant moisture penetration from water splashing up from the road surface, while at the same time their material forms a natural link to the countryside.

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1 **Concrete barrier with aluminium front-mounting shells – motorway A99 /** Allach
2 **Free-standing concrete barrier –** Munich-Lochhausen
3 **Timber-concrete composite with glass structures for the A96 motorway** bridge over the river Lech near Landsberg
4 **Porous concrete wall with posts on the back: motorway A9** Eching – seen from the outside
5 **Porous concrete wall with posts on the back: motorway A9** Eching – seen from the motorway

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Picture credits: SSF Ingenieure GmbH

Concrete noise barrier with posts set in front – wire mesh screening – motorway A9 / Munich -Fröttmaning

Aluminium cassettes with screening over the posts: motorway A8 west / middle barrier on the bridge over the Lech in Augsburg

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1 Retaining wall with aluminium screening, embankment, concrete noise barrier with wooden battens and aluminium fitted to the side, height: 13 m; motorway A9 / Garching
2 Composite glass noise barrier on wildlife crossing – Rote Tor bypass AugsburgAugsburg
3 Acrylic glass wall on a steel bridge: motorway A3 / Bridge over the Danube at Schalding
4 Acrylic glass noise barrier fastened at individual points: motorway A96 / Freiham junction
5 Acrylic glass noise barrier fastened at individual points: motorway A8 west / Lechbrücke Augsburg
6 Large-sized aluminium elements: motorway A99 / freight bypass flyover near Allach

Noise barriers on building structures

Noise barriers should be transparent when fitted on bridges. The reflecting surfaces may make it necessary to tilt the barrier surface to the outside to rule out multiple reflections between the two noise barriers facing each other on either side of a bridge.

Composite glass panels and synthetic panels made of transparent acrylic have proven to be suitable here. Composite glass is much stiffer than acrylic with less deformations. Very large panels can be fitted and panels fastened at individual points. These need less steel substructure. Scarcely any dust settles on the very smooth surface, with rainfall cleaning the glass panels to a certain extent. However, the brittle behaviour of the material can cause problems, and unfortunately, damage to the panels from vandals cannot be ruled out. However, the composite structure can usually prevent total failure of the system as a rule.

Acrylic panels can be produced with integral polyamide filaments to give the material a high level of ductility.

Until a few years ago, the state-of-the-art method for fastening these structures was by linear attachment clamped to the steel posts. Thanks to an initiative by the South Bavaria Motorway Authority, Degussa has meanwhile developed a method for fastening acrylic glass panels at individual points.

SSF Ingenieure designed and implemented an alternative to this method of attachment as part of a building project.
If elements with high absorption values are required on building structures, aluminium elements will have to be used here because of the weight aspect. Largesized elements should be fitted between the steel posts in such way as to conceal the posts. In this case, a horizontal structure is urgently required on the outside so that the noise barrier system on the bridge does not appear too high and too oppressive.

Special areas

In many cases the need arises to close the gaps caused when interrupting noise barriers, for example at underpasses of the

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1+2 Noise protection bridge with planar glazing fastened at individual points: motorway A9 / underpass Schleißheim canal near Garching (Munich)
3 Transparent cross bulkhead at a wide underpass structure: motorway A9/ Garching – B471 underpass
4 Concrete wall with posts in front: wire mesh screening: motorway A9 / Munich-Fröttmaning – here view from the back with overhanging composite glass panels 2 m high
5 Noise protection bridge next to an underpass with scaled glazing and noise protection shell along the top: motorway A9/ Munich-Freimann: Heinemannstrasse underpass

motorway. As a rule, transparent noise barriers are mounted on the underpass caps and connected to the embankment by cross bulkheads. At relatively narrow underpass structures, the cross bulkhead sections will dominate, often resulting in the rather unsatisfactory impression of a bastion. Here it is far more elegant and also more economical to produce a noise protection bridge made of transparent material that connects the two ends of the embankments in their own axis. The example shown here features planar glazing with relatively large composite glass panels fastened at individual points over the Schleißheim Canal which is under a preservation order. The share of the steel substructure has been reduced to a minimum.
Alternatively, a noise protection bridge can be constructed which slants in the slope of the embankment with vegetation on the road side. The embankment is thus extended by the structure without a break.

In built-up areas, the gap between the embankments often has to be closed completely for noise protection reasons.

Relatively high noise barriers are usually very close to buildings. To reduce the shadow effect to a tolerable level, glass sections can be used in the upper part of the barrier. Composite glass panels can be fastened particularly well to concrete elements. The upper line of glazing elements needs no additional steel substructure and offers maximum transparency.

In the course of construction on existing bridge structures, noise barriers often have to be continued across traffic routes. From a certain barrier height, these can no longer be anchored on the existing bridge caps. Remedies consist of noise protection bridges right next to the underpasses. Reinforced steel beam frames have proven effective as load-bearing structures, e.g. on deeply founded round supports.
The contours of the underpass structure can still be seen when transparent elements are fitted to the beam with opaque noise protection elements on top if necessary. The line of glazing in the middle relieves the stringent appearance of the overall structure with an added dynamic effect.

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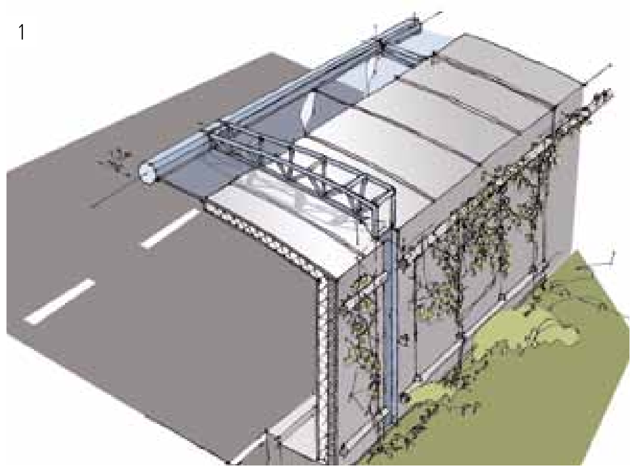

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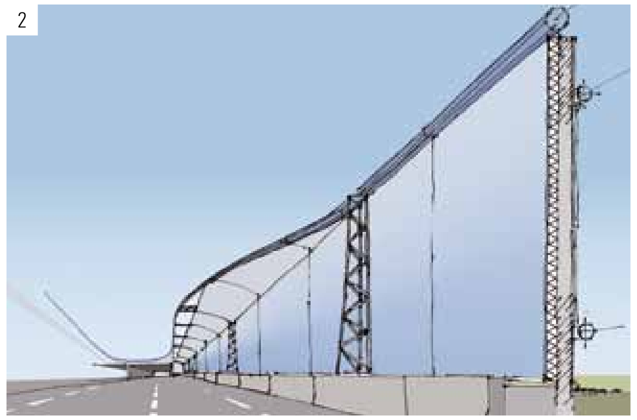

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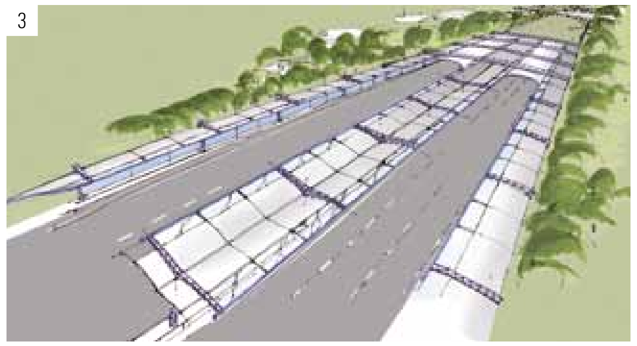

1 Project study offset barrier: expanding the motorway A 7 / Hamburg
2 Project study offset barrier: expanding the motorway A 7 / Hamburg
– here showing the transition to noise reduction tunnels
3 Project study offset barrier: expanding the motorway A 7 / Hamburg
– bird's-eye view, transition to noise reduction tunnels

High noise barriers

Noise barriers exceeding 6 m in height need to be designed with particular care and attention. These are large engineering structures that have to undergo regular inspection and maintenance in the same way as bridges. This must be taken into account in the design stage, together with the requirements for producing the structures under confined conditions with flowing traffic.

Regulation ZTV-Lsw 06 does not stipulate the need to rate the designs for vehicle impact. Even so, consideration should be given to vehicles straying from the road. Rating the design for vehicle impact is always uneconomical for linear structures, so that the safety aspect has to be addressed by choosing corresponding vehicle restraint systems in combination with redundancy in the design.

Together with structural verifications, it is vital for individual components (e.g. connection parts) to be assessed under dynamic impacts as well.

As the height of noise barrier elements increases, the demands made of posts and foundations are increased by the power of 2. The relative costs of high noise barriers per m² barrier area are therefore always greater than for conventional heights. In many cases, it is no longer possible to anchor posts directly in the piles because of the large anchor forces involved. These can be remedied by a continuous pile head beam on which the posts can be anchored at intervals to the piles. The costs for the beam increase the unit prices even more.

Great attention has to be paid to the design of these barriers. As a general rule, noise barriers should not be higher than 9 m. This already corresponds to the height of a three-storey building. If the noise protection aims cannot be achieved with this height, it is better to bend the upper edge of the noise barrier towards the noise source. This can consist among others of shaping the barrier elements with a concave rounding on the road side to absorb as much noise as possible, or by offsetting the top part of the barrier towards the roadway.
Physical elements should be generated to give the wall sufficient structure and minimise its perceived height. In the case of very high systems with protruding sections, the use of transparent materials is appropriate for generating a certain transparency and lightness.

Outlook

Comprehensive active noise protection can only be provided by noise reduction tunnels over the traffic routes. With high noise barriers rather good results can be achieved at low situated immission sites.

Noise reduction tunnels exceeding 80 m in length have to be equipped with a high level of safety features increasing costs immensely. Up to now, conventional solid tunnels have proven to be the most favourable solution in terms of overall costs – production costs and maintenance.
Efforts have been and still are being made to design „light" and thus low-cost noise reduction tunnels. However, require-ments in terms of operational safety and fire protection always implicated costs much higher than expected.

SSF Ingenieure is following a new course with the design of „light" noise reduction tunnels. The almost fully developed structure leads for the first time to the prospect of reduced overall costs. Still, even this very economical tunnel would bind more resources than high noise barriers.

In future noise barriers will keep their importance as economically efficient constructions. They are combined very efficiently with open-pore asphalt which reduces tyre noise at the source. The potential savings, relatively high compared to continuous tunnelling of traffic routes, implicate in return the commitment to obtain high quality in design and construction. The acceptance of a traffic route is always in direct context with the aesthetics and quality of the constructions.

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