Proof of usability for noise barriers with laminated safety glass along railway lines

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Introduction

Noise barriers are a common measure to protect the public from railway noise. A standard noise barrier consists of metal posts and noise-reducing elements mounted between the posts. The elements are usually made of aluminium or of concrete and need to be highly absorbing. As noise barriers interfere with the land- and cityscape, residents often ask for less obtrusive designs, e.g. transparent noise barriers. This is one reason that drives development of new types of noise barriers or noise-reducing elements. Other reasons are reducing costs and maintenance effort, using more environmentally friendly materials and reducing the carbon footprint. Furthermore, there are various ideas to design noise barriers with an additional benefit like photovoltaic elements.

From an acoustician's point of view, it is obvious that new noise barrier designs need to fulfil the acoustic requirements necessary for adequate noise protection. The DB guideline 804.5501 [1] specifies requirements for sound insulation and absorption. Sound insulation is measured in a building acoustics laboratory according to DIN EN ISO 10140-2 and sound absorption in a reverberation room according to DIN EN ISO 354. Highly absorbing noise barriers are important because a reverberant sound field is created between the noise barrier and the large reflective surfaces of the car bodies of a passing train. This poses a challenge when designing transparent barriers as transparent materials are reflective. Transparent noise barrier designs with absorbing properties were the subject of a former research project [2, 3]. Although an interesting and relevant subject, it is not the primary focus of the present paper.

The present paper aims to raise awareness for non-acoustic requirements for noise barriers along federal railway lines that are of equal importance. These requirements are very strict, because safe railway operation needs to be ensured at all times. Noise barriers need an approval from the Federal Railway Authority and DB InfraGO AG. This approval process can be complex, which is one of the reasons why the range of noise barriers currently in use is limited. For example, there is only one transparent material with an approval for use in noise-reducing elements: acrylic glass (PMMA). Therefore, the German Centre for Rail Traffic Research (DZSF) initiated a research project on laminated safety glass (LSG) as infill for noise-reducing elements.

Project: Noise-reducing elements filled with LSG for use along railway lines

LSG is a compound material made of silicate glass and a splinter-binding intermediate plastic layer, see figure 1. It is highly transparent and has a high stiffness and physical stability. High transparency is relatively easy to maintain due to low dirt accumulation and high resistance to chemical substances, which facilitates cleaning. Because of these properties, LSG is a promising material for transparent noise barrier elements. However, it has no approval for use along federal railway lines.

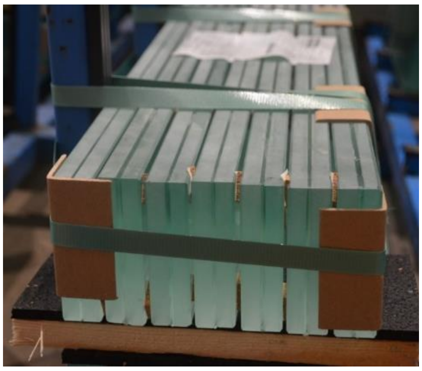

Figure 1: Small samples of laminated safety glass made out of two silicate glass panes and an intermediate plastic layer (photo: MFPA Leipzig).

The aim of the approval procedure is to demonstrate that a new noise-reducing element type can withstand typical loads and impacts occurring along railway lines. This involves many laboratory experiments. The Federal Railway Authority provides a guideline regarding these experiments (EBA-guideline) [4]. Currently, it covers aluminium and concrete elements as well as transparent PMMA-elements. The chapter on experiments for noise-reducing elements with LSG infill is left empty. In order to add this chapter, the DZSF initiated the research project "Nachweisführung zur Verwendbarkeit von Scheiben aus Verbundsicherheitsglas (VSG) als Ausfachung von Lärmschutzwandelementen zur Anwendung in Lärmschutz-anlagen in Pfosten-Element-Bauweise" [5]. The project title translates approximately to "Verification of the usability of LSG-panes as infill for noise-reducing elements for noise barriers".

The project has a duration of three years (2021-2025) and is carried out by MFPA Leipzig GmbH. It consists of four work packages:

1. Analysis of the applicability of existing national and international standards and the state of the art,
2. Analysis of the loads acting on noise barriers along railway lines and derivation of a testing programme for elements filled with LSG,
3. Examination of the suitability of the testing programme using small sample sizes,
4. Validation and examination of the suitability of the testing programme using full-scale elements.

Non-acoustic requirements and loads acting on railway noise barriers

Non-acoustic requirements for noise barriers include load-bearing capacity, serviceability (e.g. maintaining transparency) and durability. The requirements depend on potential loads and impacts as well as the useful life, which is assumed to be 50 years [1]. Noise-reducing elements are exposed to potential damages, e.g. impacts from stones. Visual inspections take place at regular intervals to detect these damages. It is important that the residual load bearing capacity after a damage is sufficiently high, so that the damaged part causes no danger until it is detected and removed.

The following list gives an overview of typical loads and impacts acting on railway noise barriers [6]:

- Self-weight,
- Climate induced loads: thermal actions, wind, rain, snow, ice, UV radiation,
- Ambient influences: chemically active substances, road and sea salt, dirt water, dust, ground-borne vibration, rock fall,
- Operational loads (specific for rail traffic): train operation, snow clearance, impacts from flying ballast stones and ice falling from trains,
- Other loads: maintenance work, vandalism, brushwood fire.

It is important to note that railway operation results in much higher dynamic loads than road traffic, due to pressure-suction waves caused by passing trains. These dynamic loads can lead to material fatigue and increase with train speed. Therefore, the maximum line speed is an important criterion when testing the suitability of noise-reducing elements.

Verification procedure for LSG-elements

The project developed a verification procedure for noise reducing elements filled with LSG based on the loads acting on railway noise barriers and an extensive review of literature as well as national and international standards and regulations. A sketch of the testing programme and an overview of relevant standards can be found in [7].

The testing programme consists of three sections. The first section comprises tests to determine the material properties of the silicate glass and the intermediate layer (identification tests). The second section comprises tests with small sample sizes of LSG, e.g. load capacity with and without pre-damage and fatigue strength. Because the properties of the intermediate layer and thus of the compound material are temperature-dependent, the tests are carried out at three different temperatures to account for winter and summer conditions (-30 °C, +20 °C and +50 °C). The third section comprises tests with full-scale elements consisting of a frame and the LSG-infill. Besides load capacity and fatigue strength, stone throw resistance is tested. Figure 2 shows small sample sizes in comparison to a full-scale noise-reducing element.

Figure 2: Left: two sizes of small LSG samples; right: full-scale noise-reducing element (5 m x 1 m) consisting of a metal frame and LSG infill (photos: MFPA Leipzig).

Work packages 3 and 4 validate the testing programme and analyse its suitability. So far, the results look very promising. They will be published in detail in the project final report, which will be available on the DZSF website. The present paper gives a couple of examples to illustrate the complexity of upscaling experimental setups from small sample sizes to full-scale.

Figure 3 shows the experimental setup for testing the bending load capacity of a small LSG sample and the complete noise-reducing element. The full-scale test requires distributing the load over eight pads. The project simulated the pad arrangement prior to testing in order to achieve a realistic load distribution.

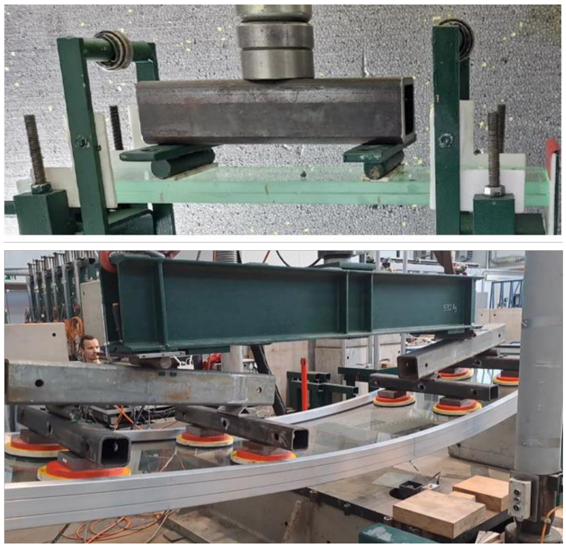

Figure 3: Testing the bending load capacity of a small LSG sample (top) and the full-scale noise-reducing element (bottom) (photos: MFPA Leipzig).

Figure 4 shows the experimental setup for fatigue testing on a small glass sample and the complete noise-reducing element. Prior to testing, the project had to determine an appropriate frequency and amplitude for the load cycles. A high frequency reduces the time needed for testing but could lead to heating of the intermediate layer. Similar to the bending load capacity test, the load needs to be distributed over eight pads. As the forces are higher, exciting the noise-reducing element requires much bigger machinery.

Figure 4: Testing fatigue strength of a small LSG sample (top) and the full-scale noise-reducing element (bottom) (photos: MFPA Leipzig).

Outlook and conclusion

The project developed a verification procedure for noise reducing elements filled with LSG for use along federal railway lines. At present, final tests are carried out to validate the developed procedure. If successful, the project results are going to be included in the EBA-guideline [4] by adding a chapter on experiments for LSG-elements. Manufacturers can then use the guideline to test noise-reducing elements with LSG and to obtain an approval for field tests under real operating conditions. These field tests are a prerequisite to obtain a full approval from the Federal Railway Authority and DB InfraGO AG.

The present paper shows that the development of noise barriers is far more than just acoustics and meeting the non-acoustic requirements can be challenging especially for application along main railway lines. When designing new noise barrier types or elements, it is important to consider acoustic and non-acoustic aspects from the beginning in an interdisciplinary approach.

Literature

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