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DOI: 10.35117/A_ENG_16_11_03

## Subgrade protection in urban environment

**Abstract:** The paper deals with protection of subgrade in densely built areas. Chosen aspects of urban rail transport were described. General principles of vibration protection were highlighted. Short comparison on vibration properties of ballasted and slab track was presented. An example from Bochum – Langendreer was described. The paper ends with final conclusions and summary.

**Keywords:** Vibroinsulation; Slab track; Urban rail transport

### Introduction

The currently observed trend of development of communication links focuses on heavily urbanized areas. Due to the collapse of spatial planning, uncontrolled sprawl of buildings on peripheral areas and suburban, as well as long overdue investment, new routes of public transport are built most frequently as an extension of existing lines. There are also cases changing the existing routes because of the emergence of a more intensive development beyond the attractiveness of the existing routes. In many places, there is the lack of sufficient field reserves for the transport corridor, which causes significant proximity of tracks or roadways to the existing buildings. In addition to specific surface structures, in such locations, it is necessary to use appropriate measures to protect the ground in order to minimize the negative impact of the new route because of vibration and noise in the environment.

### Possibilities of protection against vibration

The basic protection means in rail transport are all sorts of elements with elastic - damping characteristics. A longer tradition have components dedicated to conventional ballast surface, where e.g. subrail poplar spacers have been used for many decades, until the spread of plastic with sufficiently high performance. Despite the continuous development, the classic pavement faces significant constraints, which reduce its usefulness in extreme applications, such as high speed railways, railroads with very large axial pressures and urban rail transport. Since the most of the drawbacks of such a track is caused by the layer of crushed stone [9], intensive research and development of the non-ballast pavements were started in the mid-twentieth century. Relatively quickly it was found out that these systems are not without drawbacks because they require very high quality, have little opportunity to adjust, and above all they are characterized by larger vibration and noise than classic paving. This is due to the replacement of the ballast relatively good damping vibration by the layer of concrete. Therefore, it is necessary to supplement the paving slab by at least one type of vibration isolating elements, now made from plastic that contains relevant characteristics of materials [1]. They include subtrack mats, elastic support of sleepers and spacers (elements placed between the fastening plate, i.e. essential ribbed pad, and sleeper or a concrete slab of the pavement), but their use in new projects and realizations is not yet widespread. Knowledge about the application of such means in industry is still random and fragmented. A slightly better approach is the use of solutions for complete systems, however, they are also characterized by a volatile due to the adaptation to various conditions. Meanwhile, for efficient work of surface and substructure, the accurate and based on engineering grounds selection of appropriate products with the indicated characteristics is key. Neglect of basic requirements in this regard may lead to deterioration of the track impact on the environment in relation to the structure operated in the same place before the renovation. It should also be emphasized that the use of vibro-protection means in the construction of rail roads, reduces vibration and secondary noise, which is associated with the difficulty of transmission through the elements dispersing energy in the vicinity of emission sources [2]. At the same time, the impact of such means on the original noise level remains virtually unnoticed, and these concepts are often confused, as in [5]. Significant threat lies in the mismanagement of selected techniques of isolation, because excessive conquest of the third octave bands in the lowest frequency (about 5 Hz) can lead to resonance with the elements as walls or ceilings of buildings adjacent to the tracks and result in exceed of values indicated in the standards [6] [7] and, in extreme cases, worsen the situation in relation to that before the renovation.

**Example of Bochum Langendreer**

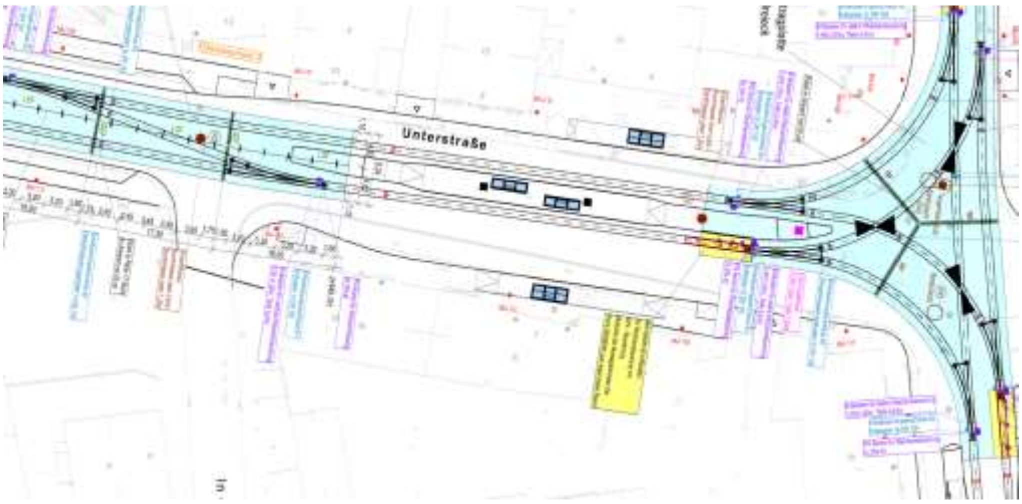
The tram line 310 connects located in the Ruhr estate Höntrop and Witten, running essentially latitudinaly. In the years 2009 - 2011, in order to better link the different elements of the transport network of the region, it was decided to partially change the course of the line. Currently, from the Unterstrasse at the intersection of Unterstrasse and Universitätstrasse to stop Crengeldanz on the outskirts of Witten, tracks run mainly along the A44 motorway corridor, which is also the edge of the building. As a result of the changes to the route new seven stops will be built, and its progress will be significantly extended in order to service the entire city Langendreer along the streets Unterstrasse and Hauptstrasse. Such a decision was taken due to the expected large passenger flows - despite a moderate population Langendreer of approximately 25 thousand people. The parameter determining the change of the route is relatively high population density (2,101 persons/ $km^2$), comparable with e.g. Wroclaw (2,160 people/ $km^2$). What is important from the point of view of traffic management, the essentially one-track segment with a short turnout on the viaduct over the motorway route will be replaced by the fully two-track line. A special element among tram or light rail lines will be service of indirect switch located at the railway station Bochum - Langendreer to better link the tram and S-Bahn (S-Bahn). Pass through this stop is associated with the change of front of the vehicle. Analysis of this solution leads to the conclusion that it is reasonable extension of routes to handle the large traffic, which is confirmed e.g. in [3].

To connect the branch of route leading to the north towards the station Bochum - Langendreer with the basic course of the route, twisting from the latitudinal Unterstrasse to Hauptstrasse situated in south, it was necessary to construct a junction node. It was decided to conventional two-track system in a T-shaped, with additional track connection (i.e. the semi-trapeze pass) outside platforms within Unterstrasse. In the node were located two groups of stops; within Unterstrasse there are tram stop island and located to it parallel, two bus stops in sidewalks, while two stops in the form of one-edge islands are located externally to the track in Hauptstrasse.

Due to the close location of large building to the tracks, in places not exceeding 4 m, and the nature of the building (residential and service), it was necessary to achieve a low impact on the environment. The object of particular concern was the half-timbered house from 1812, situated close to the intersection. According to the assumptions described in [4], the impact of vibration on buildings and people in buildings with such small distances is very large. It is estimated that the impact zone for passenger traffic extends to 35 m in the case of buildings and 65 m considering perceptibility by man, whereas for freight and mixed traffic the distances are 45 m and 80 m, respectively. Due to the minimum distance from buildings and related forecasted significant impact, a detailed analysis was conducted [8], where certain basic parameters as the desired thickness of the mat, the static and dynamic rigidity were determined. Given the small cross-section of the street, it became apparent the need to place all media, including gravity sewers, under the plate of mass-elastic system. Since there was a damage risk of the individual conductors and connections, it was decided to increase the thickness of the foundation layer made of aggregate with efficient drainage in the form of 2 - 4 series, depending on the location. Alternatives in this case, could be the system mass-elastic surface-supported, lying on band supports, the elastomeric point supports, steel and combination supports, i.e. elastomeric-steel supports. Due to the fact that there are many underground installation, it was decided to apply the solution with the smallest possible thickness of the construction.

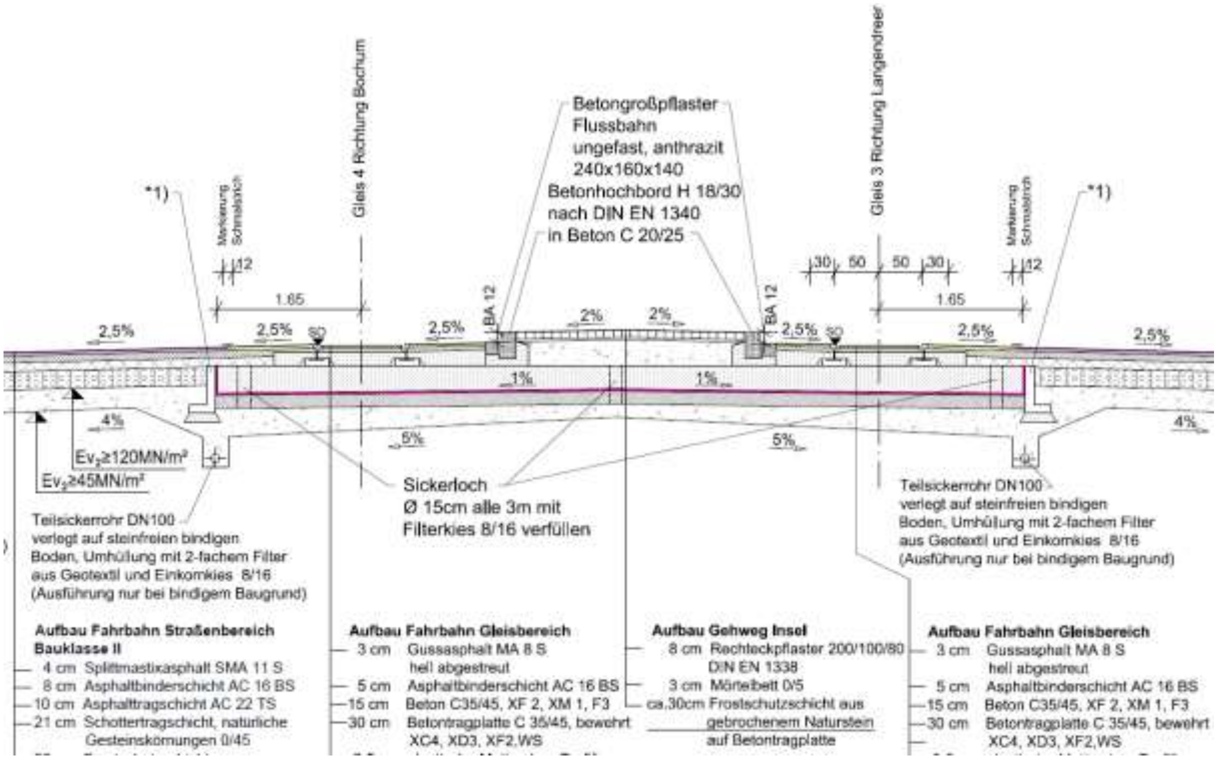
**Mass – elastic system**

In view of the findings contained in [8], the two key areas, i.e. junction node and semi-trapeze with their crossovers and crossings were made in the form of light surface-supported mass - elastic system. Plates of node and semi-trapeze were divided into three parts, wherein in the node, segments have adopted the shape of deltoids meeting by their tops, whereas in semi-trapeze - rectangles arranged in series. They were connected to each other by expansion joint bolts, spaced 25 cm, as is shown in Figure 1. In some places, was also used the full coating of rails and track crossbars using elastic elements in RCS system, which consists of perforated rubber profiles.




**1**. Plan of track system with an indication of the area of application of the mass - elastic system (blue colour), Bogestra 2013

On the concrete floor and side walls it was arranged anti-vibration mats, which served both as formwork for the support plate of the tracks (Fig. 2). It was decided on the profiled mats USM 2020, which require laying on a flat supporting surface, but with flexible cones, regularly disposed on a lower surface, there is completely predictable and linear response to load changes. Smaller items as wells are covered with double-sided smooth mat made of rubber granules. To avoid a large amount of cuttings, the mat was laid from the roll longitudinally to the future course of tracks (Fig. 3.4). Since the mat has at one edge a protective sleeve with the width of 10 cm, there was no need for an additional protective geotextile laying on the upper surface of the vibration isolation. To protect against penetration of concrete mix between the cones, the sleeve was attached by building stapler to an adjacent surface. The construction was completed in August 2015.




**2**. Cross-section of the street Unterstrasse system showing mass - elastic system, Bogestra 2013

**3**. General view of the assembling mass - elastic system: folding of horizontal anti-vibration mat on a prepared surface, phot. Calenberg Ingenieure


**4**. General view of the assembling mass - elastic: stage system: folding of vertical anti-vibration mat and connecting profiles, phot. Calenberg Ingenieure

Thanks to the relatively shallow system it was avoided not only a profound interference with underground installations. Since the mass - elastic construction is supported by the surface and set on a uniform bearing concrete layer, pressures on the ground base under the construction of the track and the road were minimized and levelled. Therefore, during exploitation of the track should be expected small and uniform settlement of the structure. It should be noted, however, that despite these advantages, the size of the entire bearing plate in conjunction with its monolithic character causes significant difficulties with access to underground installations, in the case of their replacement or repair.

**Summary**

Polish cities will lead in the coming years, intensive renovation and reconstruction of infrastructure of rail and tram transport. In both cases, there are many locations where the impact generated in tracks substantially exceed the requirements allowed by standards. The same store in the project, the need to carry vibroacustic security does not yet solve the problem. Dangerous is also thoughtless transfer to Poland solutions from Western countries, and copying designs and requirements for vibration isolation for a variety of investment tasks. It is important to introduce the effective, based on the engineering assumptions, calculations and computer modelling, selection of appropriate systems to ensure sufficiently large decrease in the level of interaction in all one-third octave bands. Only such a solution will mean improving the comfort of the residents and increase in the durability of the structure.

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