Feasibility study on railway structures with a light-weight EPS sub-base

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Summery

The subsoil in the Netherlands consists of poor to very poor civil engineering characteristics. Building embankments for railway structures in the traditional way on such subsoil is time consuming. Light-weight materials like Expanded PolyStyrene (EPS) could solve this problem. On the basis of the results of the use of EPS in the pavement structures a feasibility study is set up on light-weight rail structures with an EPS sub-base. An EPS sub-base contributes not only to the reduction of the dead weight of the rail structure, but could also improve both the noise and vibration damping. Because of the very low bearing capacity of EPS a concrete slab must be put in the structure. The first static calculations showed that the thickness of the concrete slab could be very reasonable.

Samenvatting

De draagcapaciteit van de ondergrond in Nederland is voor een groot gedeelte slecht tot zeer slecht. Het bouwen van een zandbed voor een spoorconstructie is erg tijdrovend. Lichte ophoogmaterialen zoals EPS zouden dit probleem kunnen oplossen. Aan de hand van de resultaten van het gebruik van EPS in wegconstructie is een haalbaarheidsstudie opgezet om het gebruik van EPS in een spoorconstructie te onderzoeken. Een EPS funderingslaag draagt niet alleen bij tot een reductie van het eigen gewicht, maar kan ook een gunstige bijdrage leveren aan de geluids- en grond dempende eigenschappen van de constructie. Vanwege de erg lage draagcapaciteit van EPS moet er een betonplaat in de constructie worden toegepast. De dikte van deze betonplaat is op basis van de eerste statische berekeningen zeer acceptabel.

Table of contents

1 Introduction

Considerable large and heavy populated areas of the western and northern parts of the Netherlands consist of subsoil with poor to very poor civil engineering characteristics. For carrying railway structures it is needed to improve the soil by building embankments. The building of embankments for road and railroad on such soft saturated subsoils in the traditional way is time consuming. The main problem is pressure of the dead weight on the subsoil, what will cause extreme settlements in the subsoil. To reduce the extent of the settlements, it will be necessary to reduce the dead weight of the rail structure. In this way a balance in weight of the excavated soil with the weight of the railway structure can be achieved.

Extremely light-weight material such as Expanded PolyStyrene (EPS) geofoam has the potential of solving the problem described above. In the last decennia EPS has been applied to a still increasing extent for light-weight building purpose, especially in pavement structures. However, there is no adequate experience with the use of EPS material in the sub-base of railway structures. Based on the engineering judgement and in analogy with heavy duty light-weight pavement structures the implementation of an EPS sub-base in railway structures is expected to be a realistic option. The use of EPS blocks in the sub-base will not only reduce the settlements of the railway structure, but could also improve the noise and vibration damping characteristics of the construction. On the basis of the above mentioned considerations, a feasibility study on light-weight railway structures with an EPS sub-base has been set up.

In the scope of this study, performed at the Road and Railroad Research Laboratory of the Delft University of Technology, both conventional and embedded railway structures have been analysed. The first modelling of the light-weight railway structure has been performed by the multi-layer program Geotrack. This model is based on requirements, concerning the deformation of the rail and the stress and strain development of the rail structure. The calculated stress and strain values in the EPS sub-base have been compared with the boundary elastic deformation of the EPS blocks. It has been settled that the stress and strain values may not exceed the values of the elastic region. The linear-elastic region, the EPS material modulus and the stress and strain values, corresponding to the beginning of permanent deformations were determined by means of uniaxial cyclic loading tests, where the samples have been exposed to combined static and dynamic loading.

2 Material properties

In the literature [1] the characteristics of EPS described above, have been measured very detailed, therefore these values will be used in this study. For the calculations two different EPS materials are used, with densities of 20 kg/m^3 and 35 kg/m^3, respectively EPS 20 and EPS 35. The characteristics of EPS 35 will be somewhat better than the characteristics of EPS 20. The boundary of the linear-elastic region of both materials is settled by 0.6 % for EPS 20 and 1.0 % for EPS 35. The Young’s modulus of both materials, corresponding to the boundaries of the linear elastic region, is 7.5 MPa for EPS 20 and 12.5 MPa for EPS 35. The decided value of Young’s modulus for EPS 35 is a little conservative, because the survey for EPS 35 is not that thorough as the survey for EPS 20 is. The pressure strength corresponding to the beginning of the permanent deformations (yielding zone) is 50 KPa for EPS 20 and 75 KPa for EPS 35. Two important characteristics are of main interest for the durability of the EPS material. Both of them, the creep and the dynamical behaviour do not have a great influence when the applied static load respectively cyclic load will stay beneath the values described in table 1 [2]. Noted that the cyclic load, for deciding the dynamical behaviour, is applied in combination with a static load of 20 KPa.

Material	EPS 20	EPS 35
Maximum static load	20 KPa	60 KPa
Maximum cyclic load	35 KPa	60 KPa

Table 1

The Poisson's ratio what is used in this study is decided as 0.1. In the literature [1] it is noted that EPS won't affect the temperature in the pavement layer, so it can be assumed that EPS won't have a negative influence on the temperature difference in the rail, what is important in case of a continuous welded rail. Also water and freeze-thaw cycle won't affect the mechanical behaviour of EPS. In the different literature it is mentioned that the production of EPS and the use of EPS are environment friendly

On the basis of the results in the study on EPS as a light-weight sub-base in pavement structures it is assumed that a concrete slab (B35) is needed in a railway structure with a EPS sub-base. The first calculations have been made to determine the thickness of the concrete slab. The input was not only changed according to the different tracks (ballast and ballastless) but also the applied load and the stiffness of the subsoil were changed. The ballasted track was modelled with UIC 60 rails and concrete monoblock sleepers, the ballast bed had a thickness of 250 mm. The slab(B35) track was modelled as an embedded rail construction, with UIC 54 rails . The first applied load was an axle load of 225 KN (Q = 112.5 kN) conform loading category D4, the second applied load was an axle load of 150 kN, corresponding to loads of high speed lines or heavy haul lines. According to the geotechnical standards the subsoil for peat is 10 MPa, but 30 MPa is a more realistic value for poor subsoil. In this calculations both values were used.

3 Modelling

The thickness of the concrete slab will depend on the maximum acceptable stresses and deformations of the several layers. For the deformation of the rail the NS handles for a ballast track a deformation of 2 mm ± 0.5 mm. For a ballastless track no valid requirements are settled by the NS, for this structure a maximum acceptable deformation is assumed of 3 mm [3]. The first calculations showed clearly that the maximum acceptable deformation of the rail is decisive, although the stresses and strains in each layer are also limited. In the first stage of this study the maximum acceptable deformation of the rail will decide the thickness of the concrete slab.

The thickness of the concrete slab, determined by the first static calculations, is at best 225 mm for a conventional ballast track with EPS 35 and a stiffness of the subsoil of 30 MPa. The thickness of the concrete slab for a ballastless track is at best 300 mm. The stress and strain values of the EPS blocks of these both models do not exceed the linear elastic region. On the basis of these first results it can be concluded that the density of the EPS do not have a great influence on the minimum thickness of the concrete layer. Noted that these results have been achieved with only static calculations.

In the second stages of this study calculations are envisaged which also consider the dynamic behaviour of a railway structure with an EPS sub-base. For this purpose the FEM program RAIL will be used, which is able to compute the dynamic track response to moving vehicles. Another point of view is the wave propagation in the EPS sub-base, which will be important when used in a structure for high speed track. Furthermore the behaviour of an EPS sub-base in case of large (differential) settlements is handled. This will be important for transitions between engineering structures, like bridges, and plain track.

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