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Deformability of the upper zone of railroad subgrade with geotextiles

Abstract: The aim of this article is to estimate the influence of the separation geotextile, placed in the upper zone of railroad subgrade, on the deformability of the subgrade. Vertical stresses in the subgrade of the protective layer with different thickness, due to the test and operational loads, were determined. The influence of variation in two different thicknesses of geotextiles on the stiffness measurements of railroad subgrade was examined. Practical conclusions were formulated on the basis of conducted analysis.

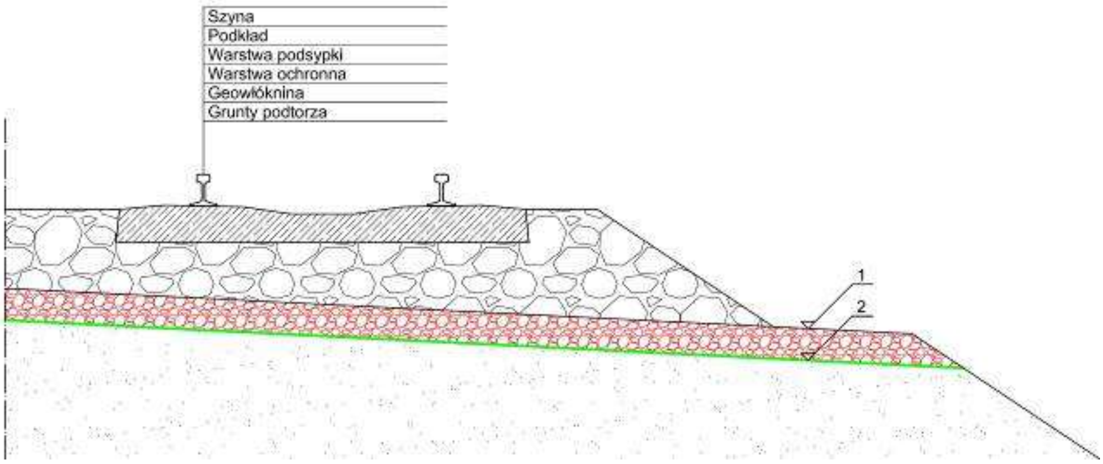
Keywords: Railroad; Subgrade; Deflected state; Geotextile

Introduction

In the course of modernization or repair work of subgrade, it happens that executors, in spite of the tasks made in accordance with the construction art, face difficulties with the preparation of the subgrade according to the required values of modules of the secondary deformation measured on the trackway. This situation happens particularly when in the construction of the upper zone of the subgrade there is a separating and separating-draining geotextile. The reason of that is the change in the thickness of geotextiles under load [2]. As a remedy for, determined in the test loads, excessive deformability of rebuilt substructure containing geotextile, it is proposed the modification of dimensioning method of protective layers or liberalization of acceptance requirements [2,3,4]. Implementation of the suggested methods can: require thicker protective layers and ultimately lead to the use of expensive reinforcement the structure. It may also complicate receiving research. Moreover, it can cause that the rebuilt subgrade will be characterized by greater deformation in dependence on local soil and water conditions. Therefore it is advisable to search for other solutions enabling application of geotextiles in the upper zone of the substructure so that as a result it was durable and comply with the requirements. One may use a material (e.g. geotextile) with adequate characteristics to realize functions assumed by it and at the same time securing the receiving structure satisfying the receiving requirements of the subgrade.

Geotextiles in the upper zone of subgrade

Geotextiles are textiles made of polyester fibres (PES) or polypropylene (PP) by mechanical (needling or stitching), heat (welding) or chemical (bonding) combining [1]. Geotextiles are placed over the whole width of the track under the protective layer in the upper area of the subgrade (Fig. 1). They are used mainly to play a separation, filtration or drainage function. Selection of parameters geotextiles should be dependent on their purpose and fulfilled functions, because, depending on the type of fibre used and the manufacturing process, at the same surface mass, geotextiles are characterized by different properties, i.e. mechanical strength, porosity and water permeability [1]. Basic requirements for separation-filtration geotextile laid under the protective layers of track [6.12] are shown in Table 1.



1. The cross-section of subgrade strengthened by geotextile

Tab. 1. Required parameters of separation-filtration geotextile laid under the protective layer [6,12]

Property	Research method	Required value
surface mass	PN-EN ISO 9864	≥ 250 g/m^2
resistance to static puncture	PN-EN ISO 12236	≥ 2,0 kN
resistance to dynamic puncture (hole diameter)	PN-EN ISO 13433	≤ 20 mm
tensile resistance	PN-EN ISO 10319	≥ 16 kN/m
elongation at break		50-100 %
water permeability in the direction perpendicular to the surface of the product	PN-EN ISO 11058	≥ 1 x 10^{-4} m/s (separation) ≥ 5 x 10^{-4} m/s (drain water)
The ability of the water flow in the plane of the product at the pressure of 20 kPa	PN-EN ISO 12958	≥ 5 x 10^{-4} m/s (drain water)
pore size O_{90}	PN-EN ISO 12956	0,06 – 0,12 mm (cohesive grounds) 0,08 – 0,20 mm (non-cohesive grounds)
thickness at a pressure of 20 kPa	PN-EN ISO 9863-2	≥ 15xO_{90} mm

Measurement of subgrade deformability

Deformability of the substructure is determined during the load test. The test apparatus consists of: a rigid steel plate with a diameter of 300 mm, hydraulic jack supplied with a manual oil pump with pressure gauge, displacement sensors, and a stand constituting the reference level. During the test, two cycles of loading and unloading the disc are performed. The load of the plate is carried out with steps of 0.05 MPa up to the maximum load (p_{max}). Relieving is carried with steps of 0.10 MPa. The maximum load value and load interval (Δp), from which the deformation moduli are defined, depend on the type of subgrade. The study determined the value of the initial deformation modulus (E_1) from the first load and a secondary deformation modulus (E_2) from the second load [6]:

$$E_{1,2} = 0{,}75 \cdot \frac{\Delta p}{\Delta y} \cdot D \quad (1),$$

where: $E_{1,2}$ – initial ($_1$) i secondary ($_2$) deformation modulus [MPa], Δp – load interval [MPa], Δy – difference in settling plate in the assumed load interval [mm], D – diameter of the measured plate [mm]

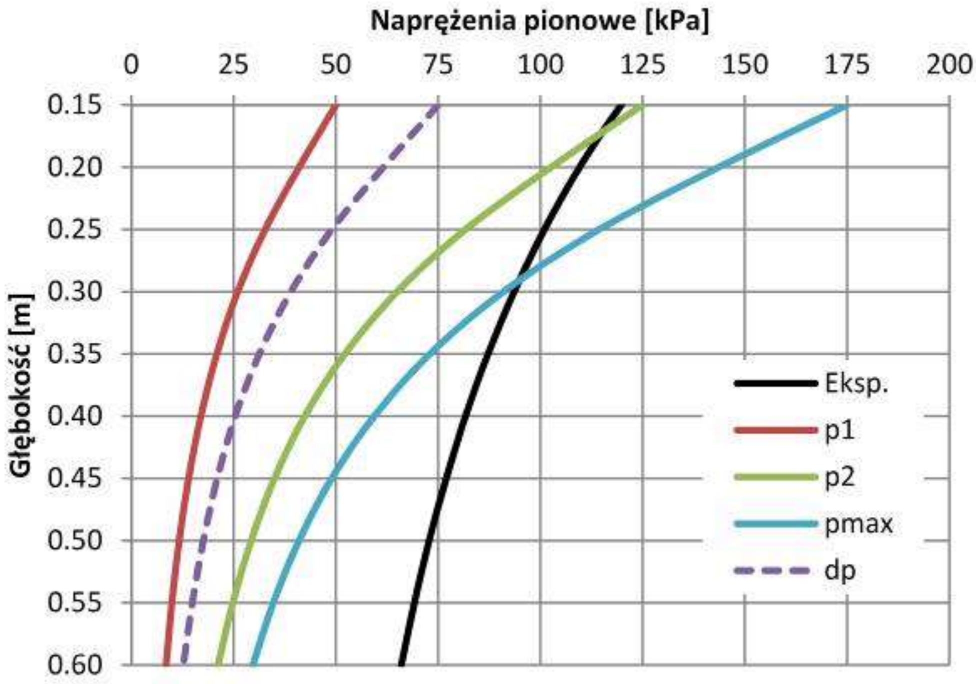
Stresses in the subgrade

In order to determine the pressure exerted on the geotextile in the subgrade, we determined the vertical stresses in the subgrade resulted from the exploitation load and load by circular rigid plate.

The calculations were performed by treating subgrade with the protective layer as a half-space, limited from the top by the tracks and extending infinitely deep. In determining the stress of the external load it is assumed that the subgrade is elastic (linear-deformable), isotropic and homogeneous. The stress was determined from a depth of 0.15 m below the rails - from the top to the bottom of the protective layer with the minimum thickness of 0.15 m (Fig. 1, level 2) - as the minimum depth of installed geotextile.
The analysis of the vertical stress under the railway sleepers resulted from the exploitation load has been made in accordance with the calculation algorithm presented in [10] for the track with rails on wooden sleepers UIC60 I/B at a spacing of 0.60 m. The track was loaded with a set of 4 axial pressures of 250 kN each, at a spacing of 1.6 m (model 71) [8]. Pressures of sleepers on ballast were calculated using the method of continuous beams resting on the elastic substrate with application of factor increasing load α = 1.1, factor of ground vulnerability 50 N/cm^3 and the impact of pressures from adjacent sleepers. The calculated values of the vertical stress in the subgrade under the exploitation load are summarized in Table 2 and presented in Figure 2.

Tab. 2. Values of vertical stress in the subgrade of exploitation loads and loads of the rigid circular plate with a diameter of 0.3 m.

The depth from the track (Fig. 1, level 1) [m]	The vertical stress in the subgrade under load [kPa]				Δp = p2 - p1 [kPa]
	exploitation	circular rigid plate with the value [kPa]			
		p1 - 100	p2 - 250	pmax - 350	
0,15	119,8	50,0	125,0	175,0	75,0
0,20	109,6	41,0	102,6	143,6	61,6
0,25	101,0	32,7	81,7	114,4	49,0
0,30	93,6	26,0	65,0	91,0	39,0
0,35	87,2	20,9	52,2	73,0	31,3
0,40	81,7	17,0	42,4	59,4	25,4
0,45	77,0	14,0	35,0	49,0	21,0
0,50	72,8	11,7	29,3	41,0	17,6
0,55	69,2	9,9	24,8	34,7	14,9
0,60	66,0	8,5	21,2	29,7	12,7



2. State of vertical stresses in the subgrade of exploitation loads and loads of the rigid circular plate with a diameter of 0.3 m (plate load: p1 - 0.1 MPa, p2 - 0.25 MPa pmax - 0.35 MPa) and an increase in the range of unit load dp = p2 - p1

The vertical stresses in the subgrade under the load of circular rigid plate were determined according to the calculation scheme shown in [9]. On the basis of [6], the analysis assumes as for reinforced substrate, the load by test plates: p_1 = 0.10 MPa, p_2 = 0.25 MPa and p_{max} = 0.35 MPa. The calculated values of the vertical stresses in the subgrade under the load of plate are summarized in Table 2 and presented in Figure 2.

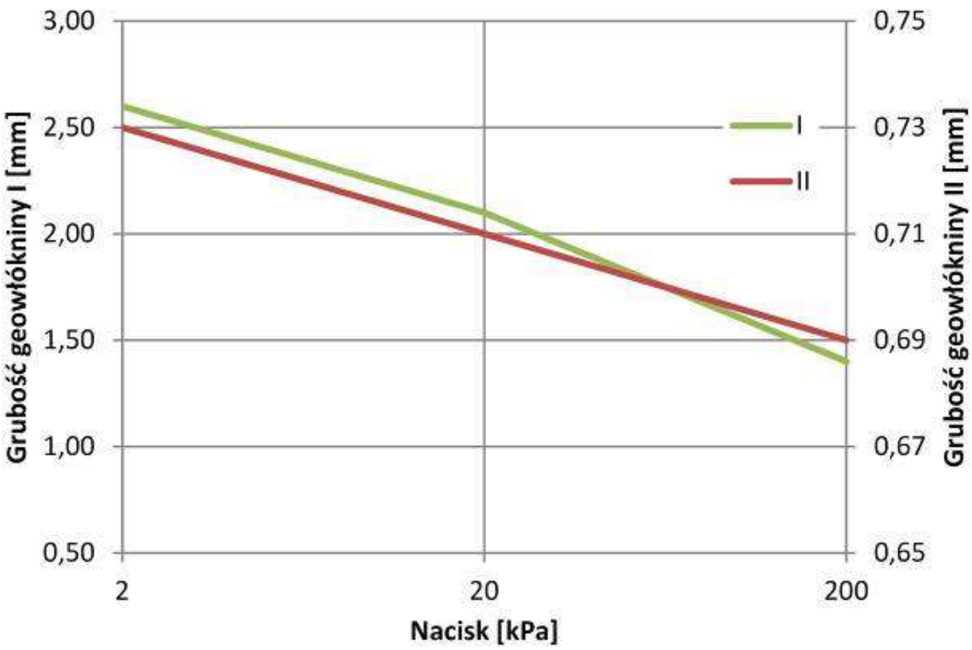
Based on the analysis of vertical stresses in the subgrade, the exploitation load and load of the circular rigid plate with a diameter of 0.3 m (tab. 2 and Fig. 2), it can be stated that the pressure transmitted to the geotextile built under the protective layer (Fig. 1) depends on the thickness of this layer. The greater thickness of the protective layer, the lower pressure provided on the geotextile. At the thickness of the protective layer in the range of 0.15 m to 0.30 m, the maximum pressure applied to the geotextile during the test load is greater than the pressure derived from the exploitation load. At the greater thickness of the protective layer, the pressure on geotextile from the exploitation loads is greater than the pressure exerted during the test load. In the view of the results of measurements of the subgrade deformability, differences between stress of the unit load (p_2 - p_1) (Fig. 2, curve dp) decrease with the increasing thickness of the protective layer. Thus, the greater thickness of the protective layer, the smaller effect of thickness variations of geotextile during the test loads of the subgrade on their result.

Changing the thickness of the geotextile under load

On the basis of the requirements for separation-filtration geotextile laid under the protective layers of the track (Table. 1) for further analysis, were chosen two examples of products approved for use on Polish market, made in two different technologies (needling (geotextile I) and welding (geotextile II). Their technical parameters met the requirements imposed on them, with one exception - welded geotextile has a thickness slightly smaller than that required. Summary of the geotextiles' properties, prepared on the basis [1], is presented in Table 3. Based on these data, (tab. 3) plots of variations in the thickness of geotextiles under load were made (Fig. 3).

Tab. 3. Parameters of selected separation geotextiles [1]

Property	Geotextile I	Geotextile II
surface mass [g/m^2]	250	290
resistance to static puncture [kN]	3,0	3,15
resistance to dynamic puncture (hole diameter) [mm]	15,0	16
tensile resistance [kN/m]	25	21,3
elongation at break [%]	95	55
water permeability in the direction perpendicular to the surface of the product [10^{-4} m/s]	710	150
pore size O_{90} [mm]	0,070	0,070
thickness at a pressure of 2 kPa [mm]	2,6	0,73
thickness at a pressure of 20 kPa [mm]	2,1	-
thickness at a pressure of 200 kPa [mm]	1,4	0,69

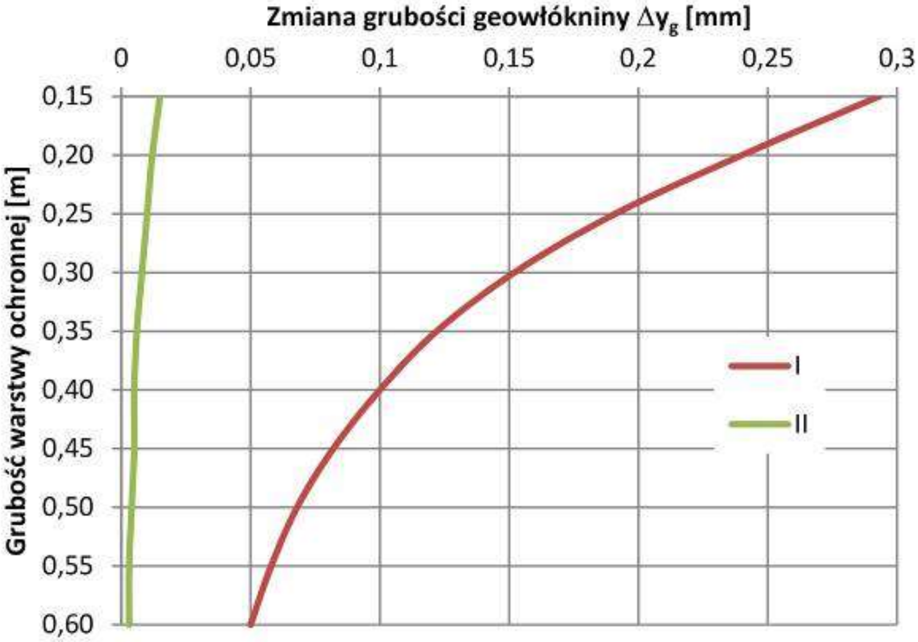


3. The dependence between the thicknesses of selected geotextiles from the pressure

Reducing the thickness of the geotextile under load depends on the technology of their preparation and initial thickness (at a load of 2 kPa). In Figure 3, can be seen a significant (over 45%) reducing the thickness of the geotextile I and the minimal change in the thickness of geotextile II (approximately 5%). Changes in the thickness of the selected geotextiles under the load are linear or close to linear, as it was also observed in [4].

Changes in the thickness of the analysed geotextiles Δy_g occurring during the test load exerted on the subgrade, in the accepted range of load $\Delta p = p_2 - p_1$, depending on the thickness of the protective layer, are illustrated in Figure 4.

Changes in the thickness of the geotextile I, in the range of computational load depending on the thickness of the protective layer are in the range of 0.293 to 0.050 mm, and for geotextiles II in the range of 0.015 to 0.003 mm, and decreases with the increasing thickness of the protective layer. The determined maximum change in the thickness of geotextile in the adopted load range may in fact be smaller due to the susceptibility of the substrate under the geotextile or pre-compression of the product during the process of laying and compacting the protective layer.



4. Changes in the thickness of the analysed geotextiles Δy_g in the assumed range of load Δp depending on the thickness of the protective layer

In order to determine the influence of variation in the geotextile thickness under load on the deformation of subgrade, as the standard was adopted a subgrade with a protective layer without geotextile, characterized, regardless of layer thickness, by the secondary deformation module with 120 MPa, measured on an even railway. The subgrade modulus value (with the protective layer and geotextile) measured on the railway was determined for different thicknesses of protective layers, using the formula:

$$E_{v2} = 0{,}75 \cdot \frac{\Delta p}{\Delta y + \Delta y_g} \cdot D \quad (2),$$

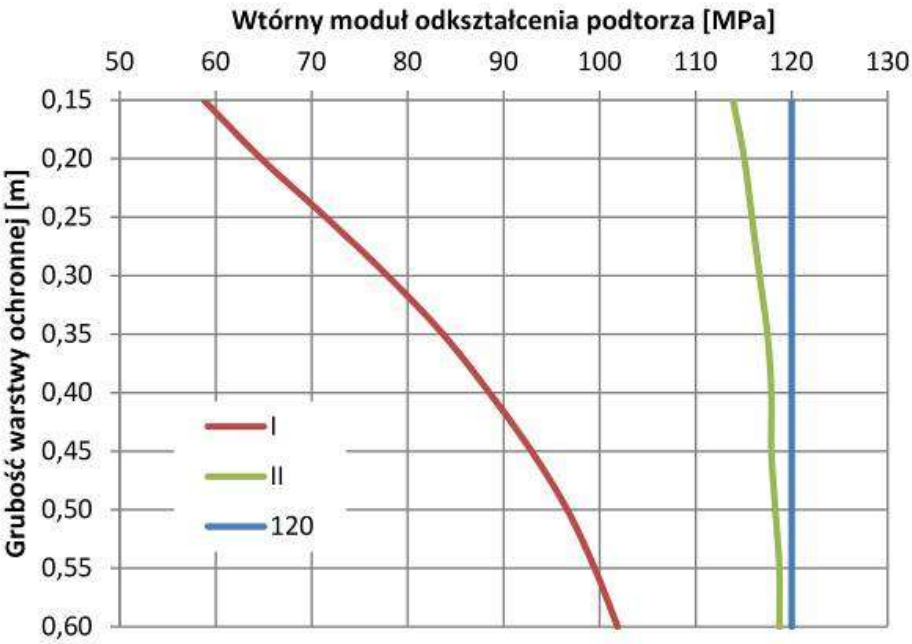
where: Δy_g – change in the thickness of geotextile in the accepted range of load [mm], other markings as in (1)

The calculated effect of changes in the thickness of geotextile on the value of the secondary deformation module with the protective subgrade layer, depending on the thickness of the protective layer is shown in Table 4 and Figure 5.

According to the previous calculations (Tab. 2 and fig. 4), the effect of changes in the thickness of loaded geotextiles on the deformation module decreases with the increasing thickness of the protective layer. When using geotextiles I and the protective layer with a thickness of 0.15 m, the reduction in the value of deformation module of subgrade in the relation to the expected module is about 50%. The use of geotextile II, in the same design for subgrade reinforcement allows obtaining the deformation module almost twice higher than in the case of application of geotextile I and it is only about 5% less than the expected value. At the protective layer with the thickness of 0.60 m, the use of geotextile I affects causes about 15% reduction in the value of deformation module, and the use of a geotextile II only 1%, which falls within the measurement error [5].
Exploitation loads transmitting cyclical pressures through the surface on the subgrade can during its use lead to a permanent reduction in the thickness of geotextile, which ultimately will reduce the overall deformability of rebuilt upper zone of the subgrade [2].

Tab. 4. The impact of variations in thickness of analysed geotextile on the value of the secondary deformation module with the protective subgrade layer, depending on the thickness of the protective layer.

The thickness of the protected layer [m]	Modulus of subgrade deformation [MPa]			Reducing the value of the deformation module of subgrade with geotextile in the ratio to the expected value [%]	
	expected	with geotextile			
		I	II	I	II
0,15	120	58,8	113,9	51,0	5,1
0,20	120	64,7	115,1	46,0	4,1
0,25	120	71,5	115,9	40,4	3,4
0,30	120	77,9	116,7	35,1	2,8
0,35	120	83,7	117,5	30,3	2,1
0,40	120	88,5	117,9	26,2	1,7
0,45	120	92,9	117,9	22,6	1,7
0,50	120	96,6	118,3	19,5	1,4
0,55	120	99,5	118,7	17,1	1,1
0,60	120	101,9	118,7	15,1	1,1



5. The impact of changes in the thickness of geotextile on the value of secondary deformation module with the protective subgrade layer, in dependence on the thickness of the protective layer

Conclusions

On the basis of analysis of the impact of changes on the thickness of geotextile under load can draw the following conclusions:

1. Selection of parameters of geotextiles should be dependent on their purpose and functions which they have to fulfil, because geotextiles are characterized by different properties depending on the type of fibre used and the manufacturing process.
2. The thicker protective layer, the effect of built-in geotextile on the deformability of the

substructure smaller.
3. Impact of changes in the thickness of geotextile, on the deformability of subgrade may in fact be less due to the susceptibility of the substrate under geotextile or pre-compression of the product during the process of laying and compacting the protective layer.
4. The choice of material with suitable properties eliminates almost completely the problem of changes in the thickness of the separation geotextiles under load during the execution of test load of the subgrade.
5. It should be conducted further research on the impact of application of geotextiles on deformability of subgrade in order to apply the results in engineering practice.

Source materials

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