

# GEOGRID REINFORCED SUBBASE UNDER THE IMPACT OF MINING SUBSIDENCE

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## Abstract.

*Influence of geosynthetic localization in subbase was examined considering its effectiveness and mining influences. Large-scale apparatus was used to simulate horizontal unloading strains  $\varepsilon_x$ . A coefficient of lateral earth pressure  $K_\varepsilon$  determined on horizontal and vertical stresses was used to compare effectiveness of geosynthetic in different height of subbase. Results for unreinforced and reinforced subbase were compared. Implementation of geosynthetic reinforcement allowed to withstand higher values of horizontal unloading strains  $\varepsilon_x$ .*

## Keywords

**Geogrid reinforcement, glass fibre mesh, mining subsidence, reinforced subgrade.**

## 1. Introduction

Geosynthetic main functions in pavement engineering are separation and reinforcement of weak layers in pavement construction [1] [2] [3] [4] [5] [6] [7] [8]. This ability to separate layers and thus preventing grains from migrating between them is the main determinant of how pavement construction lifetime is improved. Unbound granular layers, placed one on top of the other, are subject to dynamic tension from traffic load, which causes grains movement between layers. Those movements lead to a local bearing capacity loss in base/subbase over time. One of a viable preventive measure is an application of geosynthetic as a separation layer to delay or completely obviate the aforementioned phenomenon and to significantly prolong a lifetime of the pavement. Effectiveness of reinforcement applied to unbound aggregate layers depends on cooperation between the geosynthetic and granular material and on the ability of the reinforcement to counteract the unloading tensile stress at

the bottom of the unbound aggregate layer under traffic load. Slip between granular material and geosynthetic leads to a minimal or no effectiveness of the applied reinforcement [4] [3] [5]. Using geosynthetic materials as separation and reinforcement layers allow the following:

- significant cost reduction by minimalization of aggregate layers thicknesses,
- using materials with lower bearing capacity,
- improvement of bearing capacity in long-time performance.

Using geosynthetic layer as a reinforcement of subgrade under mining influences in flexible pavement construction was described widely [1] [2] [3] [4] [5] [6] [7]. The application directly on top of old asphalt layer under overlay allows to delay or prevent cracking propagation between layers [8] [9] [10] [3] [11] [12]. In articles [13] and [14] authors were investigating the influence of glass-fiber grid reinforcement on pavement construction using the 4PB test. The increase of pavement fatigue resistance was proven. Geosynthetic applied in road constructions should exhibit high tensile strength and elongation lower than 3% [3] [15] [16]. Reinforcement applied under or in asphalt layers have the following functions [9] [16] [12]:

- stress-relief,
- improvement of the fatigue resistance of asphalt concrete layer,
- improves shear resistance against rutting in high-stress locations,
- delay of crack propagation.

Amongst the previously mentioned functions of the geosynthetic application, the most effective are those applied to subgrade and embankments. The application below subbase allows to reduce the influence of horizontal unloading strains  $\varepsilon_x$  and thus to improve a whole pavement construction's resistance to loss of the equilibrium state from mining subsidence [3], [4], [5]. The previously mentioned solution does not prevent subsidence

completely but may decrease them significantly [1][7]. Some doubts arise as a trend to apply an interlayer reinforcement in pavement construction grows. Reinforcing a pavement construction previously deformed by mining subsidence may prove ineffective according to short time-periods between rehabilitation treatments [18]. The popularity of this solution amongst road management units comes from the assumption that the application of reinforcement just under asphalt layers will increase significantly pavement fatigue resistance. This approach is common for low-class roads like municipal and local roads, which has not been properly designed to withstand mining influence. Proper geosynthetic reinforcement localization is still a matter of contention despite years of practical experience and researches, especially when mining subsidence is considered. In this paper, authors propose to use the coefficient of lateral earth pressure  $K_e$  to evaluate the effectiveness of given reinforcement localization. Its variability is analyzed for subgrade both reinforced and unreinforced with glass-fiber mesh on woven textile under horizontal unloading strains  $\varepsilon_r$ .

## 2. Materials and Research Methods

Laboratory tests were carried using a large-dimension apparatus [18], seen in Fig.2, that allows simulating horizontal unloading strains  $\varepsilon_r$ . Unbound granular layer represented by coarse sand simulated deforming mining subgrade with and without geosynthetic reinforcement applied at the bottom. The coarse sand was used because it was deeply investigated by the creator of the large scale apparatus, thus providing us with well documented mechanical properties[18]. Horizontal and vertical stresses were measured to calculate the coefficient of lateral earth pressure.



Fig. 1: A large scale apparatus (own source).

Glass fiber mesh, used as a reinforcement applied to an unbound granular layer, has the following parameters: breaking tensile strength  $\geq 80$  kN/m, tensile strength by elongation of 3%  $\geq 50$  kN/m and mass per unit area of 450 g/m<sup>2</sup>. In order to provide right cooperation between

geosynthetic reinforcement and unbound layer, the bottom of the geogrid was underlaid with a 3 cm of medium gravel. The dimensions of a box are 1,68 m x 0,30 m x 0,40 m. Measured were taken in three series for reinforced and unreinforced subbase for the following values of horizontal unloading strains  $\varepsilon_r$ :

- 1)  $\varepsilon_r = 0$  mm/m
- 2)  $\varepsilon_r = 1,0 - 5,0$  mm/m (step by 1 mm/m)
- 3)  $\varepsilon_r = 7$  mm/m

After each series box was emptied, the box's walls were set in neutral position ( $\varepsilon_r = 0$  mm/m), and the whole set of layers was prepared and compacted. Three series were necessary to verify the repeatability of the results. Sets of tensiometers were placed accordingly in  $\frac{1}{4}$ ,  $\frac{1}{2}$  and  $\frac{3}{4}$  of the box's height symmetrically by its width and length. In order to register the values of horizontal and vertical stress simultaneously, sensors were placed perpendicularly towards each other. Fig. 2 shows a sensor with a screen reader. Each sensor consisted of 6 tensiometers placed on a thin side of an aluminium cylinder. Fig. 3 shows a scheme of sensors placement and layers with a geocomposite reinforcement.



Fig. 2: Sensor with tensiometers (own source).

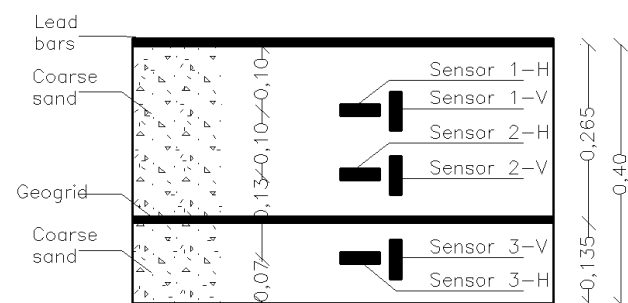


Fig. 3: Scheme of sensors localization (own source).

After the horizontal unloading strains occur in a subbase, the coefficient of lateral earth pressure  $K$  can be described with the following equation:

$$K_{\varepsilon}^r = \frac{\sigma_{22}^r}{\sigma_{11}} \quad (1)$$

where:

$\sigma_{22}^r$  – horizontal stress after horizontal unloosing deformation occur [MPa],

$\sigma_{11}$  – vertical stress

### 3. Results

The coefficient of lateral earth pressure  $K_{\varepsilon}$  was determined based on registered horizontal and vertical stress values for each value of horizontal unloosing strains  $\varepsilon_r$  as shown in tab. 1.

Tab.1:  $K_{\varepsilon}$  mean value from three measures.

Mean value of the coefficient of lateral earth pressure K <sub>ε</sub> for ε <sub>r</sub> [mm/m] based on three measures						
ε <sub>r</sub>	Unreinforced subbase			Reinforced subbase		
	Sensor number					
	1	2	3	1	2	3
0,0	0,96	1,00	0,99	1,03	1,04	1,01
1,0	0,63	0,63	0,63	0,83	0,74	0,56
1,5	0,55	0,46	0,46	0,75	0,63	0,45
2,0	0,28	0,30	0,29	0,55	0,43	0,29
3,0	0,23	0,28	0,25	0,46	0,37	0,26
4,0	0,20	0,21	0,20	0,42	0,35	0,24
5,0	0,17	0,15	0,19	0,31	0,28	0,20
7,0	0,14	0,13	0,15	0,28	0,25	0,18

Fig. 4, 5 and 6 present data for each set of sensors with trend lines. Values of the coefficient of lateral earth pressure are the mean of three readings. The horizontal red line represents the critical, minimal value  $K_{min}$ . Values under minimal means that equilibrium state was lost and subgrade represented by unbound coarse sand layer lost its bearing capacity. The critical value was calculated for coarse sand, properly compacted and angle of internal friction of  $\phi = 35^\circ$  [18]. Consolidation was performed until the initial coefficient of lateral earth pressure  $K_0$  was equal to or greater than 1, which describes the case of pavement exploitation when horizontal stress is greater than or equal to vertical stress. Minimal value  $K_{min}$  was calculated accordingly with equation 1 [4]:

$$K_{min} = \frac{\sigma_{22}^{(min)\varepsilon}}{\sigma_{11}} = tg^2 \left( \frac{\pi}{4} - \frac{\phi}{2} \right) = tg^2(27^\circ 30') = 0,267 \quad (2)$$

The coefficient of lateral earth pressure relations to the values of horizontal unloosing strains  $\varepsilon_r$  was presented for the following sets of sensors:  $1^{H/V}$ ,  $2^{H/V}$ ,  $3^{H/V}$ . The results

shown in Fig. 4-6 indicate that the unreinforced unbound sand layer loses its equilibrium state as soon as the value of horizontal unloosing strains reaches 2,0 – 3,0 mm/m. Application of glass-fiber mesh improved the horizontal unloosing strains value threshold up to  $\varepsilon_r \geq 5,0$  mm/m for layers located above geosynthetic reinforcement, as we can see in Fig. 4 and 5. Horizontal unloosing strains, as a mining influence product, reduce the horizontal stress value, and this reduction was prevented by applied reinforcement. As a result of lesser horizontal stress reduction in layers above applied reinforcement, the value of the coefficient of lateral earth pressure lowers lesser than in unreinforced layers.  $K_{\varepsilon}$  value decides about the equilibrium state („at rest” ground state) of the analyzed layer. It is especially noticeable at the level of  $1^{st}$  sensors set where the limit state was not reached in case of a reinforced layer, as can be seen in Fig. 4.

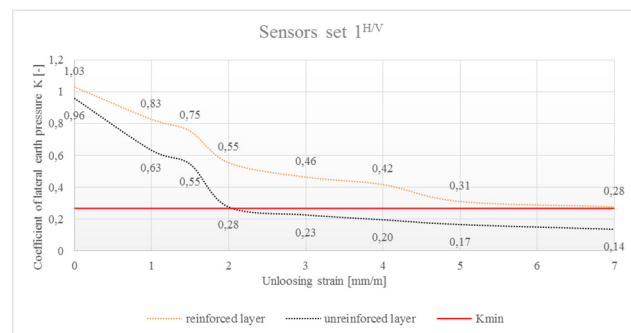


Fig. 4: Values of the coefficient of lateral earth pressure  $K_{\varepsilon}$  according to unloosing strains  $\varepsilon_r$  (sets of sensors  $1^{H/V}$ ).

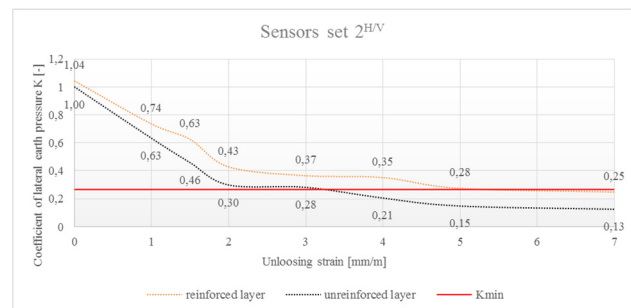


Fig. 5: Values of the coefficient of lateral earth pressure  $K_{\varepsilon}$  according to unloosing strains  $\varepsilon_r$  (sets of sensors  $2^{H/V}$ ).

As it can be noticed in Fig. 5 critical value of the coefficient of lateral earth pressure is reached at  $\varepsilon_r \approx 5,0$  mm/m for the level of  $2^{nd}$  sensors set just above glass fiber mesh reinforcement. As shown in Fig. 6, geosynthetic reinforcement did not have any effect on layers located below the level of its application. Glass fiber mesh reinforcement did not prevent horizontal stress reduction and so it didn't affect the value of the coefficient of lateral earth pressure. Limit state was reached as soon as values of horizontal unloosing strains have reached  $\varepsilon_r \approx 2,0 - 3,0$  for both reinforced and unreinforced layer.



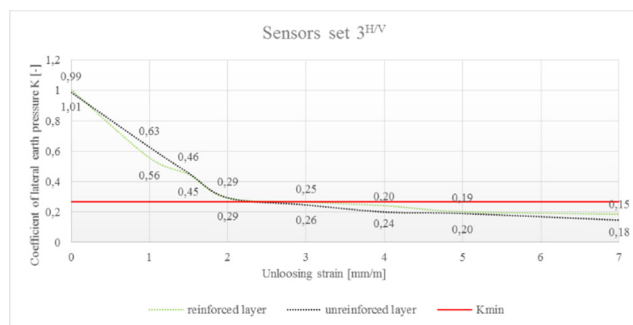


Fig. 6: Values of the coefficient of lateral earth pressure  $K_e$  according to unloading strains  $\varepsilon_r$  (sets of sensors 3<sup>HV</sup>).

## 4. Conclusions

Performed research shows that the effectiveness of geosynthetic reinforcement in the flexible pavement under mining influences depends on its localization in pavement construction. It is crucial to design the localization of reinforcement between subgrade and subbase with higher levels of application considered only during rehabilitation treatments. Reinforcing a pavement construction previously deformed by mining subsidence in a bottom of asphalt concrete layers will not provide any significant increase of fatigue resistance with reinforcement function reduced to stress-relief and cracking propagation delay. The local road at a mining subsidence area is a large scale example of glass fiber mesh applied under asphalt concrete layers above subbase. Analyses performed in [17] showed that the reliable state of cracking indicator is approximately 15% higher for lane reinforced with glass-fiber mesh which is also confirmed by the intensity of cracking represented by indices of cracking. Glass-fiber mesh improved the condition of the pavement surface, which is pictured by the state of cracking indicators, state of cracking indices and by the direct quantity of distresses. Applied reinforcement proved no effect on road ability to withstand mining deformations. Both research on the diversity of coefficient of lateral earth pressure and mentioned [17] observations may suggest low effectiveness of reinforcement applied between subgrade and asphalt concrete layers. The topic remains up-to-date and requires further investigation and analyzes.

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