

Geogrid reinforced road subgrade influence on the pavement evenness

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Abstract. As a result of increasing geogrid reinforcement applications in the road subgrade, there are number of projects where geogrid reinforcement is used to control road pavement evenness when there are small layers of peat or mud deeper under road construction. For this task geogrid reinforcement application is not documented but widely used in Lithuania for over a decade. This paper evaluates the long term influence of the geogrid reinforced soil influence on the road surface evenness, when the organic soils stratify in the deeper layers of the subgrade. The geological conditions of the investigated sections are reviewed. The experiment methodology and test results are described, which leads to the conclusions and insights how the pavement evenness depend on the geological conditions and its enhancement. The question is raised about the need for including this geogrid application to the normative documentation. Explanation of the problems that are encountered and the need for further research is given.

Keywords: subgrade, pavement evenness, enhancement, geosynthetics, geogrids, soil reinforcement.

1. Introduction

Due to the deterioration of the condition of Lithuanian roads, the number of road sections, that do not meet the required bearing capacity for the pavement construction and do not provide the sufficient traffic quality, are being reconstructed. During the reconstruction, geometrical parameters of the road are changed and the pavement construction is strengthened, therefore it is important to evaluate the existing geological conditions. After geological investigations, it is often found that a poor state road sections with cracks, ruts and potholes or bumps are located above the organic soils, i.e. peat or mud.

In the roads that were built over organic soils many years ago, the soil loading technology was often used, where the existing organic soil was not replaced, but a certain size of soil mas was filled over it, which had to increase the organic soil consolidation time. The structural works took place after the biggest settlements occurred. Due to such construction practices, carried out several decades ago, reconstructing the existing Lithuanian roads nowadays, the geological situation is often found as the following: on the top, there are filled sandy soils which lay from 1 to 6 m deep and below them there are organic soils (peat or mud) which lay approximately till 10–14 m deep. Problems of this type are usually solved by constructing a pile system and a geogrid reinforced soil platform above them which holds the road construction in place. This method has been globally used for about 25–30 years, and has been well documented in the normative documents. When the peat layer is small and it lays not deeper than 5 m, the pile system cost around the same amount as the excavation and replacement of the soil. However, in any case, this is a costly solution, especially when there is a need to increase the



quality of the roads when having the same budget for road maintenance (A. Vaitkus et al. 2016). For this reason, after the geosynthetic materials were being started to be used, a number of Lithuanian road reconstruction projects have been implemented over the last 10 years, where instead of excavation and replacement of soil or pile systems various strength geogrids were used directly under the road construction or a bit lower, making up to 0,6 m soil replacement. With this method of strengthening the subgrade, it was expected that the reinforced soil under the road construction will prevent from undesirable pavement cracks, ruts, potholes or bumps that could be caused by the existing partially consolidated organic soil layers.

This type of use of geosynthetics is not regulated either in Lithuania or in normative documents of other countries (A. Vaitkus et al. 2014). For this reason, an experimental study is carried out to determine whether this type of road strengthening is suitable or not, looking from long term perspective, for the road to maintain its strength and quality requirements (A. Šiukšcius et al 2017).

2. Tested road sections

Two different categories of roads were chosen in order to get the best results when estimating the geogrid influence on the pavement evenness. The first road is the main road A6 Kaunas–Zarasai–Daugavpils, the second is the country road No. 131 Alytus–Simnas–Kalvarija. The main road A6 was reconstructed in sections from Kaunas to Zarasai, and the reconstruction works began more than 10 years ago.

We were looking for a geological situation as described above, where there are filled soils over the peat layers and where the geogrid reinforcement was used under the road construction. After studying the whole available information it was found that main road A6 had those conditions in the sections of 66,20–68,76 km (the end of construction at 2007), 137,35–142,00 km (the end of construction at 2011) and 142,00–150,10 km (the end of construction at 2016). Altogether in these sections there are 5 places with a geogrid reinforcement over the organic soils that lays deeper in the strata. On the same principle the country road No. Nr. 131 was reconstructed and it also has already 10 years passed from the beginning of the reconstruction works. The local road No. 131 had required conditions in the sections of 44,80–50,80 km (the end of construction at 2010) and 52,45–57,12 km (the end of construction at 2009). Those two sections has 8 places with a geogrid reinforcement over the organic soils that lays deeper in the strata.

3. Designed solutions in the projects

3.1. Main road A6 Kaunas–Zarasai–Daugavpils (section 66,20–68,76 km)

Geogrid was installed under the designed road construction without any additional soil replacement in section 67,26–67,45 km. The geosynthetics installed was a 30/30 kN/m tensile strength polypropylene (PP further in the text) geogrid and a GRK3 (according MN GEOSINT ŽD 13) class non-woven geotextile. According to the project, in this section, the road goes over a 0,9–1,4 m thick peat layer, which is compressed till 30% and it lays in 2,3–3,4 m depth. Under the peat layer, in a 2,3–4,8 m depth, there is a mud layer with the thickness of 0,7–1,5 m. There is no geological investigations given in the design project. Construction year 2006–2007.

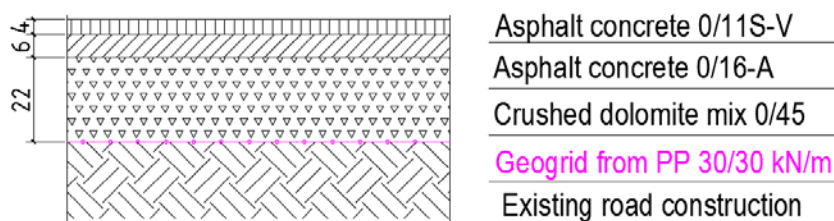


Figure 1. Main road A6 section 67,26–67,45 km designed road construction.

3.2. Main road A6 Kaunas–Zarasai–Daugavpils (section 137,35–142,00 km)

Geogrid was installed under the designed road construction with an additional 0,3 m soil replacement in section 141,047–141,123 km. The geosynthetics installed was a 400/40 kN/m tensile strength polyester (PET further in the text) geogrid in crosswise direction and a 200/40 kN/m tensile strength PET geogrid along the road, a GRK3 (according MN GEOSINT ŽD 13) class non-woven geotextile was also used. The geological investigations shows that in this section, there is a 0,4 m thick well-decomposed peat layer in a 2,7 m depth. Not only is the peat layer is soaked, but also the part of the loamy soil part above it. Below peat there is a soft plastic clay. Construction year 2010–2011.

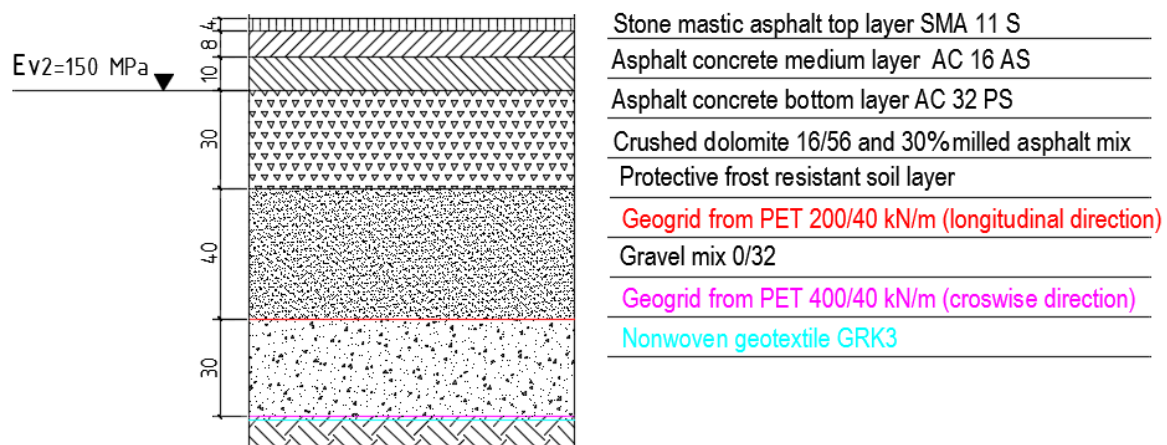


Figure 2. Main road A6 section 141,047–141,123 km designed road construction.

3.3. Main road A6 Kaunas–Zarasai–Daugavpils (section 142,0–150,1 km)

Construction year 2015–2016. Geogrid was installed under the designed road construction with an additional 0,3 m soil replacement in sections 146,21–146,44 km; 147,65–147,80 km; 148,94–149,26 km and 149,73–149,83 km. The geosynthetics installed was a 120/120 kN/m tensile strength PET geogrid and a GRK3 (according MN GEOSINT ŽD 13) class non-woven geotextile. The geological investigations shows that:

3.3.1. Section 146,21–146,44 km. At a depth of 3,9–6,3 m, there is a 0,3–2,0 m thick well-decomposed peat layer. Below it, at a depth of 5,2–8,3 m there is a 0,3 m thick mud layer. Not only peat layer is soaked, but also a part of the dusty sand above it. Below mud there is a liquid plasticity dust.

3.3.2. Section 147,65–147,80 km. At a depth of 14,0 m, there is a 0,5 m thick well-decomposed peat layer. Below it, at a depth of 14,5 m there is a 3,5 m thick mud layer. Not only peat layer is soaked, but also a part of the dusty sand above it. Below mud there is a medium roughness gravel.

3.3.3. Section 148,94–149,26 km. At a depth of 1,0 m, there is a 0,4 m thick filled softly plastic clay layer which is with organics. Below it, there is a filled softly plastic clay layer and deeper there is natural softly plastic clay layer. Ground water level is in 2,2 m depth, under the clayey soils.

3.3.4. Section 149,73–149,83 km. At a depth of 3,1 m, there is a 0,6 m thick well-decomposed, soaked peat layer. Above it, there is a 1,5 m thick filled dusty sand layer. Below peat there is a natural low plasticity, softly plastic clay.

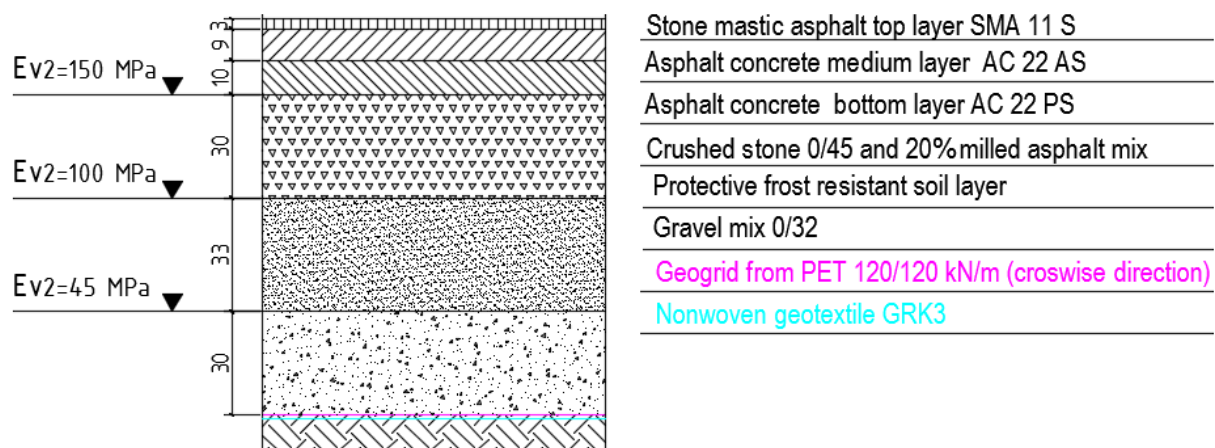


Figure 3. Main road A6 sections 146,21–146,44 km; 147,65–147,80 km; 148,94–149,26 km and 149,73–149,83 km designed road construction.

3.4. Country road No. 131 Alytus–Simnas–Kalvarija (section 44,80–50,8 km)

Construction year 2009–2010. Geogrid was installed under the designed road construction with an additional 0,6 m soil replacement in sections 45,965–46,14 km; 46,45–46,72 km; 46,865–46,95 km; 47,32–47,425 km and 49,22–49,295 km. The geosynthetics installed was a 60/60 kN/m tensile strength PP geogrid (crosswise in two layers at every 0,3 m) and a GRK3 (according MN GEOSINT ŽD 13) class non-woven geotextile. The geological investigations shows that:

3.4.1. Section 45,965–46,14 km. At a depth of 2,2 m, there is a 0,8–0,9 m thick well-decomposed soaked peat layer. Above it, there is a filled low plasticity clay, in some places with organics. Below peat there is a natural low plasticity clay.

3.4.2. Section 46,45–46,72 km. At a depth of 2,0–2,5 m, there is a 0,5–1,2 m thick medium-decomposed soaked peat layer. Above it, there is a filled low plasticity clay, in some places with organics. Below there is a natural low plasticity clay.

3.4.3. Section 46,865–46,95 km. At a depth of 2,6 m, there is a 0,8 m thick well-decomposed, unsaturated peat layer. Above it, there is a filled low plasticity clay, in some places with organics. Below there is a natural low plasticity clay.

3.4.4. Section 47,32–47,425 km. At a depth of 3,0–3,1 m, there is a 0,8 m thick well-decomposed, unsaturated peat layer. Above it, there is a filled low plasticity clay. Below there is a natural dusty clay.

3.4.5. Section 49,22–49,295 km. At a depth of 2,3 m, there is a 0,5 m thick well-decomposed soaked peat layer. Below it, at a depth of 2,8 m there is a 0,8 m thick mud layer. Above it, there is a filled dusty clay. Below there is a natural dusty sand and clay.

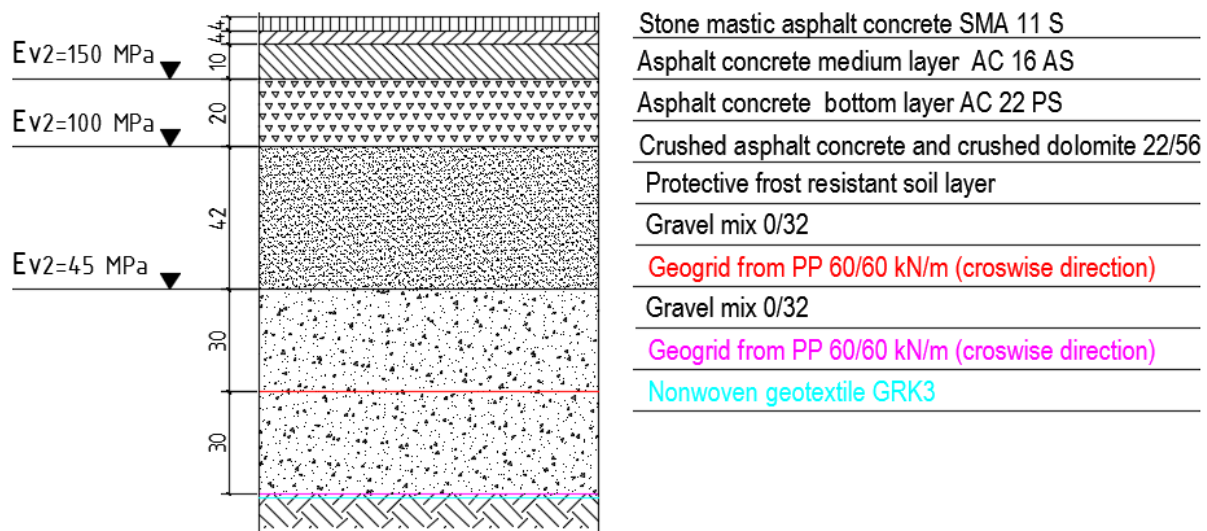


Figure 4. Country road No. 131 sections 45,965–46,14 km; 46,45–46,72 km; 46,865–46,95 km; 47,32–47,425 km and 49,22–49,295 km designed road construction.

3.5. Country road No. 131 Alytus–Simnas–Kalvarija (section 52,45–57,12 km)

Construction year 2007–2009. Geogrid was installed under the designed road construction with an additional 0,3 m soil replacement in sections 53,91–54,09 km and 56,74–56,94 km. The geosynthetics installed was a 60/60 kN/m tensile strength PP geogrid (crosswise) and a GRK3 (according MN GEOSINT ŽD 13) class non-woven geotextile. The geological investigations shows that:

3.5.1. Section 53,91–54,09 km. At a depth of 2,2 m, there is a 0,8 m thick well-decomposed soaked peat layer. Above it, there is a filled dusty clay. Below peat there is a soaked natural dusty sand.

3.5.2. Section 56,74–56,94 km. At a depth of 3,0 m, there is a 0,7 m thick mud layer and in 3,7 m depth there is 0,6 m thick peat layer. Above them, there is a 0,3 m thick organic clay layer and filled dusty sand. Not only peat and mud layers are soaked, but also a big part of the dusty sand above them. Below peat there is a soaked natural dusty sand.

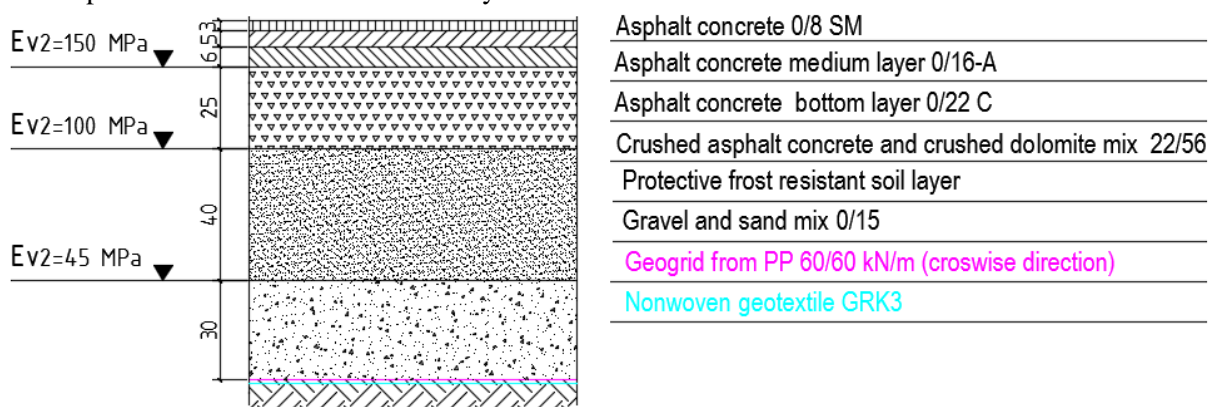


Figure 5. Country road No. 131 sections 53,91–54,09 km and 56,74–56,94 km designed road construction.

4. Research

The road surface evenness is one of the main parameters that describes the ride comfort and it is the indicator of the pavement condition. That can be described by the International Roughness Index (IRI further in the text) which is most commonly obtained from measured longitudinal road profiles. It is

calculated using a quarter-car vehicle math model, whose response is accumulated to yield a roughness index with units of slope (m/km). When trying to evaluate pavement vertical displacements comparing the geogrid reinforced and unreinforced road sections from a long term perspective, the IRI measurements were taken in a different periods of the road service.

Periodic IRI measurements were carried out by the Road and Transport Research Institute. The mobile road research laboratory RST-28 was used to take the IRI measurements. RST-28 laboratory is a mobile, multi-component pavement surface quality measuring equipment, which uses the technology to ensure the precise and comprehensive test results of the road condition. To collect the data, it uses 19 laser sensors, 2 accelerometers, 2 gyroscopes and 2 inclinometers, which are mounted on the front measuring beam (laser frame). The car has road surface photographing equipment, consisting of two video cameras, aligned vertically to the road, pavement surface illuminators, an air compressor for cooling the equipment, a control unit, an equipment start/stop switch. The cabin of the car has a signal processing system, main computers and other devices. The entire system is controlled by the system switches, keyboard and monitor from the operator's workplace. An air compressor and generator, which is mounted in a special box, is located on the rear of the cabin (separated from the front by the device cabinet).

5. Results of the research

After IRI measurements were completed, all 5 test sections were evaluated throughout their whole length where some trends can be observed. The tested roads were divided in to the sections with geogrid reinforced subgrade and the remaining parts with various subgrade conditions. Statistical analysis with average IRI values of the sections shows that in general, when assessing the results of IRI measurements, it should be noted that the pavement evenness is not in any case much lower or higher comparing with unreinforced sections pavement evenness. However, looking at each tested section it can be stated that geogrids has a positive effect on the pavement evenness.

The first good example can be main road A6 Kaunas–Zarasai–Daugavpils section 66,20–68,76 km, where we can see that even the 1,6–2,9m thick peat and mud layer in the subgrade can't do no clear negative effect on only one geogrid layer reinforced section 67,26–67,45 km (see figure 6). Geogrid reinforced section shows average IRI value of 1,68 m/km after 4–5 years after reconstruction, when remaining parts shows average IRI value of 1,40 and 2,16 m/km. Unfortunately the result for 2013–2014 year test is not clear because of the installed 6 speed bumps in that section, where they are clearly visible in the whole section (figures 6 and 7).

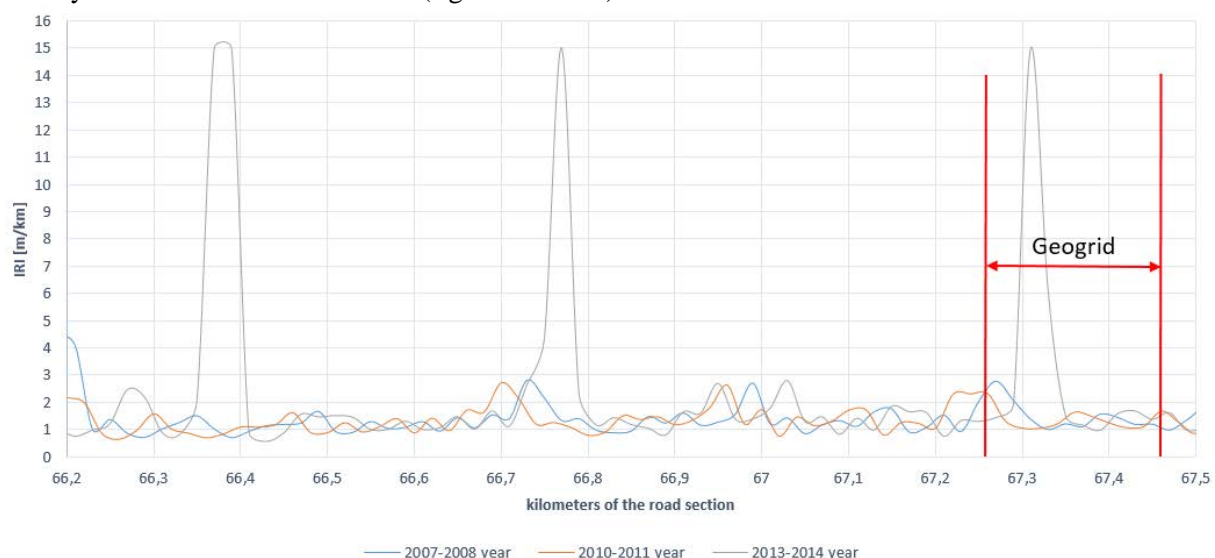


Figure 6. Main road A6 section 67,26–67,45 km pavement IRI results (first half of the section).

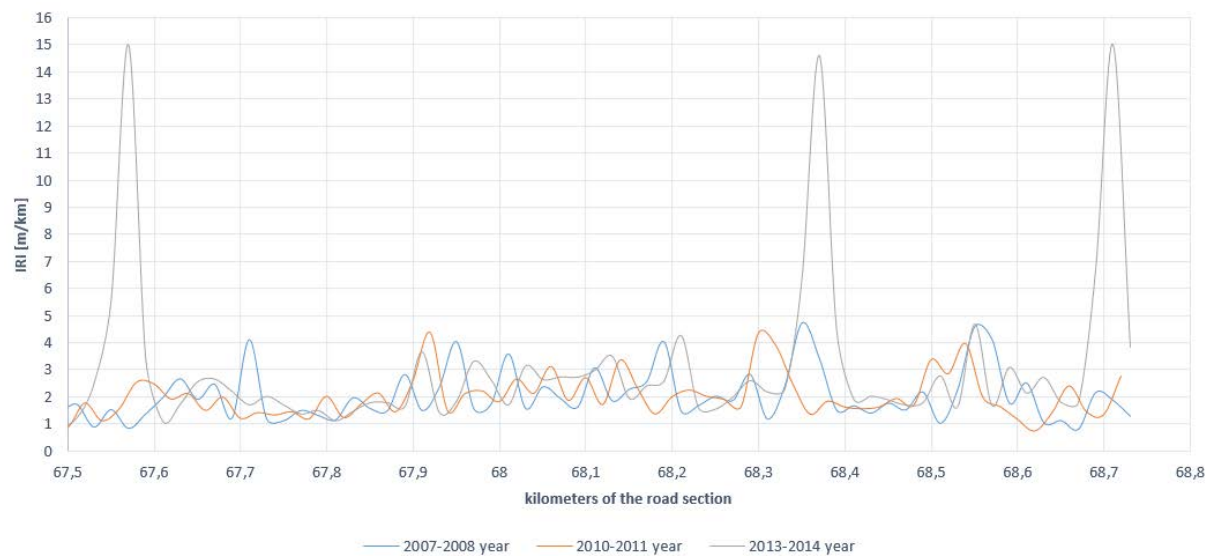


Figure 7. Main road A6 section 67,26–67,45 km pavement IRI results (second half of the section).

Anyway, comparing the average IRI values we can see the same tendency as for the year 2010-2011. Geogrid reinforced section shows average IRI value of 3,20 m/km after 7-8 years after reconstruction, when remaining parts shows average IRI value of 2,39 and 3,34 m/km. Unfortunately there is no data how IRI looked before the road reconstruction, so there is no possibility to see how this reinforced section improved the road quality.

The main road A6 Kaunas–Zarasai–Daugavpils section 142,0–150,1 km has 4 sections reinforced with geogrids and there is lots of IRI data before the road reconstruction was finished. Unfortunately there is only one IRI measurement that was taken at 2016, few months after the road was finished so there is no comparable data as this section should be monitored for more years. However, there is one place, where we can see a benefit from the geogrid reinforced section, when we compare the IRI at the end of the section where the reinforcement ends at 149,73–149,83 km. There we can clearly see much higher average IRI values (2,95 m/km) which means that the road is reflecting the situation that was earlier (3,56 m/km), which is not the case with reinforced section (0,98 m/km), and this is measured only a few months after the reconstruction finished.

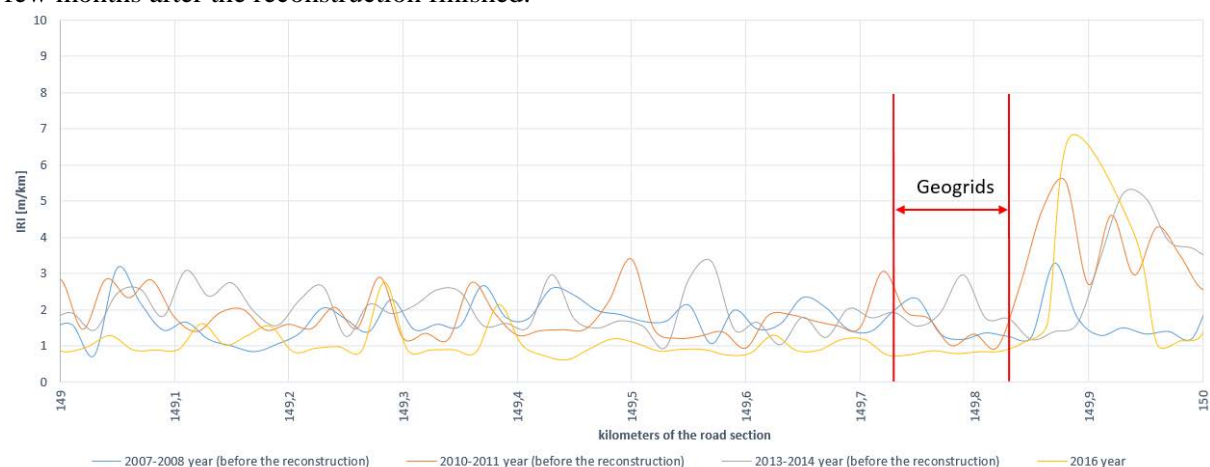


Figure 8. Main road A6 Kaunas–Zarasai–Daugavpils section 142,0–150,1 km, reinforcement at 149,73–149,83 km.

Country road No. 131 Alytus–Simnas–Kalvarija section 52,45–57,12 km has 2 geogrid reinforcement sections and the data of IRI measurements is available a year before the reconstruction and 5 years after the reconstruction. This example shows the general view of the pavement evenness. The IRI values before the road reconstruction was really high, the highest value of 14,75 m/km. In the reinforced sections the average IRI values before the reconstruction were 4,70 and 5,49 m/km and the first measurements after the reconstruction which were performed 2 years after the reconstruction shows the average IRI values of 0,81 and 0,87 m/km. After two more years another measurements were performed and they showed average IRI values of 0,82 and 0,85 m/km (see table 1 and fig. 9 and 10). Comparing average IRI results for this section it can be stated that sections with geogrid reinforcement has not higher IRI values than sections without geogrid reinforcement and in fact slightly lower, which shows that geogrid has long term influence. High IRI values at 56,55 km also shows speed bump, so this place is giving a negative effect on the average value. Having IRI not higher than 2 m/km for a country road is a really good result. Another point to note is that sections before and after the geogrid reinforced sections are stabilized by lime and if we look at the charts, we can see that the pavement with lime stabilized subgrade is not as smooth as geogrid reinforced section.

Table 1. Average IRI values for the road No. 131 Alytus–Simnas–Kalvarija section 52,45–57,12 km.

| Section | Reinforcement | Year tested | | |
|----------------|---------------|-------------------------------------|-----------|-----------|
| | | 2007-208 (before reconstruction) | 2010-2011 | 2013-2014 |
| 52,45–53,91 km | NO | 4,21 m/km | 0,85 m/km | 0,91 m/km |
| 53,91–54,09 km | YES | 4,70 m/km | 0,81 m/km | 0,82 m/km |
| 54,09–56,74 km | NO | 4,29 m/km | 1,06 m/km | 1,12 m/km |
| 56,74–56,94 km | YES | 5,49 m/km | 0,87 m/km | 0,85 m/km |
| 56,94–57,12 km | NO | 4,98 m/km | N/A | 1,78 m/km |

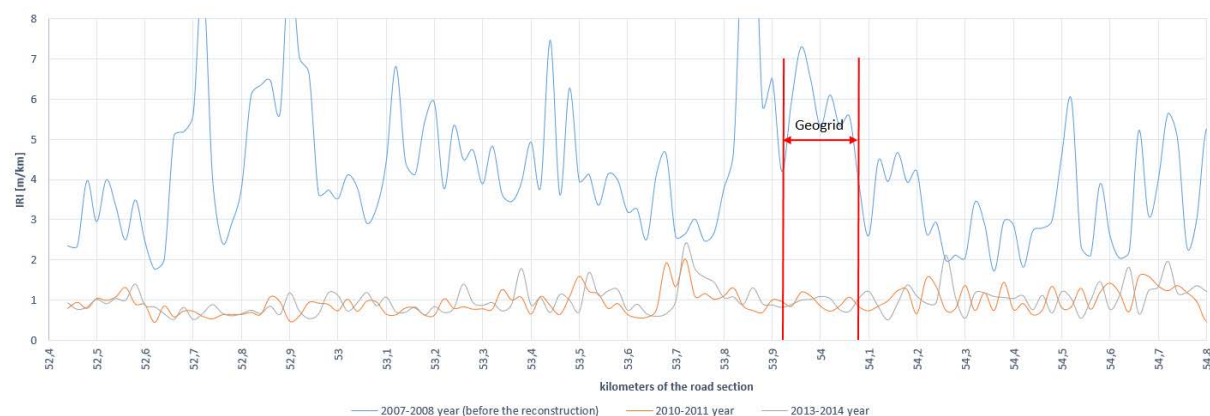


Figure 9. Country road No. 131 Alytus–Simnas–Kalvarija section 52,45–57,12 km pavement IRI results (first half of the section).

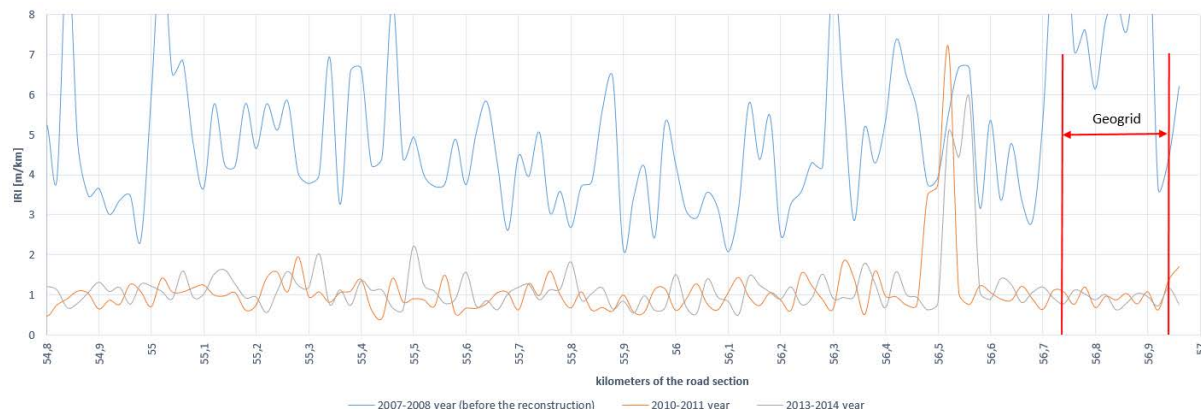


Figure 10. Country road No. 131 Alytus–Simnas–Kalvariija section 52,45–57,12 km pavement IRI results (second half of the section).

6. Conclusions

After examining the results of the International Roughness Index (IRI) for the tested road sections and observed tendencies, we can draw the following conclusions:

All geogrid reinforced subgrade sections performed well, showing average IRI values not higher compared to other road sections, excluding A6 Kaunas–Zarasai–Daugavpils section 66,20–68,76 km, which needs further investigation. This leads to a positive geogrid effect on the pavement evenness not even when there are soft soils deeper in the subgrade, but it also shows that in long term perspective geogrid reinforced subgrade can handle unfavorable conditions better than lime stabilized soil;

In some places, tested few months after the road reconstruction, IRI results are starting to show high values and it needs more investigation. This could lead to a necessity of Falling Weight Deflectometer (FWD) test;

The geogrids used for the road reconstruction is really different, starting from one layer of 30/30 kN/m and ending with two layers of 200/40 kN/m and 400/40 kN/m tensile strength. All of them are stiff geogrids with low elongation. However, the place which is starting to show high IRI values is reinforced with the 120/120 kN/m tensile strength geogrids. This also leads to the necessity of additional investigation of soil bearing capacity;

The geogrid reinforcement application for paved roads over the peat and mud layers, which are deeper in the subgrade, could be explained in a national methodical instructions for usage of geosynthetics MN GEOSINT ŽD 13.

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