



APPLICATION OF GEOSYNTHETICS IN THE REMEDIATION OF URBAN ROADS

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Abstract

In order for a pavement structure to maintain its adequate load-bearing capacity and surface properties during its design life, which primarily enable safe and comfortable driving, it is necessary to regularly carry out simpler or more complex maintenance or remediation measures. The deterioration of pavements is influenced by various factors such as traffic load, weather conditions, used materials and the thickness of the pavement structure layers, as well as the quality of execution and the effectiveness of previous maintenance measures. The requirement for the shortest possible time for carrying out remediation works, especially in urban traffic conditions, as well as the desire to increase the durability of the pavement structure by selecting the proper remediation measure, impose geosynthetics as a rational and sustainable choice. The paper will describe various applications of geosynthetics in pavement structures and their contribution to the increase of the load-bearing capacity. Special emphasis will be given to cases of installing geogrids for asphalt reinforcement as part of street remediation in the city of Osijek and the importance of proper installation on the efficiency of reinforcement, the load transfer mechanism and the interaction of the geogrid and bituminous binder.

Keywords: urban roads, geogrids, deterioration, maintenance, durability

1 Introduction

Geosynthetics, developed as a product of the chemical industry, with at least one component made of synthetic polymer materials [1], were first used in roads and hydraulic engineering at the beginning of the twentieth century [2]. From the 1960's to the 1970's their use has become increasingly widespread. In the following period, up to the present day, research and industrial production of geosynthetics have been strengthening over the years. It is estimated that in 2025 the geosynthetics market weighted about 18 billion dollars [3]. In modern times their application in road construction is almost irreplaceable. Modern applications of geosynthetics in roads, in addition to the benefits they bring in the layers of the pavement structure, also appear in other elements of the road infrastructure. They are being used in slope stabilization and landslide remediation, in supporting structures for roads, in strengthening - improving the base soil, in waterproofing, drainage and in erosion protection. In construction of new roads solutions with geosynthetics contribute to the resistance of structures with significant savings in construction time, costs and extended durability, increasing the period in which increased maintenance is not required. In pavement structures, e.g. in unbound base layers, their role is filtration, separation, stabilization and reinforcement.

Geotextiles, geogrids or geocomposites through different mechanisms of action increase a mechanical resistance of pavement structure as well as their durability [4-6]. Geosynthetics in unbound base layers also affect the overall increase in the load-bearing capacity of the pavement structure. The mechanisms through which they act as reinforcement in pavement structures are lateral restraint, increased load-bearing capacity and the effect of a tensioned membrane [7, 8]. In addition to the construction of new roads, geosynthetic are significantly used in the reconstruction, rehabilitation and maintenance of existing roads, where they can play a key role. Regarding the quality and durability of the solution, the possibility of installation and gaining load-bearing capacity in a short time, often requiring the execution of works without stopping traffic, some problems could not be solved without their use.

An overview to the application of geosynthetics in pavement structure layers will be given in the paper, with special emphasis to asphalt reinforcement. The restoration of pavement structure by reinforcing the asphalt with geogrids will be elaborated showing the restoration of streets in the city of Osijek. This example will show the importance of proper installation on the effectiveness of the reinforcement, the load transfer mechanism and the interaction of the geogrid and the bituminous binder.

2 Geosynthetics in bonded base layers of pavement structures – reinforcement of asphalt layers

The idea of reinforcing asphalt pavements is based on a general mechanical principle that the asphalt layer is relatively resistant to compressive stresses, but sensitive to tensile stresses. By introducing reinforcement, it is possible to increase the resistance to tensile stresses, in a manner similar to the principle of reinforced concrete. Geotextiles, geogrids and various geocomposites can be used for asphalt reinforcement and the use of steel mesh has also been recorded. Glass fiber geogrids, carbon fiber geogrids, basalt geogrids, as well as bitumen-impregnated geotextiles are used in the reinforcement of asphalt layers, with experimental applications of other products [9]. An overview of different types of geosynthetics for asphalt reinforcement is given in figure 1.

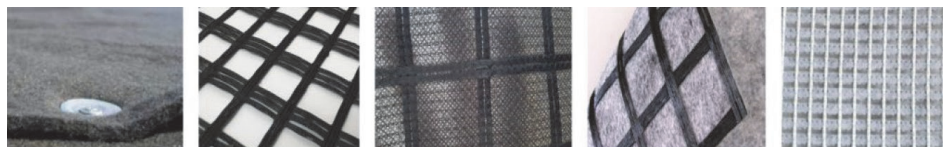


Figure 1 Example of different geosynthetics for asphalt reinforcement [10]

In asphalt reinforcement, geogrids show different effectiveness depending on their properties such as composition, surface coating, geometry, aperture dimensions and their position within the pavement structure. Geogrids increase tensile strength of asphalt layers, increase traffic load energy absorption capacity, limit lateral spread (material movement by trapping aggregates within the apertures), increase resistance to reflective cracking, allow horizontal deformations without failure, provide water tightness that prevents water from penetrating the lower layers. They also reduce the concentration (load is transferred more widely) and the amount of load in the load-bearing bounded and unbounded layers below the asphalt layers [11]. This can be seen in figure 2, which shows the aforementioned properties through increased resistance to rutting, which is essentially plastic deformation of the asphalt layer.

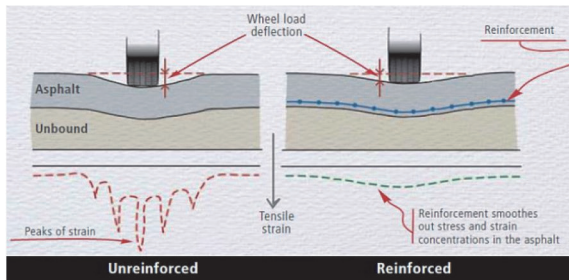


Figure 2 The application of geogrids for reinforcement in asphalt, which, by limiting lateral expansion, increase resistance to rutting [11]

When using geogrids for asphalt reinforcement, a negative effect may occur, such as a decrease in the adhesive force between the asphalt and the geogrid, known as “de-bonding”, which leads to slipping of the upper surface relative to the geogrid [12]. With appropriate design-defined provisions and proper installation of geosynthetics in asphalt layers of the pavement structure, fatigue resistance is increased, rutting is prevented or significantly slowed down. Also the occurrence of reflective cracks is limited, tensile strength and energy absorption capacity are increased, and lateral stability is enhanced due to the interlocking effect. An example of the effect of asphalt reinforcement on limiting reflective cracks is visible in figure 3.

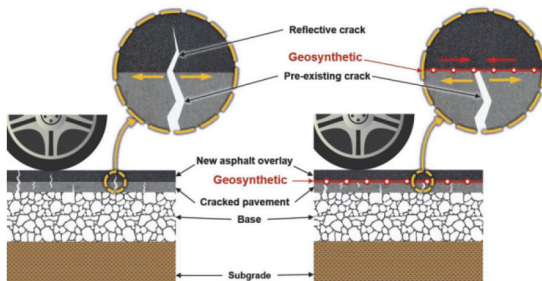


Figure 3 Effect of asphalt reinforcement on limiting reflective cracks [12]

Pavements in urban areas are exposed to a complex spectrum of traffic and environmental effects (including temperature changes; summer-winter) that cause gradual or immediate (less frequently) degradation of asphalt layers and/or other parts, or the entire pavement structure. Due to continuous traffic load (as well as other influences), cracks and other damage occur (deterioration of the surface layer of the wearing layer of asphalt, weakening of the binding properties of bitumen, etc.) and cracks appear on the surface of the wearing asphalt layer in various forms (longitudinal, transverse, mesh, etc.) [13].

When repairing pavements (unplanned maintenance operations) in urban areas, it is often technically and economically unjustified to carry out a complete reconstruction of the pavement structure, in the sense of completely replacing all layers of the pavement structure. In cases where base layers (unbound base layer, base layer of asphalt) and base soil (or subgrade) retain satisfactory bearing capacity, a rational approach is to remove the degraded asphalt wearing course and construct a new asphalt layer using geosynthetics for reinforcement, with a possible expansion of the scope of local type works (local repair of blowouts and/or replacement of the base layer of asphalt on a smaller part of the project in order to level the base for the wearing course).

3 Rehabilitation of the pavement structure by reinforcing the asphalt of the city street in the city of Osijek

This paper presents the technical elaboration (with an overview of the solutions provided from the design plans) of the rehabilitation of the pavement structure in a section of Stjepana Radića Street in the city of Osijek. Here, a geosynthetic - mesh for reinforcing asphalt, were used to increase the resistance of the pavement structure to damage and slow down the development of possible reflective cracks. For the rehabilitation works, projects [14] and [15] were prepared, defining all parameters of the application of the material, along with the definition of other design elements, horizontal, vertical and transverse.

3.1 Existing situation

Stjepana Radića Street is an unclassified road under the administration of the City of Osijek. In nature, it is a connecting, transversal street near the city center where increased traffic of passenger cars, trams and other vehicles occurs continuously. The section of the street covered by the project is from Reisnerova Street to Europska Avenija. Within the street, there are numerous facilities in the form of restaurants and other users, which requires both delivery vehicle traffic and secured access. The review prior to the project development focused on the condition of the pavement. Other technical elements (such as sidewalks, the eastern side of the curb) were not taken into account because they were in satisfactory condition. A visual inspection and analysis of the existing pavement condition identified damage typical for pavement structures exposed to long-term traffic load without previous rehabilitation procedures or local repairs. Laboratory tests of the composition and properties of pavement structure were not conducted. Degradation of asphalt wearing course was manifested in the form of transverse and network cracks and local deformations in the form of initial ruts, which were not present on the entire observed section, but only on a very small part. The structure and distribution of cracks indicated fatigue of the asphalt layers, and very few signs of extensive weakening of the unbound base layers or significant subsidence/separation of the material were recorded, in terms of potholes and local depressions. Such condition indicated the possibility of carrying out rehabilitation of the pavement structure without complete replacement of all layers. Based on the technical analysis, it was concluded that the main problem is related to the degradation of asphalt layers, while the primary load-bearing capacity of the structure (according to the visual inspection and damage categorization) remains within acceptable limits for the designed traffic load (light and very light traffic load).

3.2 Design solution for rehabilitation using geosynthetics - mesh for asphalt reinforcement

Unplanned maintenance is a group of more demanding and extensive road maintenance works, with the aim of long-term improvement of individual parts of the road without changing its technical elements, ensuring the safety, stability and durability of the road and road structures and increasing traffic safety. Extraordinary maintenance works are carried out periodically, and their scope is related to the degree of deterioration or damage to the road [16]. The execution and design in this case were planned in two phases/sections. For the purposes of execution, two detailed designs were prepared [14, 15]. The designs were prepared in accordance with Article 42 of the Road Maintenance Ordinance [16]. The detailed designs contained a technical description, graphic attachments (drawings), a quality control and assurance program and a cost estimate for the execution of works. The horizontal elements were designed identically to the existing ones, the vertical elements were defined so as to drain rainwater from the road surface and maintain satisfactory driving-dynamic characteristics at lower speeds. Normal cross-sections define the technical elements that are present in continuity.

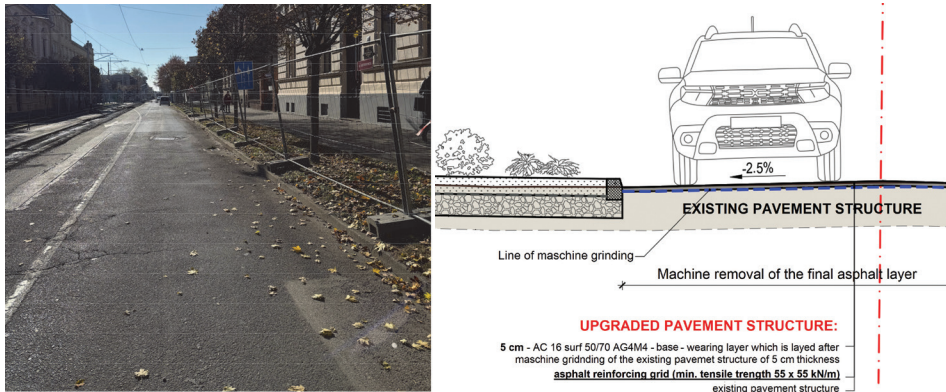


Figure 4 Condition of the pavement surface on Stjepana Radića Street in Osijek before reconstruction (left), the rehabilitation design solution (right) [14]

The work execution procedure is also defined by the project. Machine removal of the final asphalt layer was planned to be 5 cm thick. The pavement structure is retained and after the removal is completed, the existing structure was upgraded to an average layer thickness of 6 cm (min. 4 cm, max. 8 cm). The thickness of the layer to be installed may vary depending on the condition of the sublayer after the machine removal (which may show undulations, longitudinal and transverse irregularities and local depressions), the designed vertical alignment and the designed transverse slopes to ensure storm water drainage.

In the locations of local depressions or zones where the pavement structure had failed, it was necessary to carry out a complete pavement rehabilitation. This required the removal of all material from damaged and weakened layers (asphalt, aggregate) that had lost their load-bearing capacity to a stable, healthy base, and to install a layer of crushed stone material with a continuous granulometric composition of 0/63 mm ($M_s \geq 100 \text{ MN/m}^2$, $S_2 \geq 100\%$) before paving. In general, at the locations of the construction in question, where the asphalt layer needed to be made thicker (greater than 8 cm), the layer had to be made in two layers. A geogrid was installed between the load-bearing and wear-resistant asphalt layers. The project requires the use of geosynthetic mesh for asphalt reinforcement, with a tensile strength of 55 kN/m (in both directions), a tensile resistance of 46 kN/m at an elongation of 2.5% (+/- 0.5%), which has a self-adhesive layer on the underside to ensure contact with the sublayer. The installed geocomposite - a glass fiber mesh - consisting of a twisted mesh (mesh) with inserted threads whose properties are better than those prescribed by the design was used. The installation of the geosynthetics was carried out in accordance with the standard [17], while the Technical Regulation for Asphalt Pavements [18] was applied for the construction of the asphalt layers.

3.3 Execution of rehabilitation works

The machine removal of the existing wearing course was carried out, as planned in the project, with layer thickness of 5 cm. The removal was carried out continuously at the same thickness, which was a requirement due to the simpler execution. There was a possibility of performing machine removal of different thicknesses in partial sections of the sections, but in this case the asphalt thickness varied. Degraded material (milled asphalt) was removed to ensure properly prepared surface. The cleaning of the milled surface was carried out thoroughly.

Inaccessible parts were cleaned with hand-held motor brushes to cover every part of the surface. On a smaller surface of the pavement structure, it was necessary to perform a base layer of asphalt before the wearing course (AC 22 base AG6M1). New curbs were also constructed to form green areas and the edge of the pavement due to the height change of the final layer. The height of the drain grates was adjusted to the new designed plane. After cleaning the surface, the dry, clean and prepared surface was sprayed with bitumen emulsion in the designed quantity (0.35 kg/m^2), in some places even more, with the aim of ensuring adhesion between the layers (asphalt-mesh, mesh-asphalt). The asphalt reinforcement mesh was installed on the prepared surface, without forming folds and without losing contact with the substrate. Special attention was paid to the correct overlap and continuity of the system.



Figure 5 The reinforcement mesh on the prepared base and laid asphalt layer

Immediately after the mesh was installed, a new load-bearing and wear-resistant asphalt layer (AC 16 surf 50/70 AG4M4) was laid with a variable thickness of 5-8 cm, in accordance with the designed final level, with controlled mixture temperature. The implemented solution is based on increasing the resistance of the structure by increasing the resistance to tensile stresses in the lower zone of a new asphalt layer. The asphalt layer AC 16 surf AG4M4 was chosen in order to meet the min.-max. technological installation thickness (4-9 cm) and to ensure the necessary load-bearing capacity. It is expected the service life of the structure would be extended. Long-term evaluation will require monitoring the condition of the pavement during exploitation, which will allow quantification of the actual effect of the intervention.

4 Conclusion

The use of geosynthetics in roads, especially in the layers of the pavement structure, has positive effects on both the load-bearing capacity and durability of the road, as well as on the total costs that include maintenance. In the rehabilitation of roads, especially alongside existing traffic, the requirements for speed and efficiency of execution can be crucial, and geosynthetics can be an important element that contributes to the success. The use of geosynthetics for asphalt reinforcement, which affect the behavior of asphalt layers in terms of stress distribution and crack control is significant. The effectiveness of such a system depends on the quality of the sublayers, the proper application of certain type of geosynthetic and asphalt, and precise execution.

An analysis of a current state of the pavement structure load-bearing layers in the city street Stjepan Radića in Osijek showed that the degradation mainly affected the asphalt layers, while the primary load-bearing capacity of the other layers allowed structural rehabilitation without complete reconstruction. Given the importance of this street for the functioning of city traffic, a need for efficient and time-limited rehabilitation emerged. It was possible to implement it by applying a system of reinforcing asphalt layers with a geogrid reinforcement.

The use of geogrids for asphalt reinforcement between existing and new asphalt layers gives a more favorable distribution of tensile stresses and increases the system's resistance to the appearance and propagation of cracks. Such approach represents a technically sound and rational solution in urban traffic infrastructure conditions, assuming proper design and strict implementation control.

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