Ten years of experience in geosynthetics application in Croatian road construction

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ABSTRACT: Application of geosynthetics, as an important element in structure design, has increased in road construction in Croatia over the past 10 years. In view of the projects including the application of geosynthetics realized in Croatia to date, it can be stated that the application of geosynthetics is rather limited and comparatively minor considering the size of investments in motorway construction. There is rarely any interest for and understanding of long-standing effects and benefits of application of geosynthetics, which initially, at the beginning of the design life increase the cost, but over the long term bring savings through reduced maintenance. The continuous education of all participants in construction in Croatia is aimed at activating and raising the awareness about functions and effectiveness of certain geosynthetics, always emphasizing what they do and how much they contribute, rather than what they are like and how much they cost. These efforts are always the same, regardless of the target group – Investors, Designers, Supervision, Contractors and Dealers.

1 HISTORY

The Republic of Croatia has declared its independence from Yugoslavia in 1991, at the time when the country was already under attack of the Yugoslav National Army and Serbian paramilitary units. The most intense war operations took place in 1991 and 1992, but even after the combats ceased in 1995, one part of Croatia remained under the occupation of Serbian army, so that Croatia has gained its overall territorial integrity as late as in 1997.

Over all these years the devastation was huge, affecting not only cities and villages, but also industry, agriculture and tourism – all of which were the base of the national economy. In such circumstances it was crucial to start major infrastructural projects that would support the economic recovery.

At that time, Republic of Croatia has defined the construction of road infrastructure as a strategic requirement of economic development, considering its unique position in European land and maritime traffic flows.

In the period from the end of the war to the year 1998, studies and designs were developed that provided accelerated construction that is still underway.

The road infrastructure that was left from Yugoslavian federation provided a good foundation. Therefore, capital investments could be primarily oriented to construction of motorways, while alternative sources of financing had to be found for local and state roads, so that they were provisionally rehabilitated or, not so often, reconstructed.

Exactly 10 years ago the expansion of motorway construction began, facilitated by the reorganization of the road system and by development of the original financing model. In this way the motorway network could be established as a part of Pan European traffic corridors Vb and Vc, X and Xa, connecting Croatia with the EU member countries.

The first major road project in Croatia has been realized through the concession that Croatian Government granted to Bechtel-Enka Joint Venture, which provided financing of the first 130 km of new motorways in the Republic of Croatia. Although still considered as controversy, this project has initiated the recovery of Croatian contractors and has at the same time resulted in significant introduction and use of new materials and technologies.

The subsequent construction works were financed from several sources, including the budget, toll revenue, income from gasoline price, loans of the World Bank and European Bank, but also further concessions and programs of public-private partnership.

The motorway network in the Republic of Croatia is defined in the National Physical Planning Strategy of the Republic of Croatia of 1997, and especially in the Transport Development Strategy of 1999. Within

the framework of this Strategy, 1 514 km of motorways is planned, of which a total of 1 231.2 km has been constructed to date.

Though this might not seem much, considering the size of Croatia (56 542 m^2, population of 4 million), this indeed is rather impressive achievement, especially in view of the heterogeneous geographic conditions and climate zones, calling for a variety of construction solutions.

2 LEGISLATION AND STANDARDIZATION FOR GEOSYNTHETICS IN CROATIA

In the Republic of Croatia and in former Yugoslavia geosynthetics have been used prior to the commencement of this major investment cycle and of the "new era" of geosynthetics. These were primarily locally manufactured geotextile and woven geogrids.

As this industry has been destroyed in the war, the application of geosynthetics stagnated and engineering practice included little or no knowledge of types, possible applications and benefits of applying geosynthetics in construction industry. As a result of such situation, no adequate technical regulations existed and consequently there was no standardization for this type of products.

These processes were set in motion trough Croatian state Office for Standardization and Metrology, subsequently the Croatian Standards Institute (CSI), under the significant influence and initiative of economic entities interested in opening and expanding the market for geosynthetics in the Republic of Croatia. In 2 000 CSI established a technical committee for geosynthetics TC 221 *Geosynthetics*, which corresponds to the international committee ISO TC 221 and European CEN/TC 189 with respective subcommittees.

As the Republic of Croatia is a candidate for joining the European Union, the adoption of European standards is one of the chapters included in the accession process. Late in 2008 the Technical Committee TO 221 has processed and adopted all European standards relevant for geosynthetics testing and quality assurance procedures issued to that date and the Croatian Standards Institute has qualified for full membership in European standardization organizations such as CEN and CENELEC, which is to be effected in 2010.

The technical conditions of road and motorway construction are defined in „General Technical Conditions for Road Works" (GTC) issued by the Civil Engineering Institute of Croatia (IGH). As a result of the cooperation with economic entities engaged in geosynthetics, the GTC define minimal quality requirements and minimal technology requirements for placing geotextile and polymer geogrids for the application in weak soils and for slope protection against erosion. General technical conditions also provide detailed guidelines for the use of geosynthetics in terms of placing, overlapping, fixing, limitations, but also in terms of acceptability, preliminary, control and audit testing and technical characteristics.

Application of geosynthetics for water protection zones (geomembranes, GCL) and for reinforced soil, also applied on motorways, is not defined in technical conditions. In such cases the Technical Conditions (TC) are stipulated in the designs.

2.1 *Technical conditions for geotextile application*

The specified applications of geotextile in roads are the applications for the purpose of separation, stabilization, filtration and drainage.

The minimum quality requirements for geotextile intended to separation and stabilization are determined by a series of parameters. The required characteristics of this geotextile type (maximum tensile strength in kN/m, tensile yield in %, static puncture strength in N, hole diameter in mm and dynamic puncture strength in N) are defined with respect to the largest grain size of fill material and to the grain shape for three foundation soil types (types U1 to U3), as well as with respect to deformation and compressibility modules and according to various load values. By way of illustration, for U1 type soil the requirements are $EV_1 \leq 5$ MN/m^2, $Ms \leq 6$ MN/m^2, while for the U3 type soil the requirements are $EV_1 \geq 15$ MN/m^2 and $Ms \geq 20$ MN/m^2, i.e. the minimal required tensile strength of geotextile for U1 soil with equivalent 20 years traffic load must be ≥ 23 kN/m, and for U3 soil this requirement is ≥ 11 kN/m.

Minimum quality requirements for geotextile intended for filtration and drainage are determined by the aperture size, permittivity and transmissivity, whereas the key mechanical characteristics are maximum tensile force, yield and puncture strength, as well as aperture size.

The nominal values used for defining the quality requirements for geotextile clearly show that minimum requirements for mechanical characteristics were stipulated, thus offering scope for the application of low-quality materials. It is for that very reason that the type of placed geotextile used to be determined primarily by the price, and only secondary by the characteristics. In addition, the characteristics were often considered selectively and not within the proper application context, so that in some cases it would have been better if the geotextile has not been applied at all.

2.2 *Technical requirements for application of geogrids*

GTC classified geogrids in road construction according to types A to G. For the application of geogrids in slope protection the same quality requirements apply.

The above specified geogrid types differ in terms of mass per unit area, opening size, tensile strength (maximal and at 2% and 5% deformations), in-plane torsional stiffness, node thickness (in percentage) and roll dimensions. Such rough classification does not provide for achieving the expected effects of the material applied.

Geogrid properties are determined in line with certain manufacturer specifications, in an attempt to set a certain quality level whilst also enabling the competitive edge on the market. Despite these efforts, low product price still remains the key factor in the selection of the material and this is a basic issue in all major applications.

3 GEOSYNTHETIC APPLICATION IN ROAD CONSTRUCTION

Although small in terms of surface, the Republic of Croatia is due to its shape a land of major geological and climatic differences. The areas in the East have the moderate continental climate of lowlands with prevailingly clay materials. In the central part of the country the landscape is in the transition from lowlands to hilly configuration with marls, sandstone up to limestone, whereas in the southern part of the country, along the Adriatic coast, the terrain changes into mountain massifs (limestone, granite, basalt), criss-crossed with lowland surfaces of terra rossa and in places wetland.

In such conditions the geotextile is commonly used in separation, filtration and drainage. As a rule, a non-woven PP geotextile is applied, often defined by the weight of 300 g/m^2 (not defined as a property in the GTC) which corresponds to the requirement of tensile strength ≥ 21 kN/m. Woven geotextile has not been applied in construction up to now, although it was included in some soil stabilization designs, but mostly for the reason of convenience, geogrids where used instead.

Geogrids have been applied for stabilization of weak foundation soil with $Ev \leq 5$ MN/m^2, where PP monolithic biaxial geogrids of tensile strength 20/20 kN/m up to 40/40 kN/m were typically used. Woven geogrids with the same strength range were used rarely, mostly for rehabilitation of existing pavement structures, as a direct substitute for monolithic geogrids, which – together with careless placement – lead to poor application results and finally to less common application.

Geogrids have also been used in embankments of reinforced soil, mostly as noise protection, when the goal was to use the low-quality excess excavation material, but due to the lack of space the slope inclinations ≤ 45° were not possible. Monolithic uniaxial HDPE geogrids were used. The major challenge of this application was landscaping of embankment slopes.

In view of the fact that the major part of the motorway was passing through rocky area of sedimentary, metamorphic and magmatic rocks, the opportunities for application of reinforced embankments with polymer geogrids were very rare and gabion structures were mostly used, both in retaining structures and in noise protection.

The next major application of geosynthetic materials was for slope protection, where three-dimensional polymer geogrids and web structures were mostly used. The major issue was landscaping, as the common challenges were lack of high-quality topsoil on the route, inappropriate hydroseeding mixture and its application to the slope, as well as poor maintenance.

The use of geomembranes was less common – it was mostly limited to the application in lagoons within closed drainage systems and for the protection of underground water against accidents such as oil spill or other pollutants on the road.

Despite numerous problems that had to be faced from design phase to maintenance in the application of geosynthetics, each implemented solution has provided experts with new insights, especially in the determination of appropriate solutions for individual geographic areas in the Republic of Croatia. According to the current references, at least 5 000 000 m^2 of geosynthetics of various types have been placed in Croatia.

4 WHAT'S THE FUTURE LIKE FOR GEOSYNTHETICS IN CROATIA?

Anybody interested in application of geosynthetics must face the fact that the Investors often lack an objective perspective when it comes to geosynthetics. Usually, they will assess geosynthetics trough initial increase of investment and not by the long term benefits. It is for that reason that these design solutions are often considered to be unnecessary investments.

There is a prominent interest of the Contractors who are not into saving natural row materials, as often they are the owners of such materials (e.g. stone), or they want to use the cheapest material meeting the specified requirements without true understanding the impact mechanism of geosynthetics within the structure, as well as differences in effects determined by the production technology, opening size, row materials, etc.

Therefore, it often occurs that the designed material is substituted for a material of the same nominal strength, but different production technology (e.g. monolithic with woven grid) without recalculation of the structure. The designer and the supervision engineer sometimes contest such substitutions, but in the practice they are often accepted, as the material certificates show the required mechanical values and other properties, thus meeting the stipulated form and requirements whilst reconciling the interests of both Investor and the Contractor regarding saving.

In such constellation of approaches and interests, each application of geosynthetics - other than the application of geotextile as commodity for separation or drainage courses – has been resisted by some of the participants in the construction process, and such resistance was mostly motivated by the price, by Contractor's interest for applying their own material (stone, asphalt) or by the distrust for a tentatively new solution that has not been previously applied in our country.

In first applications of some systems and materials, especially of mats for slope protection and geogrids for soil stabilization, some negative effects were observed, caused by improper installation of these materials, resulting in such damage that it would be better if no material at all had been placed. Geogrids were insufficiently fixed to the base, which resulted in occurrences of "nests" in the pavement structure and subsequent damages under traffic load, or the vegetation could not develop on the slopes, which then resulted in the degradation of geosynthetics and slope erosion.

Such cases have generated an atmosphere of distrust for the solutions including the application of geosynthetics and this distrust is still present, despite the fact that a number of projects have been successfully realized. It can therefore be said that the views of the professionals with respect to the application of geosynthetics are still divided.

Still, we are witnessing a huge development of geosynthetics market and much larger understanding and willingness of professionals for geosynthetics application. This development happened mainly due to the huge and constant effort of few companies and individuals who recognized endless possibilities of geosynthetics as well as good business opportunities. Since the construction of highways and roads are ongoing as well as the rehabilitation of existing roads, it can be expected that geosynthetics will be continually used in road structures in more diverse application.

Even though we are facing recession and economical crisis as the rest of the world, future investment cycles are either in preparation or starting, so we expect a large market for geosynthetics in landfills and railroads. These projects will require different approach and solutions, but good foundation in knowledge and standardization are prepared.

5 CONCLUSION

The Investors of major infrastructure projects are mostly government-owned companies, where the political changes result in frequent changes of CEOs and decision makers. For this reason there is rarely any interest in and understanding long-term effects and benefits of the application of geosynthetics, which maybe raise the cost at the beginning of the service life, yet bring savings in the long-term due to lower maintenance requirements.

In addition, the market is currently swamped with low-quality geosynthetic materials and due to the irresponsible behavior of geosynthetics dealers, who compromise even quality geosynthetics through improper applications – we are now facing a growing distrust of professionals towards the application of geosynthetics, not only locally in Croatia, but also in other European countries.

In order to improve the situation and ensure the future application of geosynthetics, the following measures needs to be taken:

- Quality control and quality assurance in the production of geosynthetics (QC &QA), as well as distribution through ISO certified companies;
- Active participation of geosynthetics community in defining all relevant quality parameters in technical regulations;
- Definition of technical requirements for application of geosynthetics in various structures, as well as monitoring and supervision of such applications (ISO certified dealers!);
- Continuous education of professionals and training of all participants in the construction process on the proper application of geosynthetics in structures, on actual implications of short-term and long-term mechanical properties and on the long-term benefits of the application in terms of service life of structures and reduced maintenance costs;
- When promoting geosynthetics the emphasis should be on environmental protection in terms of reduced use of natural resources and underground water protection.

Experiences in developing geosynthetics applications and market in countries such as Croatia have shown that these main points, when applied, are leading to success.

REFERENCES

Crnjak, M. & Puž, G. 2007. *Capital Traffic Infrastructure in Republic of Croatia*
http://www.hzn.hr

Croatian Roads & Croatian Highways 2001 *General Technical Conditions for road construction*
http://www.werkos.com