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Cover Illustration: Porte di Pinerolo, north western Italy. Bridge located on Chisone river after the flood event occurred on October 2000. The photo shows the effects of extreme hydrological events on anthropic areas and infrastructures. *Photo*: Giorgio Lollino.

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Challenges of Renewable Energy Source Utilisation at Section of Future Highway E-763 Belgrade-Southern Adriatic Across Karst Plateau of Pešter Plateau (Western Serbia)

113

Milenic Dejan, Stevanovic Zoran, Dragisic Veselin, Vranjes Ana, and Savic Nevena

Abstract

The highway Belgrade-South Adriatic is part of the big European corridor E-763 that should connect Rumania and Hungary with southern Italy and Albania. The longest part of the Corridor 11, as it is called, passes through Serbia for an overall length of 258 km. The longest part of the corridor E-763 through Serbia is at the same time the most challenging one. It is anticipated to reach the border with Montenegro by the construction of an entirely new route across the Pešter plateau, one of the highest and largest plateaus in Europe with average altitudes from 1,200 to 1,500 a.s.l. It has been calculated that the necessary amount of thermal energy to be provided per m^2 is 200 W, which for the overall section across the Pešter plateau gives the total amount of thermal energy of about 100 MW. A prognosis model of such a solution to the problem with accompanying techno-economical analysis is presented in the paper.

Keywords

Karst plateau • Highway heating • Renewable energy source • Geothermal energy

113.1 Introduction

The Belgrade–Southern Adriatic highway is part of the big European Corridor E-763 which should connect Romania and Hungary to southern Italy and Albania (Fig. 113.1). The longest part of the Corridor 11, as it is also named, passes through Serbia with a total length of 258 km. It is anticipated that the border with Montenegro will be reached by the construction of an entirely new direction across the Pešter plateau, one of the highest and largest karst plateaus in Europe with average altitudes ranging from 1,200 to 1,500 a.s.l.The length of the section of Corridor 11 passing through the Pešter plateau, which also represents the most challenging part of the Corridor, is 26 km.

The Pešter plateau is a tectonically controlled karst depression covering a surface of about 50 km^2. From a demographic point of view, the Pešter plateau is a depressive area. Settlements are of a mountain type, with the population tendency to migrate towards administrative centres (Sjenica 10,000 inhabitants, and Tutin 6,000 inhabitants).The road infrastructure network is developed only in the northernmost parts of the plateau while in its central and southern parts transport uses macadam roads.

113.2 Aim and Methodology of the Research

Characteristics and specificity of the Pešter plateau as to climatic features, geomorphologic setting of the terrain, and geological setting represent a challenge to the design and construction of the route and especially to its subsequent maintenance. The route is designed as a communication line with two lanes, one for each direction of travel. Each

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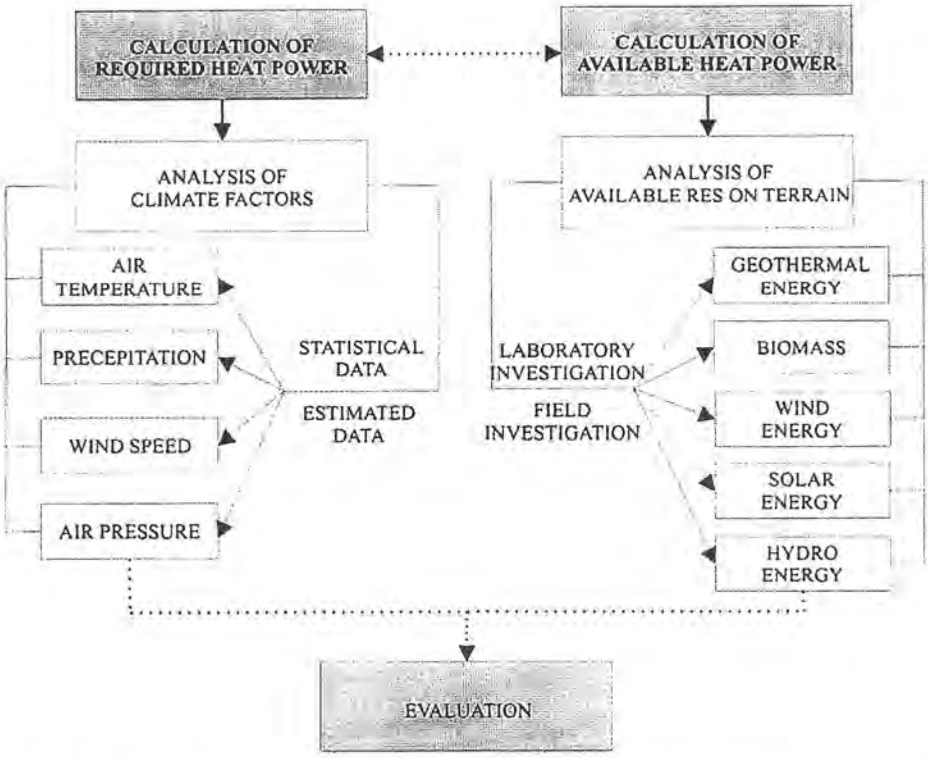

Fig. 113.2 Flowchart of applied research methodology

energy. In order to evaluate the hydrogeothermal potentiality of the terrain, field methods have been conducted: geological / hydrogeological mapping, the establishment of groundwater resource network monitoring: monitoring of groundwater temperature and yield during the hydrological cycle, groundwater sampling and chemical analyses.

113.3.2.1 Geological Setting of the Terrain

In geological terms, the terrain is dominated by carbonate sediments of Triassic age with pronounced vertical karstification towards the regional erosion basis of an approximate depth of 300 to 400 m. Karst is predominantly detected in the area of more than 50 % of the terrain, which contributes to the formation of micro-climatic conditions in the terrain. The limestone bedrock without vegetation heats and cools fast, and therefore temperature amplitudes above it increase (Zeremski 1960). The northern part of the plateau is covered with Miocene sediments in which a significant deposit of lignite brown coal has been formed. South-eastern part of the plateau is flooded by young proluvial deposits. The oldest rocks on the route through the Pešter are represented by serpentinite and diabase—chert formation of Jurassic age (in the central part of the route). Alluvial sediments are found in the valleys of large river flows intersecting the route. In the Pešter plateau area, there are pronounced cave systems, of which the longest one is the Đalovića cave with over 12,000 m of explored passages. There are also recorded three large underground streams, of which the most significant one, the Borošnica sinks carrying several hundred litres minimum in the underground karst system. It is essential to note that, on the Pešter plateau, there have been recorded significant amounts of peat, which has been exploited for the purposes of humus and compost for plants, while they have not been considered as an energy resource.

113.3.2.2 The Possibility of Utilisation and Evaluating of Geothermal Energy Potentiality

In Table 113.1, the data of groundwater yield and temperature monitored during one hydrological cycle, correlated with the observation data of several years, are presented. The observation network includes sources that are recorded at the 2 km distance from the future route of the Corridor 11 through the Pešter plateau. Observations also included mine waters of the Štavalj mine. The available thermal power that can be obtained by hydrogeothermal resource exploitation with heat pumps is about 61 MW. For the calculation of the available heat power the formula (Milenic et al. 2010) is used:

$$E = C_p x\ Q\ x\ \Delta T$$

where:

E Available nominal power (kW)
C_P specific water heat (constant, 4.2 kJ/kg/°C)

Table 113.1 Summary table of hydrogeothermal resource thermal power

Type	Q_{sr} (l/s)	T_{water} (°C)	E (kW)
Springs	4.000	8.0	50.400
	200	12	5.880
	22	20	1.386
Mine water	100	12	2.940
Σ			61.606

Q source yield (kg/s, the same as l/s)

Δ T-temperature reduction that can be achieved in a heat pump (up to 5 °C)

The analysed groundwater chemism of the Pešter plateau points to typical karst water of a hydrocarbonate class calcium type of low mineralization. Parameters of the chemical composition, including the chemism of mine waters, whose values impact the utilisation of the groundwater in heat pump systems (Cl, SO_4, NO_3, Mn, CO_2, NH, Fe, O_2, H_2S, SO_3, Cl_2) are within the allowed limits.

113.3.2.3 Possibility of Other RES Utilisation

In the area of the Pešter plateau, exploratory work is under way in order to evaluate the potentiality of solar, hydro and wind energies. There is a two-purpose application of solar energy: for melting of snow and ice, when it is used in combination with geothermal energy and in the form of PV panels as a sound barrier, as well as the barrier for preventing snow drifts. Coupled utilisation of geothermal and solar energies is anticipated on bridges and overpasses. The area of the Pešter plateau is also suitable for the wind energy (mean values ranging from 100 kW to 1 MW) to generate electricity as a source of highway heating. In the plateau area, a 500 kW wind turbine is running. The route of the 11 Corridor through the Pešter plateau follows the river flows of the Nosnica, Vrapska River Branjička River and Suvi potok. Six locations of the surface flow regulation with the total length of 1,633 m (Ignjatovic et al. 2008) have been anticipated on the route. The average discharge flow ranges from 0.5 to 2 m^3/s, which represents a significant energy potential.

113.4 Conclusion

The first research phase of the possibilities of renewable energy source utilisation in the section of Corridor 11 through the Pešter plateau (26 km), in order to evaluate their potentiality, began in the second half of 2012 and is still ongoing. As to the calculation of the required heat amount, it is calculated that, an amount of 200 W must to be provided per square meter, which gives the thermal energy amount of about 100 MW for the overall section through the Pešter plateau. According to past results, the hydrogeothermal energy has the greatest energy potential, about 60 MW, which meets about 60 % of the calculated heating requirements for the highway heating. The remaining 40 % is planned to be provided from solar, hydro and wind power, and their coupled use. The second utilisation phase anticipates the system optimization, including economic justification and sustainable exploitation of, primarily, hydrogeothermal resources. The optimization of the system also anticipates distribution levels of the heat energy on the section, namely the first option anticipates the heating of critical parts of the section (bridges and overpasses), and the second option anticipates the heating of 26 km, which would be the longest road of this kind in Europe. The cost of geothermal road heating systems ranges from 800 to 1,500 euro/m^2 depending on the equipment and manufacturer.

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