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THE USE OF TUNNELS TO DEVELOPMENT OF TRANSPORT IN MOUNTAIN AREAS

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Summary

The article presents several possibilities of using tunnels to solve traffic problems in the area of the Polish mountains. So far, in contrast to other countries in Europe and the World in Poland this kind of solution are benefited reluctantly. However, in the longer term, tunnels construction in conjunction with flyovers are cheaper solutions, safer and considerably reduce the negative impact of transport on the environment. The situation is beginning to change and recently in Poland increases interest in the underground construction, particularly tunnels in mountainous areas are observed. This paper describes the newly built tunnel in Laliki and planned to build tunnels in the area of Lubień, Poronin, Krynica-Zdrój, Jordanów and Węgierska Górka.

Keywords

tunnels • mountain areas

1. Use of tunnels in road transport worldwide

There are hundreds of kilometers of tunnels being built annually all over the word. Both rich and poor countries found, that tunnel construction is profitable. We have learned to build tunnels in various natural conditions: in the mountains, underwater, in loose soil and solid rock. The time has come for Poland to use this modern solution on a greater scale, especially in mountain areas. Nowadays, Italy is the absolute leader in the number and lengths of road tunnels, next comes Switzerland and then Japan and Austria. In these countries, a significant area is taken by mountains. Table 1 presents data from 10 years ago regarding the road tunnels in the leading countries [Klepsatel et al. 2003].

In Poland, as well as in Slovakia and Czech Republic the number of road tunnels is not tremendous. At the moment Poland has 2 tunnels: one in Warsaw, which is a part of Wisłostrada and the recently built tunnel in Laliki. The total length of these tunnels is 1.5 km. Slovakia has only 4 tunnels, one of which is about 5 km long, but in the near future it is planned to build 21 tunnels, whose total length will be 37 km. Likewise, Czech Republic has only a few tunnels, 4.7 km long in total, most of which are parts of bypasses of big cities, but in the near future it is planned to build 28 tunnels, 34 km long in total. Hence, in the coming years Poland and its southern neighbours will face construction of roads with tunnels and viaducts in order to meet the 21st century road standards. Similarly it is in case of railway tunnels. Japan is an absolute leader in this area, as due to the mountainous characteristics of most of its area and high speed of trains, railway tunnels are unavoidable. The data regarding railway tunnels longer than 2 km and their total lengths are presented in Table 2. Poland, Slovakia and Czech Republic have less than 20 tunnels each (most of them shorter than 1 km).

Table 1. Number and lengths of road tunnels longer than 500 m in selected countries

No.	Country	Total for tunnels longer than 500 m		Longer than 1 km		Longer than 2 km	
		number	length [km]	number	length [km]	number	length [km]
1	Italy	780	881.3	404	613.7	147	266.4
2	Switzerland	222	370.3	129	306.7	57	205.0
3	Japan	161	379.3	113	369.2	92	338.7
4	Austria	151	294.0	89	250.8	48	179.6
5	Spain	131	163.3	80	128.4	29	97.9

Source: Klepsatel et al. 2003

Table 2. Number and lengths of railway tunnels longer than 2 km in selected countries worldwide

No.	Country	Longer than 2 km		Longer than 5 km		Longer than 10 km	
		number	length [km]	number	length [km]	number	length [km]
1	Japan	240	1173.0	75	670.8	18	300.1
2	Italy	125	705.9	50	473.2	17	241.4
3	Switzerland	41	305.6	17	231.4	9	173.0
4	Spain	36	116.1	9	53.2		
5	France	34	196.4	10	120.9	2	64.0

Source: Klepsatel et al. 2003

2. Tunnels in Poland

In Poland there are currently over a dozen tunnels, most of which are railway tunnels in mountain areas. The tunnels are located on the following routes: Kłodzko – Wałbrzych (under Mały Kozioł, 1601 m long, under Sajdak between Głuszyca and Jedlina and under Świerkowa Kopa, 1560 m long, built around 1910, under Świerkowa Kopa, 1171 m long; between Gorzyniec and Szklarska Poręba Dolna; 3 tunnels on line Jelenia Góra – Lwówek Śląski; between Wojanów and Trzcińsko; under Kowary pass; near Unisław Śląski; Kulin Kłodzki (approximately 500 m) and one more Kłodzko – Kudowa Zdrój;

Bardo; Długopole Zdrój; Bielsko-Biała; tunnel (double); Kamionka Wielka; Żegiestów; Łupków; tunnel narrow-gauge on line Przeworsk – Dynów.

In recent years, the benefits of road tunnels are becoming even more visible, which results in new design and construction projects. Quite recently, “Emilia” tunnel in Laliki near Zwardoń in Beskid Żywiecki was opened. In near future, along with the construction of new highways it will be necessary to build a series of tunnels, e.g. on the route from Krakow to Zakopane, near Krynica, in Beskid Śląski. Why did tunnel construction branch develop so slowly in Poland? There could be two reasons: the unreasonable belief that tunnel construction is very expensive (even when it is, no one takes into consideration the long lasting benefits of this solution), and the fact that tunnel construction has been developing based on the mining industry. Our designers and engineers nonrelated to mining have had no experience with underground tunnel construction. Here are a few examples of tunnels and chambers constructed by mining-related companies:

- underground workings of hydro power plants “Porąbka-Żar” (1969–1977), “Młoty” (1971–1981), “Czorsztyn-Niedzica” (1977–1986),
- hydrotechnic tunnels in Tresna (1961–1964), Dobczyce (1985–1986) and two adits in Świnna Poręba (1988–1994),
- over a dozen underground workings and tunnels abroad were made by Polish companies related to mining construction – mainly Construction and Mining Companies, e.g.: underground workings of hydro power plants Markersbach (1973–1975) and Goldisthal (1975–1976) in Germany,
- underground workings of Messochora hydro power plant (1994–1997) in Greece,
- Ankaray railway tunnel (1993–1999) in Turkey,
- tunnel on route from Iijet-Ramdan to Djamel (1984–1988) in Algeria,
- road tunnels in Izmit (1988–1991) and Nur-dagi (1992–1994) in Turkey,
- Tsing Yi (1993–1995) in Hong-Kong,
- Har Gilo Long Tunnel (1993–1994) in Israel,
- road tunel in Montenegro (1991),
- 3 tunnels on Canary Islands,
- underground garages in Berlin, Frankfurt, Palma de Mallorca, etc.,
- construction of Warsaw Metro Line 1.

3. Why should we build underground objects, including tunnels

According to common perception as well as some surface construction specialists, tunnel construction can be justified only by extreme topographical and technical conditions, due to incomparably higher construction costs when compared to construction of surface objects. This applies especially to comparison of road section with a road tunnel. However, these comparisons (unfortunately) do not include the following costs [Tajduś et al. 2012]:

- costs related to purchase of land (in case of a tunnel there is no need for land purchase and owner's consent, especially when tunnel construction is based on mining and geological law),
- costs related to moving the infrastructure (e.g. pipelines, cables, high voltage lines etc.),
- road maintenance costs, especially during winter,
- costs of proofing against avalanches and falling rocks,
- costs of construction of a much longer road, which can be significantly shortened thanks to the tunnel,
- environmental costs, which are very difficult to estimate; vehicles travelling on a level road (in a tunnel) use much less energy than vehicles in mountainous terrain; when climbing a hill, vehicles use a lot of energy which is not recuperated in the downhill drive, but quite the contrary: even more energy is consumed by braking; this results in a lot environmental pollution; building a tunnel saves tons of fuel and reduces negative environmental impact,
- in open air there is no possibility to capture and utilize exhaust fumes, while in a tunnel such possibility exists.

Also, safety factors are often forgotten as a reason for tunnel construction. For example, the decision to build Seikan tunnel (in very difficult hydrological and geological conditions) was made after the Tsugaru straights tragedy, when a typhoon caused two ferries to sink, killing 1400 people. Also, the need to improve communication, tending mainly to reduce travel time between world regions is the main factor of tunnel construction development.

4. Selected mountain tunnels in Poland, under construction and planned

This section presents a list of possible road tunnel locations in Beskidy and Sub-Tatra area, which should be built in the nearest years in order to improve road communication.

4.1. Tunnels in Beskid Żywiecki

Recently, on S–69 expressway, leading to Polish-Slovakian border in Zwardoń, "Emilia" tunnel (Figure 1) was dug in Laliki [Majcherczyk et al. 2009]. The tunnel was named "Emilia" in memory of mother of Pope John Paul II. This 678 m long tunnel was opened in March 2010 and has the latest fire safety and surveillance systems. Most of the tunnel was dug underground using mining techniques and technologies; the rest of the tunnel was made using opencast method. This is a two-way traffic tunnel, oval shaped, with maximum height of 6.55 m and width of 11.2 m. In the nearest future two other tunnels are planned to be built in Beskid Żywiecki, in the district of Węgierska Górka. One of them is 1000 m long, the other 600 m long.

Photo by Napieraj

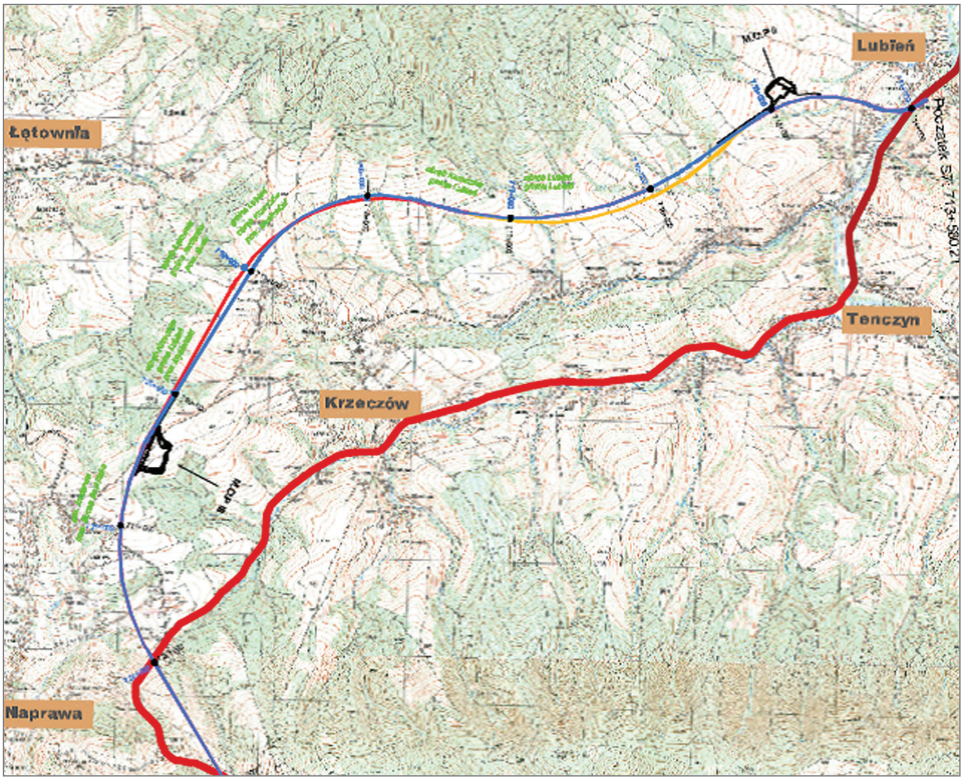
Fig. 1. The south end of the tunnel in Laliki

4.2. Road S7 tunnel: Lubień – Rabka

Currently there are 2 one way, 3 lane tunnels planned under Luboń mountain, 2.1 km each, as a part of S7 expressway Lubień – Rabka section (Figure 2). They will be oval shaped, dug using New Austrian Tunneling Method mining method. The cost is 1.3 milliard zloty. One kilometer of the tunnel is about four times more expensive than in case of the remaining sections of the road from Lubień to Chabówka, but it will shorten the travel time (no traffic jams), significantly reduce maintenance and road usage costs, especially in winter conditions, the costs of construction of a much longer road (compared to tunnel length), vehicle energy consumption costs (lower fuel consumption, and reduce the environment pollution). The profits resulting from the tunnel construction are hard to estimate, but in case of such a busy road as this one, connecting Kraków with Zakopane, they are likely to reach over a dozen million zloty each year. And the tunnel is built to last about 100 years, so the construction costs will be returned in a few decades, and then bring profits.

4.3. S7 tunnel in Poronin

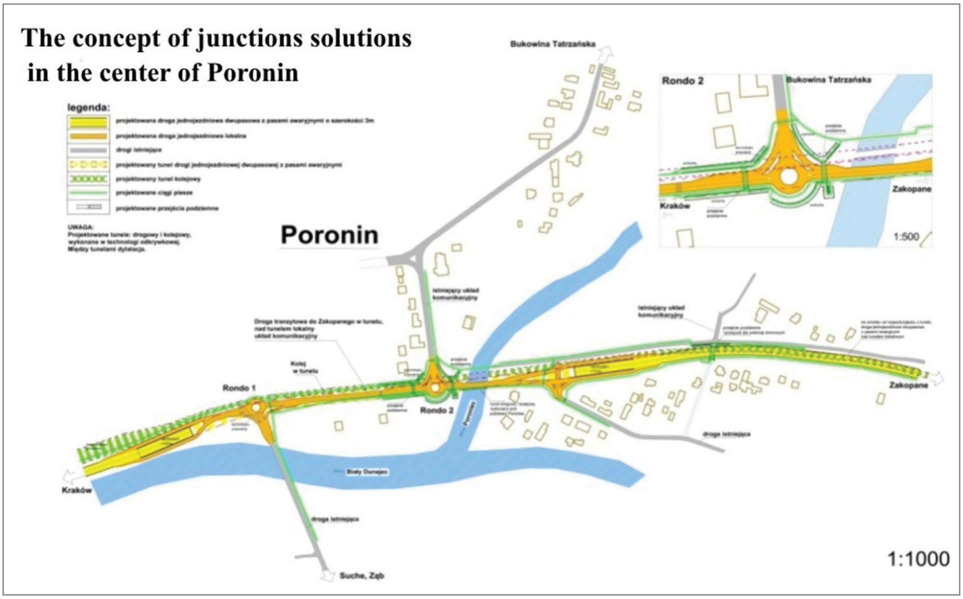
The construction of road S7 planned by GDDKiA in Poronin has led to very emotional reactions among the local community, as the project involves construction of an over a dozen meters high viaduct with junctions connecting it with towns and villages. It was assumed that this dual-carriageway road will handle the traffic of 17 thousand vehicles per day. The protests of the local communities were caused by: the necessity to demolish houses inhabited by mountaineers for generations, taking over a very big land area, worries that the attractiveness of this beautiful touristic resort will decrease (the viaduct and acoustic screens dominating the landscape), the expected increased pollution (large number of cars in poorly ventilated valley). They demanded to redesign the communication system in Poronin, so that it composes itself into the space, and interferes with the environment and buildings as little as possible. It should allow keeping the touristic and resort characteristics of the villages in the municipality of Poronin.



Source: Nawrat et al. 2012

Fig. 2. A scheme of the S7 expressway Lubień – Rabka tunnel

A new concept emerged, developed by architect Andrzej Chowaniec-Rybka in cooperation with professor Antoni Tajduś, to build a 700 m long tunnel using opencast method, which would contain a collision-free road to Zakopane and railroad tracks (Figure 3), and to recreate the existing road network on the surface adding two traffic circles at the intersections with roads leading to Bukowina and Ząb. Above the tunnel a creek would flow. Such solutions are nothing innovative. There are tunnels built under much bigger rivers ("Poroniec" creek is about 0.5 m deep and over a dozen meters wide) as well as laid on sea bottoms. The project designed by architect Andrzej Chowaniec does not require demolitions and tall viaducts. From the local community's point of view, this project is much better. Of course, other solutions are also possible, but each of them should include a tunnel or tunnels (e.g. for people or animals).



Source: archive of Chowaniec-Rybka

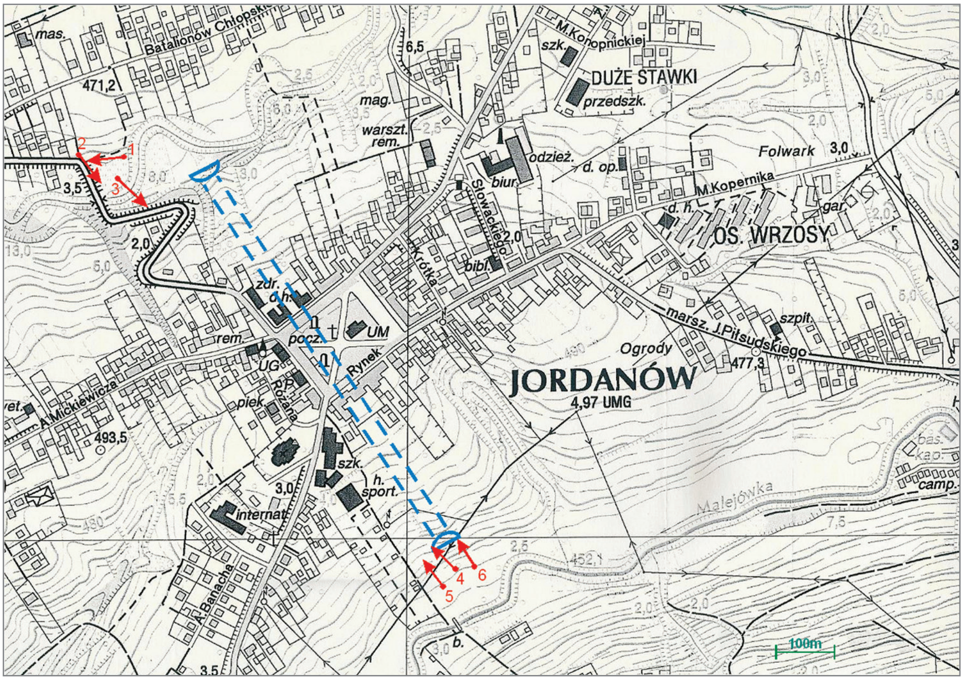
Fig. 3. A scheme of communication solution with use of a tunnel

4.4. Tunnels in the vicinity of Krynica Zdrój

Currently Krynica is undergoing preparations for construction of a bypass with two or three tunnels. This is an initial stage – concept development. We suggest the following solution: going from Nowy Sącz, the first tunnel would begin before Krzyżówka hill, and would end in Słotwiny (ca. 3.5 km), the next tunnel would run from Słotwiny to the foot of Jaworzyna mountain (ca. 2.6 km). The third tunnel would begin at the foot of Jaworzyna and end near the village of Jastrzębik. It is possible to resign from the construction of the third tunnel and use the road leading to the south of Krynica. This solution would definitely decrease the traffic in Krynica-Zdrój itself, and therefore decrease the environment pollution and make it easier to get to Krynica-Zdrój and Jaworzyna in the winter, as well as simplify the journey towards Slovakian border.

4.5. Other tunnel constructions planned in Polish mountains

For some time, a concept of constructing an about 50 km long railway line Krakow – Podłęże-Piekiełko (near Tymbark) has been under consideration. Construction of this railway line would significantly shorten the travel time in the direction to Nowy Sącz and Krynica-Zdrój, as well as Rabka and Zakopane. After modernization of railway line Tymbark – Limanowa-Nowy Sącz, the travel time from Krakow to Nowy Sącz would take a little more than an hour. The initial study indicates, that the route Kraków – Podłęże-Piekiełko would require construction of 9 to 11 tunnels.



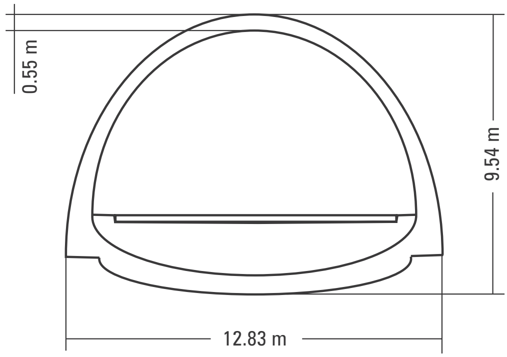
Source: Tajduś and Cała 2010

Fig. 4. Jordanów tunnel concept

Recently an initial feasibility study was performer for the tunnel in Jordanów [Tajduś and Cała 2010]. Tunnel construction under the city of Jordanów is necessary, as the city is crossed by an important communication route, National Road 28, connecting Zator with the eastern state border in Medyka (Figure 4). Road traffic density is very high. After the tunnel construction, the traffic in the city will decrease, the traffic safety will increase, and the state of the city environment will improve, thanks to a decrease of exhaust fumes and noise. Also, due to its picturesque location in the foothill climate, Jordanów is a holiday and tourist resort and a good starting point for hiking trips (e.g.

Luboń Wielki or Babia Góra). Based on the initial analyses it seems, that the tunnel should lead from the northwest to the southeast, under the market square of Jordanów, beginning near Strącze creek and ending by Malejówka river, so that it connects two valleys, going under elevated terrain. The tunnel length would be 680 m, the overburden over the tunnel being 30 to 40 m, and the tunnel inclination of 4°. Due to a big elevation difference between the ends of the tunnel, the concept also covers construction of a steel viaduct on reinforced concrete support, which would provide a gentle descent into the valley.

The tunnel can be dug through Carpathian Flysch using mining methods (e.g. NATM) [Tajduś et al. 2012]. Instead of a two-way traffic tunnel, for safety reasons, it is better to build two one-way traffic tunnels, with an option for designation of two lanes. The tunnels would be shaped in an ellipse, with the width of 12 to 13 m and the height of about 9 to 10 m. An exemplary section of one of the tunnels is presented in Figure 5.



Source: Tajduś and Cała 2010

Fig. 5. Example section of the tunnel without air duct

5. Conclusion

The article presents a few possible applications of tunnels for solving communications problems in Polish mountains areas. Unlike other countries worldwide, Poland was reluctant in using this solution. While in the long run, tunnel solutions, properly combined with viaducts, are cheaper and safer solutions, at the same time reducing the negative impact of transport on the environment. We are happy to notice a growing interest in underground constructions (including tunnels) in Poland.

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