ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 2005
Seria: TRANSPORT z. 58 Nr kol. 1688

Jaroslav BROUL[1], Miloslav ŘEZÁČ

THE RELIABILITY OF TRANSPORT INFRASTRUCTURE IN SPECIAL CONDITIONS

Summary. The article devotes to anthropogenic factors and natural phenomena influencing reliability of transport infrastructure. Among human activity factors special attention has been paid to consequences of underminig on the railway areas. The analysis of transport infrastructure damages due to water flood has been also made in the paper.

NIEZAWODNOŚĆ INFRASTRUKTURY TRANSPORTOWEJ W WARUNKACH SZCZEGÓLNYCH

Streszczenie. W artykule przedstawiono problematykę związaną z wpływem elementów antropogenicznych oraz zjawisk naturalnych na niezawodność infrastruktury transportowej. Wśród czynników związanych z działaniem człowieka szczególną uwagę zwrócono na skutki robót górniczych prowadzonych na terenach kolejowych. Dokonano również analizy uszkodzeń infrastruktury transportowej spowodowanych powodziami.

1. INTRODUCTION

The issue of transport structures is very wide and generally covers optimalization of the relation of 3 systems: **man – mean of transport – environment**. In certain conditions, transport systems together with co-existence of single types of transport and their current and future transportation links are viewed as a subsystem of development of the society.
One of the specifics of the line and planar transport structures is their layout in **special conditions,** which occur by human activities or natural phenomena.

Anthropogenic factors

- **Impacts of former or current mining activity**

Undermining effects are limited only to areas of former or current underground black coal mining, brown coal mining or ores. It concerns the whole region of Northern Moravia (Ostrava, Karviná) and the region of Southern Moravia (Hodonín, Břeclav). Undermining effects are obvious also in the areas of former raw material extraction (area of Příbram) or underground works (Brno), but only rarely and only on local communications. In this connection it is necessary to mention also subsidence caused by mining in the remote past.
Terrain subsidence increases demands for soil volumes necessary for ground objects and foundation of constructions in general, in a sufficient distance from the tailweter level.

[1] Faculty of Civil Engineering, VŠB – Technical University of Ostrava, Av. L. Podéště 1875, 708 33 Ostrava

The necessity to use materials from other technological activities are given on one hand by consequent decrease of sources and quality of natural aggregate and on the other hand by the need for ecological appraisal of **secondary raw materials** (waste rock, power-station ashes, blast-furnace slag, clean yield up material, and so on). It is necessary to watch their physical-mechanical properties and in most of the cases to improve them through various technologies. A lot of materials of this type lose their mechanical properties in the course of time unless its mechanical composition, compaction method and binding of individual layers including drainage of construction are not chosen well.

Use of waste rock with coal substance residue brought about so called "burning" in the ground body on many sections of the Czech Railways rails railroads (i.e. railway line Ostrava-Main Station – Frýdek Místek, near railway station of Kunčičky, Drahotuše). The reason for burning must be searched for in the past when technical qualitative conditions of structures allowed using waste rock as a building material without setting the conditions for using and indispensable checks.

Manifestations of natural gas are tied with areas of former mining activities (black coal deposits), where the mining was or has been terminated. Concerning the area of Ostrava we can mention a redeveloped pit Hlubina, where the operation of road tram transport was endangered as well as car and bus transport near the main bus stations. Reconstruction or modernization of the transport system must take the problem into account.

Natural phenomena

- **Consequences of flooding**

The impacts of vast flooding in 1997 and 2002 (in some areas even in other years) on transport structures have been analyzed and some future measures have been completed by adding methods for designing, putting into practice and watching all kinds of structures. It is necessary to complete the classification of possible risks in construction and in the course of operation.

- **Land slides caused by abnormal rainfall and floods**

Basis for location (lay-out) of structures in incline areas lies on the analysis of breakdowns and damages of transport structures by i.e. impacts of abnormal rainfall, which is processed in the frame of blanket screening and some local noticeable damages. Reliability of transport communication will be determined from the acceptable risk of land slides and transport endangering.

2. MINE DAMAGE DISPOSAL ON RAILWAY LINES OF CZECH RAILWAYS

When assessing mine damages and consequent extent of property loss it is necessary to take into account the specifics of transport (line) structures. Up to now used methodology that applies expenditure from the field of Building constructions (possibly expert's appraisal) from the budget items without exact data appeared to be insufficient, mainly at the time of the change of state financing towards mines further to privatisation.

Project documentation currently handles the impacts of undermining and modernization, which can be distorting in some elements (see example in Table 1).

The Department of Transport Constructions of the Faculty of Civil Engineering at VŠB-Technical University of Ostrava in cooperation with Brno University of Technology and the Institute of Forensic Engineering composed and successfully applied a unique methodology of mining damage appraisal for line structures. Now it is possible to divide the appraisal in the impact of undermining, elements of modernisation and current regulations for technical-technological elements of transport line structures.

Table 1

Review of effects on assessed section

Name	Impacts of mining activity	Modernisation	Impact of maintenance deficit	Effect of service life (natural wear)	Caused by rehabilitation of mining impacts
Project + observation of the work	■	■			
Dismantling of safety equip.		■			■
Stational safety devices		■		■	■
Provisional safety devices		■			■
O-Kunèice Long control of high voltage equip.		■			
Safety technology of railway traffic		■			
By-pass and cable protection Czech Railways+others	■	■			
Broadcast device (personal+shifting)	■	■			
Local cables	■	■		■	
Integrated telecommunications		■			■
Place of telephone centre		■			■
Signaling plant installation adjustment		■			■
Reconstr.of Reley Safety Equip.		■			■
Railway superstructure	■	■	■	■	■
Railway substructure	■	■	■	■	
Outdoor lighting	■	■			
Electrical heating of rail switches		■			
Traction line	■	■			
Rail fastening		■			■
Rail insualtion		■			■
6kV cable distribution		■			■
Road relaying	■	■		■	
Adjustment of low voltage distribution	■	■			
Adjustment of rail return		■			
Fire main-shifting	■			■	
Other costs					■

In some cases there was an effort to assort also following to mining effect:

- parking areas for disabled people and company cars of Czech Railways
- wear and damage of a railway spur track caused by operation and under-maintenance endangered the transport reliability
- the most capacious item for mining damage assessment is mucking of gravel ballast
- changes in approach and operations of a railway station and railway spur track station yard
- changes in the regime of groundwater by refuse heap strain can result in the development of caverns with possible settlement or sink of the locality (road bridge pillars)

- deformation process in constructional layers and in subsoil probably deepens by surcharge loading on the surface due to massive highway embankment and bridge structure

2.1. Technology of repairs of geometrical parameters of the rail track

Impacts of undermining of the rail track that appears as deformation of a ground body in the extent endangering reliability of railway operations are considered as mining damages. The choice of a technological technique – a method of mining damage removal depends on the decline values in the synclinal valley (declines, cross feeds) and time behaviour of the decline. In the Moravian-Silesian region (area of Ostrava and Karviná) mining damages that occurred on the rail track position (based on more than 30 years of approved experience and Principles for construction, rebuilding and rail track maintenance of full gauge in undermined areas by Czech Railways) are removed as follows:

A) by reparing sudden failures

Repair of sudden failure is understood as immediate disposal of consequences of mining activity at Rail Position of Geometry.

B) by lifting formation line without removal of track panels

Rehabilitation – reconstruction of the rail section is realized in dependence on the value of decline and its time behaviour with respect to service load of the rail track using formation line partial lifts and cross feed of the rail track.

C) by lifting formation line with removal of track panels

It is used with vast rehabilitation and reconstruction works at uninterrupted closures of rehabilitated rail tracks with temporary elimination of railway operations; vast treating of Rail Position of Geometry as well as adjustment of the shape and size of the ground body is made.

2.2. Property loss reckoning

General equation for property loss is:

VMÚ = NO + (C1 - C2) - (Z - R)

NO..... expenditure for mining damages repairs in CZK excluding VAT

C1 - C2 .. difference between the price before the repair and after the repair in CZK excluding VAT

Z – R.....value of gained material reduced by expenditure needed for gaining it in CZE

Fig. 1. Influence of undermining on a railway corridor Karviná – Louky nad Olší
Rys. 1. Wpływ robót górniczych na korytarz kolejowy Karwina – Louky nad Olzą

3. RELIABILITY OF TRANSPORT STRUCTURES IN AREAS LIABLE TO FLOODING

In countries of Central Europe, South America, South-east Asia, USA, Japan, Australia and New Zealand the issue of reliability of structures, even line structures in the areas liable to flooding constantly stands in the centre of attention. Attention is paid preferably on bridge constructions due to their purpose for transport connection and also related financial charges on their reconstruction.

3.1. Geotechnical risk of transport constructions insert

From geomorphology, geological and hydrological conditions in given places and position of transport body, is possible to divide the areas:

- mountain
- under mountain
- inundation

While usually in mountain region happens to achieve boundary limiting state of terrestrial erosion, in under mountain regions with acts about state among above-mentioned and incidence in time influence of groundwater with capillary effects - influence of porous pressure - (acc. to character of pertinent soil in body), which affected to the physical - mechanical characteristics of soil in body. In region of inundation territory is then superiority of the second character (the above-mentioned state).

Appreciation to boundary limiting state of terrestrial erosion go out from present experience – of surface erosion, depends upon gradient of slope, its length, type of soil and to the intensity of short-time rain.

From rock type point of view, the most opened to erosion are fine sands as far as silty soils (soils with low plasticity), where particles are minimal and easy to be wash out and at the same time among the smallest particles are no fetching forces, what we know for example for clayey soils. Out are the dispersive soils, which nevertheless, that giving meaningful plasticity, they are the most opened to erosion. Practical disposals for decreasing of terrestrial erosion, carrying in local running-down waters (its area concentration), modulation of terrestrial water velocity (decrease of slope gradient, generation of berms) and in time to put erosion control plan.

Erosion control plan proceedings are e.g. geosynthetics, used in first phase of slope protection before grass or in case of very sheer slope, where has function in long- time.

From views of stability calculation we must account the influence of groundwater-the other situation will near loose soil (gravel, gravel sand, sand clayey - course) and the other near high clayey, earth and clay. Effects of capillary attraction near loose earth run to in average funds into 1 m above formed surface groundwater, near cohesive soils then acts of values about several metres (soil F 6 CL as far as 3,5 m and also more).

3.2.Influence of submersion time on terrestrial body stability

Water passing through terrestrial body, depends on a lot of circumstances – terrestrial body material, granular curve, porosity, etc. Specify of terrestrial body (roads, railways, etc.) is drainage layer and next drainage equipment, which is in case of submersion water supply into body.

Terrestrial body water penetration is facilitation along transverse drainage elements – culverts - the result is destruction of airy cheek body.

Comparison of flood consequences in districts with different high above sea level

District	Main position (areas)	Area		Total Damages	Rank in ČR	Counted damages to		Number of Land-slides
		District km^2	Flood %	mil. Kč		1 km^2 mil. Kč	1 inh. ths. Kč	
Bruntál	mountains	1662	1,28	3 276	2	1,97	30,9	5
Jeseník	mountains	722	0,34	1 983	1	2,75	46,3	14
N. Jičín	sub-mountains	919	6,85	1 382	6	1,50	8,6	12
Opava	sub-mountains	1147	5,04	1 178	11	1,03	6,5	5
Vsetín	sub-mountains	1141	1,63	1 700	3	1,49	11,4	161
Přerov	inundation	884	19,2	977	9	1,10	7,1	10
Uh. Hrad.	inundation	990	9,3	1 036	7	1,05	7,1	17

Sudden (total) submersion of (earth) terrestrial body is possible in case of dam destruction in proximity transport (line) construction. Water penetration rate is proportional to

factions of used materials. The behaviour of observed body is in virtue of also thereby, what kind way of water flow back.

By sudden decrease (in some cases) could get to sand flow. Every loose soil, under definite conditions get into case of fluidity. Flow sand could begin by flow water forces in sand. By force action (changes outer pressure, shaking) matter consolidated and porosity decrease. Superfluous water from soil is expel, since cannot escape at once, swell pressure of water in porous, which decrease friction among grain and soil with getting on into liquid case. gradual submersion of terrestrial body gives a gradual saturation of material terrestrial body, the phase is proportional to coincident with previous description.

From route-identification of physical soil properties, it can be transformed drain time, under which the superfluous water getting from terrestrial body and thereby also time, up which will has earthwork project characteristics and drift load in full of scale (percent occurrence and size e.g. care axle load, etc.).

By the loose soils into calculation have given the values, corresponding to category of easement, by cohesive soils then the values for category hard, which approximately proportional to concretion of terrestrial construction (banks, embankment). The constant length of earth construction has been chosen (in length 1 m).

Soil non-cohesive	**rate [cm/s]**	**time**
A	1	1,7 min
B	0,1	16,7 min
C	0,01	2,8 h
D, E	0,001	27,8 h
F, G	0,0001	11,6 days
H	0,00001	115,7 days

Soil cohesive	**rate [cm/s]**	**time**
I	0,000001	3,2 years
J	0,0000001	31,7 years
K	0,00000001	317,2 years

In particular calculation of water penetration through slope of road body (soil H and I, cross section 33 m at maximum). By unilateral submersion will water penetration asserts approx. 10 years and approx. the same time will water flow out.

3.3. Division of transport constructions from diversification of risk destruction in territory

For preliminary information about transport constructions in inundation territories or to hand of flood undulation, can serve the suitable combination of data about territory and transport constructions.

On opposite situation of district is the map of locality floodplain soils that they are potential places of spilt (regular, special, prospective, rare) and thereby more dangerous.

On these localities tie together territory out of first wave of flood, where's permitted for construction and next investment. In case of extreme flood with water getting also into non-assumed places.

The net of road coming through locality of floodplain forests should be potential danger from contact to flow of water. This section must be under precise observation:

- fortification of slope, at the same time take into account of slope inclination, also directive
  solution of route,
- verification of available material for terrestrial construction.
- verification and reservation of drainage functionality disposals.

For necessity of surveyor's offices and decision about construction and reconstruction object making is necessary to determine the conditions of realisation. Flood territories are for assessment of particular conditions of construction possibility, according to:

- the range of drainage area flow and single tributary
- configuration and inclination of ground
- type of soils
- type of vegetation
- height flow level (HFL)
- rate of flood waves.

4. CONCLUSION

The contribution is orientated to two parts, very important for transport constructions in Czech republic and e.g. in Poland. The first part devotes to anthropogenous influences, in this case undermining and the second part to the natural influences, like water floods, land slides, etc.

Both parts (from a lot of influences) of specimen are important for solution in the next time.

Literature

1. Tylová J., Řezáč M.: Užití nových technologických prvků mostních objektů v povodňových územích (Nová železniční technika, 2/2000).
2. Broul J., Hudeček L.: Nové prvky v konstrukcích železničního tělesa v poddolovaném a zátopovém území (Sborník vědeckých prací VŠB TUO, řada stavební, Ostrava, ČR, 2001), Tomica Vl.
3. Řezáč M.: Dopravní stavby v povodňových územích (dizertační práce, FAST VŠB-TU Ostrava, ČR, 2001).
4. Broul J., Řezáč M.: Transport Constructions Safety in Czech Republic Flood Areas (6th International Conference Organization, Technology and Management in Construction, Moscenička Draga, Croatia, 2003).

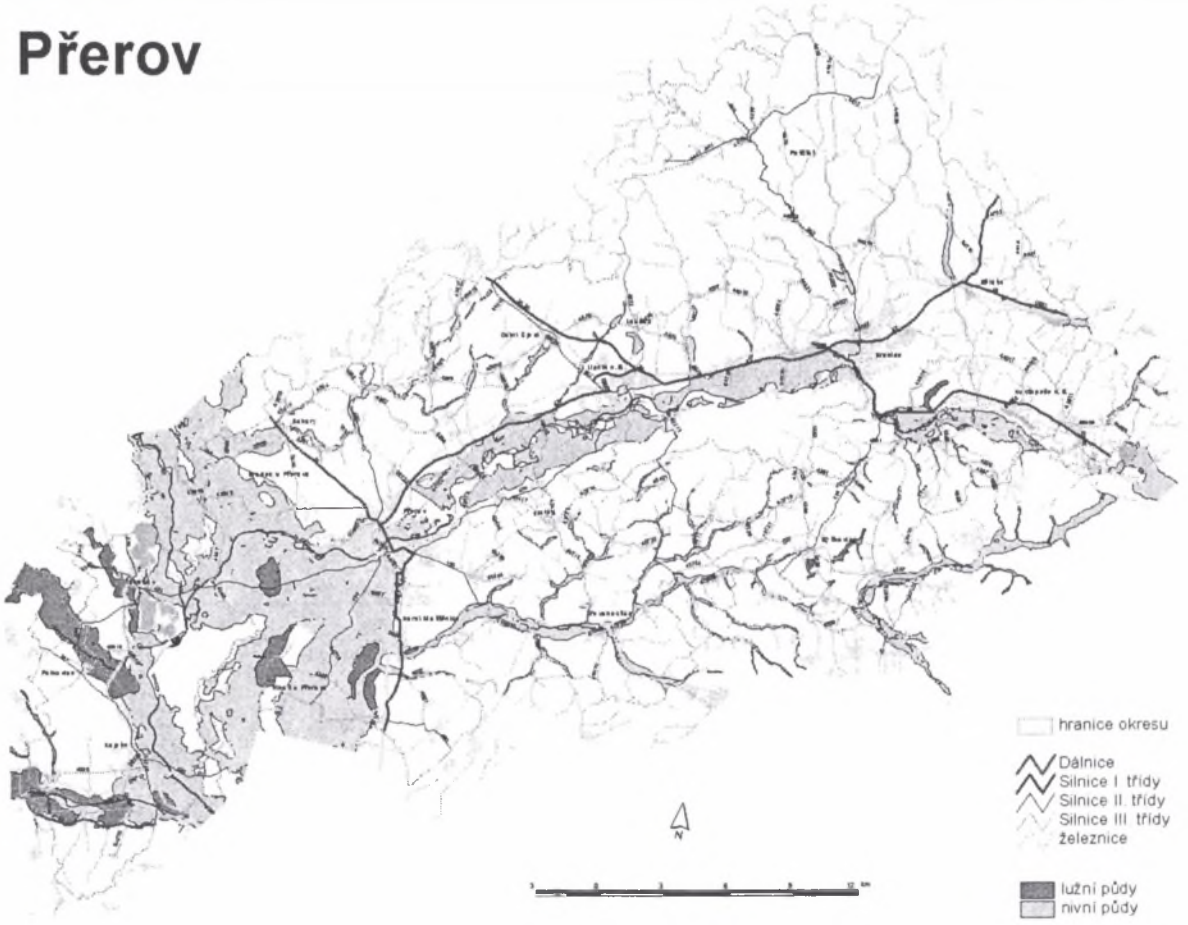

Fig. 2. Contact of roads and rails with bottomland and overbank lands – district of Přerov
Rys. 2. Połączenia drogowe i kolejowe z terenami położonymi najniżej i najwyżej – okręg Prerov