Reducing the negative effect of communication (road and railway) investments on free migration of wildlife

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Abstract. In this paper a general information about the harmful effect of transportation investments connected with free migration of the animals will be presented. A classification of typical passages for animals together with descriptions, both on roads and railroads will be included. Also general rules for designing those passages for animals are published. All these are illustrated with examples of above-mentioned constructions, both traditional and modern. On the base of extensive research carried out at the Research Institute of Roads and Bridges in Żmigród advantages of different types of passages for animals are published. The paper are finished with concluding remarks about the future design of construction of passages for animal.

Key words: fauna migration, transport infrastructure, barrier effect, technical solution, wildlife passages

1. Introduction

According to the principle of sustainable development, or in other words, ecological development, the relations between human activities and the functioning of ecosystems remain in homeostasis. The close interrelation and equivalence of economic development, the natural environment, and social development are the conditions for maintaining the stability of ecological processes and systems, including the protection of genetic diversity. This fact is of paramount importance from the point of view of fauna.

The present paper aims at to discuss and present technical solutions applied in the process of completion of communication investments, which according to the aforementioned principle, would reduce the negative effect of such investments on the possibility of free migration of wildlife. Nature protection does not entail giving up the investment. By applying the appropriate technical solutions that let the animals migrate freely, we remain in agreement with the development of roads and railways.

2. Origin of the problem

The basis for stable and lasting functioning of wildlife populations is the possibility of unconstrained movement of animals (Jędrzejewski *et al.* 2006). Dispersion and migration impact the spatial distribution of animals and the genetic structure of their population. Moreover, they constitute an important mechanism for maintaining the biodiversity of particular areas.

The construction of a communication route increases the fragmentation of habitats through the barrier effect, which leads to the reduction of wildlife habitats and to the interruption of their migration routes. This can even lead to such a decrease in the ecological value of the area that the area will not be able to provide sustenance to the populations that were separated (Katalog, 2002).

The infrastructure of communication routes such as roads and railway lines hinders and even in some cases makes impossible the genetic diversification which is necessary for the survival of a healthy population. Problems with finding partners for mating and problems with creating social structures typical for the species result in a lowered breeding rate. Mating closely genetically related individuals may result in genetic deformations. Isolation leads to reduction of a population's genetic diversity, thus reducing immunity to disease and the ability to adjust to environmental changes. This results in a decrease in the viability of a population (Jędrzejewski *et al.* 2006).

Besides the above-mentioned barrier effect, a serious consequence of the development of transport infrastructure is the increased traffic mortality of wildlife. It depends on the traffic density and the velocity of vehicles, the width of the communication route, and the area through which the route runs. Many studies analysing the effect of traffic on the number of collisions and roadkills show that the places of such accidents (so-called 'hot spots') are not accidental at all (Michelle & Page 2006; Evink 2001; Donaldson 2006). Most frequent on Polish roads are the deaths of amphibians, medium-sized forest and field-forest mammals, and large mammals. The highest mortality rates on West European (Jędrzejewski *et al.* 2006) roads and railway lines are recorded for roe deer, hare, foxes, badgers, and wild boars. This results first of all from high numbers of the populations of these wild species.

Summing up, the most serious consequences of the realisation of communication (road and railway) investments in relation to free migration of wildlife include (Jędrzejewski *et al.* 2006):

- making the displacement of many species of animals (barrier effect) impossible or limiting it
- traffic mortality on roads and railway lines as well as (which was not mentioned before)
- destruction of habitats within the reach/along the communication route, and
- expansion of foreign and synanthrope species.

3. Classification of wildlife passages and remarks on the economic justification for their construction

The effective solution to the above-presented problem is wildlife passages. They provide connectivity between two patches of environment, fragmented by the communication route, allowing the animals to migrate freely as well as ensuring stable and undisturbed functioning within the population.

Figure 1 presents the classification of wildlife passages. Below, they are briefly outlined based on Jędrzejewski *et al.* (2006) and Katalog (2002).

Small underpasses – the type of passage designed in general for amphibians, referred to as a 'frog passage', consists of a channel with a round or rectangular profile, laid out across a road, with openings fitted to the lengthwise fencing of the road at its ends. The dimensions of such an underpass are more than 2 meters in width, and more than 1.5 meters in height.

Designated use: amphibians and reptiles, mainly frogs, but it can also be used by other species of small animals like badgers, foxes, martens, weasels, ermines, otters, polecats, hedgehogs, as well as rodents.

Medium-size underpasses – objects of this type are constructed in the form of tunnels with a round or rectangular profile of inner dimensions enabling sufficient visibility of light and vegetation from the other side of the passage, that is a width of more than 6 meters and a height of more than 2.5 meters.

Designated use: mostly medium-sized mammals: roe deer, wild boars, foxes. When appropriately managed, they can also be used by lynx, wolves, and even red deer.

Large underpasses – this is a passage in the form of a tunnel under the road, with a rectangular or arched profile, built of concrete or metal elements, incorporated into the surroundings through the appropriate plantings of vegetation as similar as possible to the natural/local vegetation. Minimum parameters: width 15 meters, height 3.5 meters.

Designated use: large mammals such as moose, bear, red deer, wolf, lynx, bison.

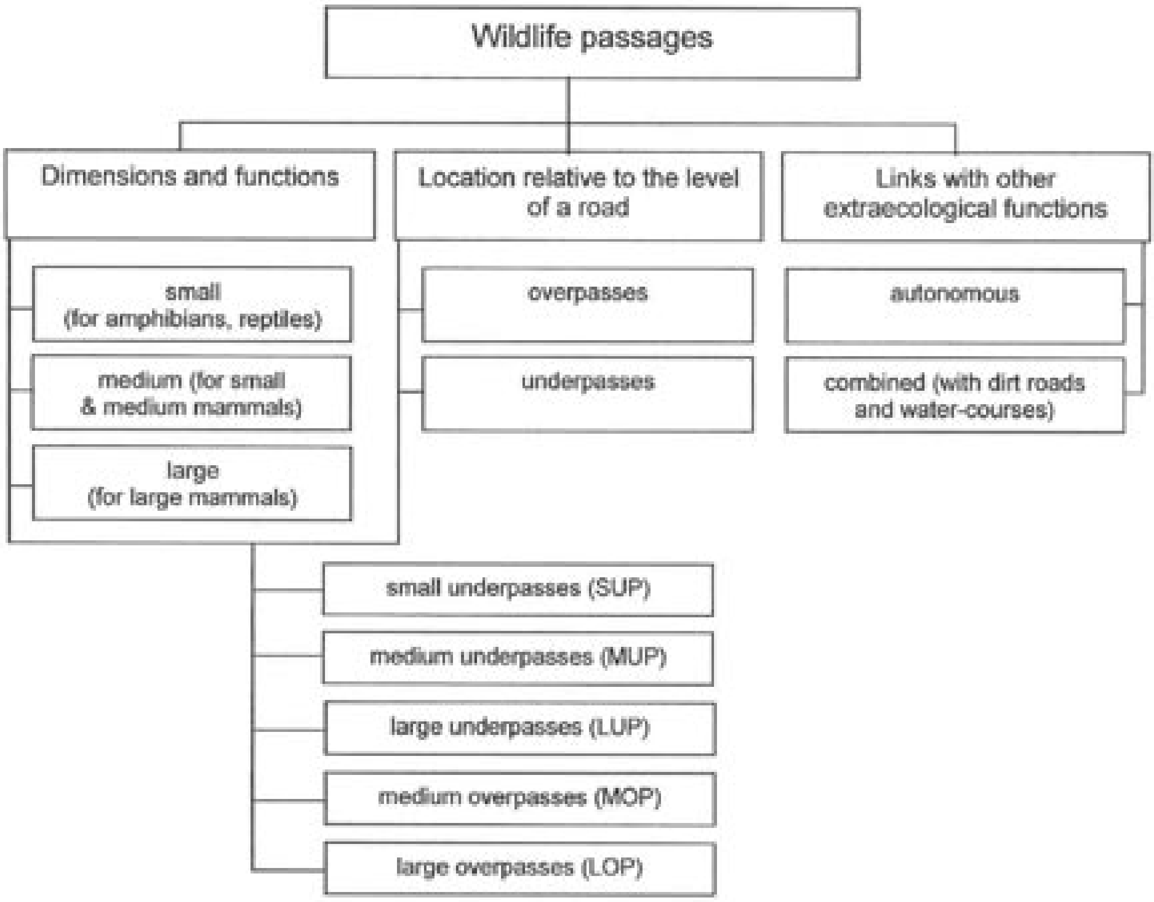

Fig. 1. The classification of wildlife passages [Source: Own research based on Katalog (2002)]

Medium-size and large overpasses – passages of this type are constructed in particular whenthe road runs through an excavation and the upper surface of the passage will be at the level of the surrounding land. These can be tunnels leading across a road or a viaduct above a road. The shape, the dimensions, and the manner of managing the passage should provide the best possible visibility of vegetation at the other side of the road. The outermost strips should be covered with natural vegetation, behind which non-transparent screens of a height from 1.5 meters to 2.5 meters should be installed, blocking out noise and road lights. The height of the screens depends on the species of animals using the passage. The screens could be extended by fencing erected along the road and appropriate bush vegetation directing the animals to the passage. An important element the management of the passage is a 30-70 cm layer of humus, on which grass and vegetation attracting animals should grow.

Designated use: medium-sized overpasses for small and medium-sized mammals; they can also be used by reptiles and amphibians, as well as by large mammals. Large overpasses for large mammals, and in particular ungulates; they can also be used by reptiles and amphibians, as well as by small and medium-sized mammals – therefore they are all-purpose.

Dirt roads for farmers, forestry, or technological roads can lead through the passes. In such situations, combined-use passages (multifunctional) are created, which besides their utility function, also have ecological functions.

In order to maintain or restore the natural environment on both sides of the road, a passage in the form of a biological or ecological bridge needs to be built – a green bridge, a landscape bridge. This type of passage is used when crossing the migration corridor of ungulates of regional importance is inevitable.

Various types of materials and technologies are used for building wildlife passes: concrete, steel, and plastics. The choice of material is often related to the size of the pass (small, medium-sized, large). The types of technologies and materials utilised were described in such works as: Janusz *et al*. (2003); Janusz & Bednarek (2005); Janusz *et al.* (2006a); Janusz *et al.* (2006b); Janusz (2006). In the USA, an algorithm was prepared enabling an economic analysis of the effects of wildlife road-kill prevention measures [Michelle & Page 2006]. Based on the record of costs of road accidents, a table was prepared, which enables financial assessment of the probable collisions and comparing them with the costs of preventive actions (including the construction of wildlife passes). Using the above-mentioned algorithm, we can look for threshold values of investment outlays for which the planned ecological investment is financially justified. The algorithm is described in works: Michelle & Page (2006); Janusz (2006); Janusz i in. (2006a).

Based on American research from Virginia (Donaldson 2006), the financial benefits generated as a result of construction of wildlife underpasses were assessed. The analysis of Figure 2 confirms that with the reduction of the potential number of deer-vehicle collisions (DVC) in a year, the savings in expenses caused by the collisions rise.

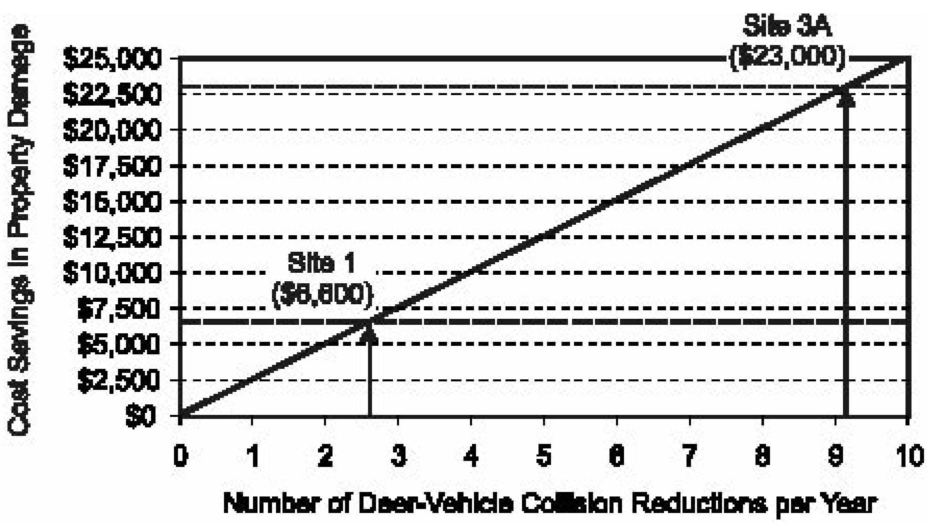

Fig. 2. Reduction of costs resulting from limiting the number of road collisions with red deer (Donaldson 2006)

4. An example of the use of corrugated steel plates in the construction of wildlife overpass over the A2 highway

In 2006, two wildlife overpasses over the A2 highway were commissioned, made in flexible structure technology. Each of the objects consisted of two structures made of corrugated steel plates of arch profile and of two structures of closed arch-round profile (Figs. 3 and 4).

Arched structures have a span of 17.67 meters and a height 5.50 meters and are founded on ferroconcrete supports. The structures were reinforced with fins made of corrugated plates. The main plate and the fins were made of 380×140×7 mm corrugated profiles. The length of steel structures at the point of support is approx. 59 meters. Closed profile structures have a span of 9.36 meters and a height 8.13 meters. They were made of plates of 200×55×7 mm corrugated profile. Their length is approx. 76 meters. Closed profile structures were founded on aggregate foundation.

All the steel structures were made of plates protected with a layer of zinc according to PN–EN ISO 1461:2000, and their internal surface was additionally coated with epoxy paint of a thickness of at least 200 μm. After assembly, the structure's surfaces that come into contact with the soil will be coated with bituminous emulsion. Structures made of corrugated steel plates are covered with a gravel-sand mix, compacted to the compaction ratio of 97% according to the standard Proctor's test. The height of the fill over the CP structures is approx. 2.2 meters. Over the structures, protective insulation was spread, protecting the inside of the structure from rain water permeation.

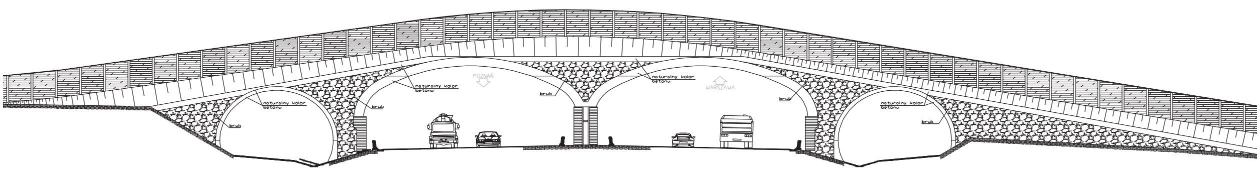

Fig. 3. Side view of the planned wildlife passage over highway A2

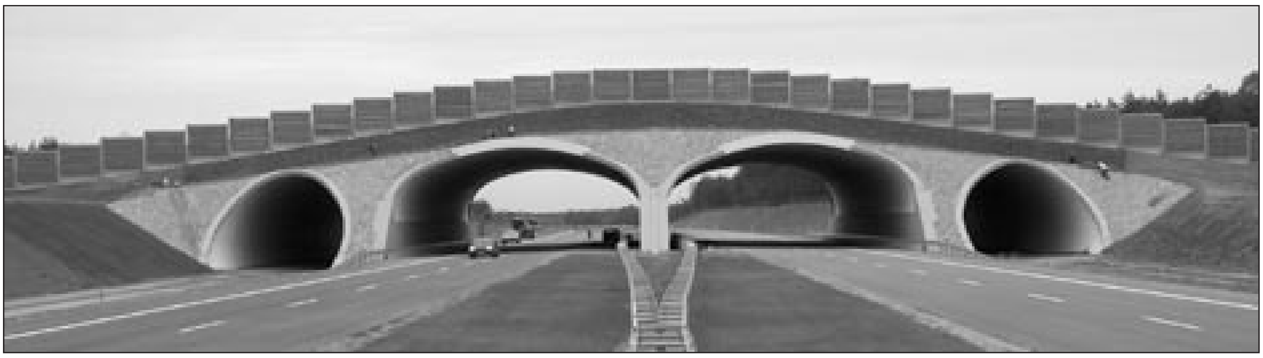

Fig. 4. The view of the completed ecological bridge

The minimum usable width of each of the passes is approx. 36 meters, and at the ends and at the foot reaches 75 meters. The planes of entrance and exit of the passage are slated in accordance with the inclination of 1:1.5 of the escarpment. The entrance and exit were reinforced with a ferroconcrete ring and escarpments reinforced with boulders and turf (Fig. 5). The objects were equipped with screening greenery and at the edges of the passage antiglare screens are planned. A fence was planned along the highway, reaching the screens, thanks to which the danger of animals entering this lane is reduced.

Fig. 5. The ends of the structure

The structures constructed over the A2 highway are the largest wildlife overpass in the world made with corrugated plates technology. The effective assembly time of four structures making one overpass is eight weeks, using one crane and a 12-person crew. The assembly was finished in the second week of September 2005. The organisation of the assembly process allowed works related to the construction of the highway under the structures to be carried out without any problems. After the completion of the structure, traces of animals which used it to walk to the other side of the highway were noticed (Fig. 6).

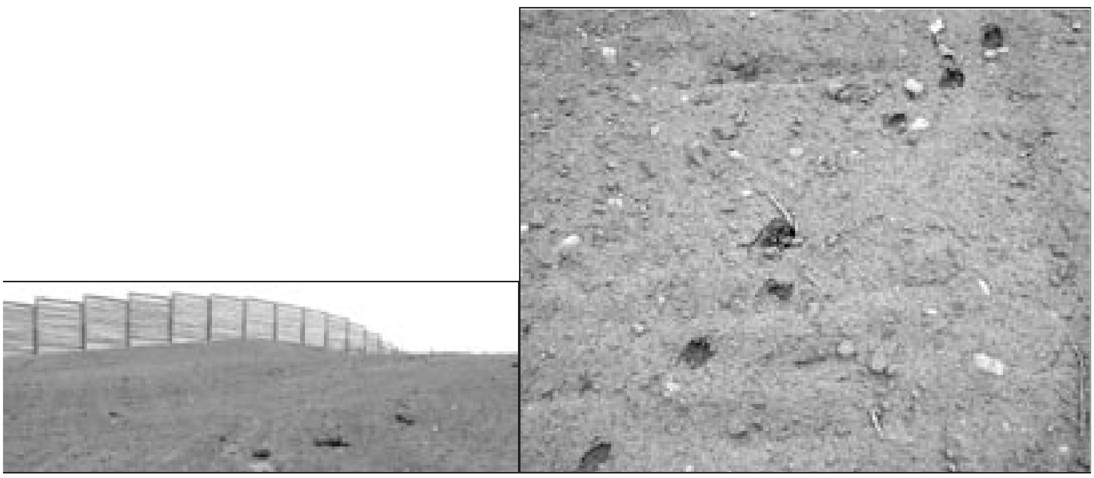

Fig. 6. Animal prints on the ecological overpass over highway A2

5. Additional examples of the use of ground-cover structures for building wildlife passes

Figures 7-9 present examples of passes for small and medium-sized animals. The above presented structures illustrate the structures which are presently most often completed on roads and railway lines in Poland.

Fig. 7. An example a pass for amphibians and small mammals under highway A2

Fig. 8. Openings providing additional lighting under the road in the road-dividing strip

Fig. 9. An example of a wildlife overpass under a highway in Canada

6. Research into modern ecological structures of wildlife passes at the Research Institute of Roads and Bridges [RIRaB] in Żmigród

Due to the advancement of the presented solutions for wildlife passes, a series of research tests of this type structures built out of various materials was realised in RSRaB, as ordered by the companies. This research was conducted in the last few years, mainly upon the orders of Viacon. The main tests completed included:

- tests of the oval structure of the Multi Plate closed profile,
- tests of the Box Culvert open profile structures of the Multi Plate system,
- tests of the Helcor steel grated structure with round profile of the diameter of 1 meter,
- test of corrugated structure of round profile made of PEHD plastics.

All these tests were performed at a natural scale on the test bridge stand in Żmigród. This research was described in several reports: Duszyński (1998), Wysokowski *et al*. (1999a) and Wysokowski *et al.* (1999b). The tests of the structures, all of which can be wildlife passes, were performed under static, dynamic, and selected ones even under extended load.

Due to the fact that the discussed structures are of the ground-cover type, the contact with the ground is very important in the tests. Therefore, the external forces in the construction of coats and the tensions in the ground were analysed. These tests showed the high rigidity and durability of these structures, due to the high cooperation of soil in the transport of tensions, among other things. The results of all the tests can be found in the respective reports and publications:Vaslestad & Wysokowski (1998), Vaslestad *et al*. (1999), Vaslestadt & Wysokowski (1999), Wysokowski (1999), Wysokowski (2001, 2002), Wysokowski and Vaslestadt (2002).

7. Recapitualtion

When summing up the present specification, it can be stated that the structures presented in the study are fully suitable for use as wildlife passage building structures. It has to be mentioned that these structures, due to their mass, do not transfer vibrations, which is important from the point of view of their use by the wildlife migrating across them. Also of importance is their high durability.

The problem presented here of building wildlife passages from the point of view of the negative effect of road and railway traffic resulting from communication investments confirms the need to abide by the principles of sustainable development of humans. The examples given show that besides ecological aspects, technical, economic, and social aspects can and should be taken into account. The skillful combination of the aforementioned aspects makes it possible to maintain sustainable development. The presented example of building a wildlife passage over the A2 highway in Poland can be a model for similar solutions in the road and railway industry.

References

Donaldson B. (2006). The use of highway underpasses by large mammals and other wildlife in Virginia and factors influencing their effectiveness. Transportation Research Board Annual Meeting. Proceedings, paper no 06-0561.Washington.

Duszyński A. (1998). Sprawozdanie z nadzoru naukowego IBDiM nad budową modelu badawczego z zastosowaniem przepustu Multi-Plate na Stanowisku Badań Mostów w OBMBiK w Żmigrodzie [A report on the scientific supervision of IBDiM over the construction of the test model using Multi-Plate culvert on the Bridge Testing Stand in OBMBiK in Żmigród. IMDiM. Żmigród.

Evink G. L. (2001). Interaction Between Roadways and Wildlife Ecology. A Synthesis of Highway Practice, NCHRP Synthesis 305. Transportation Research Board, Washington D.C, 2002.

Janusz L. (2006). Improving safety on roads and environmental care through construction of animal crossings with use of flexible steel structures. Proceedings of International Conference on Building Education and Research, BEAR 2006, Hong-Kong.
Janusz L. & Bednarek B. (2005). Największe na świecie przejście dla zwierząt nad autostradą wykonane z konstrukcji z blach falistych [The largest wildlife overpass in the world made with corrugated plate technology]. Materiały Budowlane 9, Warszawa.
Janusz L., Bednarek B., Machelski C. & Maliszkiewicz P. (2006a). Ekomosty o konstrukcji z blach falistych [Ecological bridges constructed from corrugated plates]. Eko-Most 2006. Trwałe obiekty mostowe w środowisku [Durable bridge structures in the environment]. Warszawa.
Janusz L., Bednarek B., Zouhar J. & Sana M. (2006b). The biggest animal overpass made of CSPS In the world. 11 Mezinarodni Sympozium MOSTY 2006, Brno.
Janusz L., Winkowska-Pawlak H., Bednarek B. & Mielnik Ł. (2003). Ekologiczne przejścia dla zwierząt [Ecological wildlife passages]. Magazyn Autostrada 3, Warszawa.
Jędrzejewski W., Nowak S., Kurek R., Mysłajek R., Stachura K. & Zawadzka B. (2006). Zwierzęta a drogi. Metody ograniczenia negatywnego wpływu dróg na populacje dzikich zwierząt [Wildlife and roads. Methods of limiting the negative effect of roads on wildlife populations]. Zakład Badania Ssaków PAN.
Katalog drogowych urządzeń ochrony Środowiska [The catalogue of road facilities for environmetal protection], (2002). Generalna Dyrekcja Dróg Krajowych i Autostrad. [General Directoriate of National Roads and Highways]. Warszawa.
Michelle A. & Page P. E. (2006). A Toolkit for Reducing Wildlife & Domestic Animal-Vehicle Collisions in Utah. Transportation Research Board Annual Meeting 2006, CD-ROM.
Vaslestad J., Korusiewicz L. & Wysokowski A. (1999). General Description of Static and Dynamic Testing of Instrumented Culvert. V International Conference "Durable and Safe Road Pavements", 2: 215-221. Kielce.
Vaslestad J. & Wysokowski A. (1998). Full Scale Testing Multi-Plate Steel Structures in Poland. The 6[t]h Conference "Shell Structures, Theory and Applications" Gdańsk-Jurata, s. 273-274.
Vaslestadt J. & Wysokowski A. (1999). Full scale testing of Multi-Plate corrugates steel culverts including fatigue problems. Archives of Civil Engineering. XLV, 2.
Wysokowski A. (1999). Badania odporności zmęczeniowej przepustów ze stali karbowanej i tworzyw sztucznych w skali naturalnej. IV Krajowa Konferencja Naukowo-Techniczna „Problemy Projektowania, Budowy i Utrzymania Mostów Małych" [Testing the fatigue resistance of culverts made of corrugated steel and plastics on a natural scale], pp. 380-392. Wrocław.
Wysokowski A. (2001). Method of assessing fatigue hazard to steel railway bridges. Engineering Transactions, 4: 459-483.
Wysokowski A. (2002). Effect of Fatigue on the Durability of Steel Highway Bridges. Archives of Civil Engineering, XLVIII, l.
Wysokowski A., Korusiewicz L. & Kunecki B. (1999a). Sprawozdanie z wykonania badań dla konstrukcji przepustów w systemie Multi-Plate i z rur DV/Arot Optima. Część 1: Multi-Plate. [A report on research for the construction of culverts of the Multi-Plate System and from DV/Arot Optima pipes. Part 1: Multi-Plate.] IBDiM. Żmigród.
Wysokowski A., Korusiewicz L. & Kunecki B. (1999b). Sprawozdanie z wykonania badań dla konstrukcji przepustów w systemie Multi-Plate i z rur DV/Arot Optima. Część II: rury DV/Arot Optima i Helcor. [A report on research for the construction of culverts of the Multi-Plate System and from DV/Arot Optima pipes. Part 2: DV/Arot Optima and Helcor pipes]. IBDiM. Żmigród.
Wysokowski A. & Vaslestadt J. (2002). Full Scale Fatigue Testing of Large - Diameter Multi-Plate Corrugated Steel Culverts. Archives of Civil Engineering, XLVIII, l.