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Crossings construction as a method of animal conservation

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Abstract

The negative influence of extension of transportation system over fauna populations mainly consists in destroying their natural habitats, causing higher animal death rates (road accidents), fragmentation of sites and hindering migration as well as isolating animal populations. From the point of view of ecologists, fragmentation of animal life caused by transportation ways is a much bigger problem than collisions in which individual animals die. Big animals must migrate and contact other groups, otherwise they will not survive. That is why relevant technical solutions need to be applied, for example animal crossings of relevant overall dimensions. The paper characterizes the problem of preservation of wildlife animals in connection with extension of transportation road systems. The constantly evolving transportation infrastructure in Europe, especially in its Midwestern part, on one hand connects, making it easier for people to travel and ship goods, but on the other hand it irreversibly divides and leaves its painful impress on virgin natural areas (fragmentation of the environment). It enumerates possible types of animal crossings together with their characteristics. Some examples of underpasses, overpasses and crossing on the road surface are also presented. It also presents specificity and phases of designing engineering structures of this type, as well as the most common design errors and their influence over the use of such structures by animals. The conclusion mentions complexity of the problem of animal crossing construction, which can be of use to designers and constructors of this type of engineering structures.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: animal crossing; road; collision; animal conservation

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1. Introduction

While constructing motorways and express roads one should take into consideration ways of minimizing negative influence of the projects upon wildlife populations. That is because animals are extremely susceptible to changes of external conditions. Therefore one should realize that any transportation route causes irreversible changes to the natural environment (Beben and Manko 2006; Konopka 2004; Liu et al. 2008).

The increasing number of motorways and express roads in Europe, especially in its Midwestern part, shows the scope of challenge to face for road and environmental services, and for the European Union itself. Without an effective economic policy and legal changes in line with resuming responsibility for the natural environment, execution of the road system extension plan can be threatened.

A desired compliancy of the road extension project in Europe with the environmental law is sometimes impossible due to burdening of projects with the Nature 2000 program, and lack of unshakeable and univocal data about it. Respective requirements of the European Commission are often contradictory with decisions issued by the EU member countries. Other factors hindering efficiency in organization of road designing and construction are sometimes controversial protests by ecological organizations out of governmental control (Council Directive of European Community 79/409/EEC 1979 and 92/43/EEC 1992). A possible solution can be achieved through construction of environment-friendly bridge structures of which need to be considered in two categories: (i) execution of various types of bridges constructed on the basis of non-invasive technologies and of modern environment-friendly materials; (ii) structures designed as animal crossings of culverts type, ditches, tunnels and even big bridges constructed within the roadway (or over) the motorway network, in national parks, etc. (Glista et al. 2009).

The paper describes the problem of wildlife protection in connection with extension of transportation routes. The European program Nature 2000 related to the European Ecological Network has been briefly presented within. It also gives examples and characterizes possible animal crossings. It outlines specificity of designing this type of engineering structures and points at the most common errors and their influence over the use of the crossings by wild animals. Finally it characterizes the soil-steel bridge structures in the aspect of possible use of them as animal passes.

2. Characteristics and the scope of the problem

The negative influence of extension of transportation system over fauna populations mainly consists in destroying their natural habitats, causing higher animal death rates (road accidents), fragmentation of sites and hindering migration as well as isolating animal populations. The scope of the problem related to death rate and/or decreasing population of wild animals in relation to extension of road system is very big. The majority of animals are killed on local roads where traffic is slight and where animals bravely enter on the roads. Whereas in the case of roads where traffic per day is heavier – animals hardly ever cross (Jedrzejewski et al. 2006; Konopka 2004; Van Langevelde et al. 2009). Traffic of about 2 thousand vehicles per day seems to be marginal problem (single animals die merely). The highest death rate is contained within the section of 2.5–7.0 thousand vehicles per day, whereas in the case of motorways and express roads where traffic density amount at 7.0 thousand vehicles per day – the number of deadly collisions is relatively small due to the fact that such roads constitute a practically impassable barrier for the animals – they only enter in the moments of stress, frightened by a hunter or a predator. A situation when such a road separates the habitat of one species can lead to a gradual degeneration or even extinction of the species over a given area.

European and American data on animals dying on roads are highly worrying. For example in Spain the minimal number of mammals, birds, reptiles and amphibians killed in road collisions is estimated at 10 million per year, 4 million in Belgium, in Denmark: 1.5 million mammals, 3.7 million birds and 3 million amphibians. In the USA alone in 1991 there were 500 thousand collisions with deer. In Sweden yearly losses caused by collisions with elks and roe deer amount at 100 million euro – and this concerns only accidents reported to the police, therefore the real amount can probably be doubled (Cain et al. 2003; Dodd et al. 2004; Mata et al. 2005; Ng et al. 2004).

When new roads are constructed, life of the animals inhabiting given ecosystems changes dramatically, as a result of the so called cut-through effect. It appears that preservation of ecological passages is of highest

importance even for such mobile animals as birds, game or protected species. When a habitat is divided into several islands separated with roads, genetic diversity of the isolated population is falls considerably. To slow the process down, green bridges and tunnels for animals have been initiated in Europe.

The structure of the road can also create ecological barriers – for instance using protective fencing makes animal migrations completely impossible. Also constructing roads on embankments or in excavated ditches makes it difficult to a big extent. Location of a road is of importance too – the barrier effect is closely related to the natural value and susceptibility of the habitats a road cuts through (Cain et al. 2003; Dodd et al. 2004). An ecological barrier is now defined as complex interaction of death rate, physical limitations, changes and effects which impose limits over a given species upon its freedom to cross a road. Existence of ecological barriers results in division of habitats into smaller sites (fragmentation of habitats) and difficulties in migration of organisms inhabiting these fragmented habitats (isolation of habitats). From among all the forms of negative influence of roads, creating ecological barriers which hinder or make crossing a road impossible is of highest concern for its negative environmental effects. Fig. 1 shows different forms of influence of transportation routes over selected groups of animals.

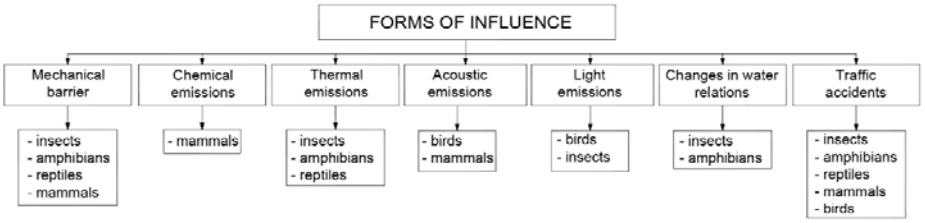

Fig. 1. Susceptibility of animal groups to various form of road interference.

The breakthrough in matter of the environment protection was the international conference in Rio de Janeiro which took place in 1992 during which the convention related to protection of natural resources of The Earth was signed. The main purpose of this convention was protection of biological variety, well-balanced using and farming of the environment as well as the fair-share of advantages derived from the genetic reserves. The European Ecological Network Nature 2000 is the way of fulfilling of convention from Rio de Janeiro by the EU.

The European Ecological Network Nature 2000 is a network of nature preservation sites on the territory of the European Union. It aims to conserve its biodiversity. The program embraces the following:

- sites classified as Special Protected Areas (SPA) – according to council directive on conservation of wild birds (Council Directive of European Community 79/409/EEC 1979),
- sites classified as Sites of Community Importance (SCI) – according to council directive on conservation of natural habitats and wild fauna and flora. It concerns natural habitats specified in appendix I and species of fauna and flora listed in appendix II to the Directive (Council Directive of European Community 92/43/EEC 1992).

The Nature 2000 areas include areas of utmost importance from the point of view of protection of endangered or very rare species of plants and animals and characteristic natural habitats with meaning to protection of natural values all over Europe. The EU member countries have been obliged to delimit protected areas, i.e. the Nature 2000 sites over their respective territories. Detailed legal solutions concerning creation and protection of the Nature 2000 ecological networks were passes as national environmental protection laws. They introduce “Nature 2000 sites” as a new, separate form of environmental conservation, whereas at the same time they can overlap or cover other forms of legal protection of a given country.

3. Types of animal crossings

3.1. General crossings descriptions

From the point of view of ecologists, fragmentation of animal life caused by transportation ways is a much bigger problem than collisions in which individual animals die. Isolating given populations of big animals will lead to extinction of whole species in some parts of Europe. Big animals must migrate and contact other groups, otherwise

they will not survive. That is why relevant technical solutions need to be applied, for example animal crossings of relevant overall dimensions. Animal crossings can be divided in accordance with the scheme presented in Fig. 2, where three main groups have been selected: namely: overpasses, underpasses and crossings on the road level.

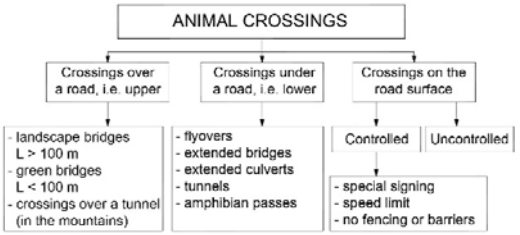

Fig. 2. Scheme representing classification of animal crossings.

In overpasses we distinguish landscape bridges, green bridges and passes over tunnels. The width of landscape bridges should be over 100 m and they should have natural vegetation on them. It is also advisable to preserve unchanged structure of the surrounding landscape. They should ensure continuity of landscape formations, of habitat areas and migration corridors for all types of animals (Beben and Manko 2006).

In the case of big overpasses, so called green bridges, their width should be contained within the scope of 30–100 m. These structures are characterized by natural ground and vegetation covering, and their suggested width should not be smaller than 50 m. Depending on their width and top layer, they can be used by various groups of animals from amphibians, reptiles to big mammals.

Rivers and river valleys form natural corridors and natural habitats for many species of wild animals inhabiting uncultivated areas. When animals meet transportation route which obstructs their migration way (for example a river corridor), they have to enter the road, which increases the risk of collision with vehicles. In such cases using underpasses is advisable. They embrace the following types: flyovers, small bridges, tunnels and culverts.

The best solution when a road has to cross a river is a bridge of a big distance between its spans. It allows free water flow and maintaining continuity of natural river bank system, and it also makes it possible for various species to go under the road. Effectiveness of functioning of this type of a passage will depend upon dimensions and height of the bridge and continuity of preservation of natural vegetation lane on the river bank. The minimal clearance for medium sized animals like deer should amount at 2.5 m so that the traffic above is of a minimum interference. In the case of areas inhabited by bigger animals, bigger passes should be built, at least 4.0 m high and 20–50 m wide. Most commonly they are made of concrete and steel with top paving of natural ground. They are suitable for mammals like foxes, badgers, hedgehogs, martens, hares, rabbits and local migrations of hoofed wild animals such as deer, roe deer and wild boars. At the same time such a form of crossing – an ecobrigde – has minimal influence on fish and invertebrate living and migrating in the river current (Beben and Manko 2006; Clevenger et al. 2001).

More often underground passes for small animals are used in the form of tunnels and culverts of round, elliptic, rectangular cross-sections the width of which is contained within the scope of 0.50–2.00 m (Fig. 3a). They are usually made of concrete, plastic or steel with natural ground top layer. They are aimed mainly for small animals hunting at night, such as badgers, foxes, martens, hedgehogs and other rodents. In this case a guiding system should also be designed (wire nets and fencings) which would lead the animals to the passage (Dood et al. 2004). Culverts for amphibians form a distinctive type (Fig. 3b) many solutions of various parameters are used, however a small tunnel of 1.00–2.00 m width and natural ground top layer is a common structure. In this case special guiding systems are used which at the same time protect the animals against entering the road. They have a form of concrete gutters (with inlets to the tunnels) and vertical concrete or plastic fencings 0.40–0.60 high.

If a road goes over the terrain or when it crosses a valley or a canyon with natural vegetation and landscape structure, flyovers should be used as they preserve continuity of migration ways of all species. In mountain areas they are often a structural element of a road exerted by topography. In plain conditions they are mainly built due to environmental reasons, for instance over river valleys or over swamp areas. The higher the flyovers are, the better they meet their designed function (the suggested minimal clearance is 6.0 m).

Crossings of animal on the road surface has been most commonly used (it is rather action unconscious than consequential from any well-thought-out analysis). Well considered solutions consist in special signing that signals possibility of appearance of animals crossing the road, as well as information of the section length (Fig. 4).

a) b)

Fig. 3. Underpasses: (a) for small animals; (b) for amphibians.

a) b)

Fig. 4. Example of crossing on the road surface: (a) for animals; (b) for amphibians.

This is the simplest type of animal crossing consisting in depriving a road section of fencing. A minimal width of such a pass is 200 m, whereas the recommended one amounts at 500 m. Often additional speed limitation on this section of the road (to 50 km/hr) is imposed. Such a road section needs to meet the level of the surrounding ground or only slightly differ in height, and it cannot have lighting or protection barriers. A solution of this type is practically the only one (except fencing and reflective elements) which can be used at reconstruction of renovation of the existing roads. In such cases the existing horizontal alignment is not exceeded, also no major changes to the road vertical alignment are introduced. Such solutions are used in big (long) forest complexes and in places where it is impossible to build an animal crossing in the form of a tunnel or a bridge. Moreover such a crossing can be located only on roads with relatively low traffic load of no more than 5 000 vehicles per day and on roads which are not located on crossings with migration corridors of national and international importance (Seiler 2003).

Threshold values of level changing, causing considerable limitations to the possibility of migration of wild animals on the road level, have been presented below: (i) for invertebrate (without capability of active flying), such as amphibians, reptiles and small mammals – embankments of > 1.0 m and excavations of >1.5 m in depth, (ii) for all groups and species of ground animals including big mammals – embankments of > 2.0 m and excavations of > 3.0 m in depth. In each of the above cases slopes of maximum 1:2 inclination are possible. Modification of the vertical alignment of the ground that would exceed the above values causes limitations to migration to such an extent, as only individuals will try to cross the road, whereas the majority of animals will migrate along the embankment bases and top edges of excavations (Maranda 2007). The crossings for animals on the road surface are however characterized by low effectiveness (quite a lot of collisions with animals) due to notorious exceeding of speed limits by many drivers. In last time the warning reflectors to repelling animals are used. Such reflectors reflect the light of vehicles on the roadside terrain mainly at right angle to the roadway (Fig. 5).

3.2. Specificity of designing animal crossings

Before designing of wildlife animal crossing work is commenced, it is necessary to undertake the following:

- Do a research on species of animals inhabiting a given area (due arrangements with forestry officials).
- Recognize migration ways of animals (location of animal crossings must obligatorily coincide with animal migration trails).

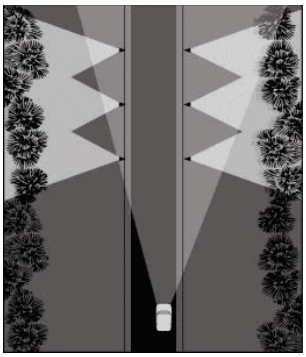

Fig. 5. The fence of light creates from reflexion of the vehicles reflectors.

- To establish preliminary geometrical parameters (vertical and horizontal) as well as the number of crossings (due arrangements with forestry officials).

At the time of execution of road works projects, bearing in mind protection of the environment, one should use both legal and technical instruments, in accordance with the scheme presented in Fig. 6.

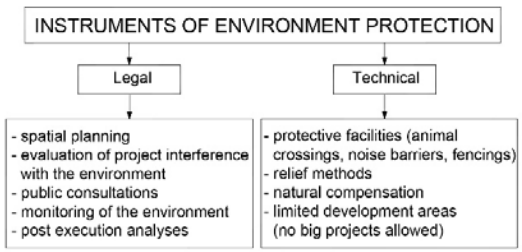

Fig. 6. Scheme representing instruments of environmental protection.

In the case of a motorway and an express road construction, the main way to protect environmentally valuable areas is avoiding, wherever possible, collision with those areas in the planning and designing phase of those projects. Due to specificity of this type of projects (linear objects), avoiding interference with the natural environment is very often impossible. In such a case, the rule of minimizing the negative influence and compensating losses in nature (natural compensation) is applied.

Relevant laws define natural compensation as a set of actions undertaken especially through construction works, earthworks, land reclamation, afforestation, planting trees and creating vegetation groups, leading to reinstatement of natural balance over a given area, compensating losses caused to the environment by execution of a given construction project and preservation of continuity of landscape values.

At the time of designing animal crossings the following elements need to be taken into consideration (Beben and Manko 2006; Kurek 2007; Maranda 2007):

- Ensuring execution of correct guiding funnels, this concerns mainly low angle of entrances to the object.
- Designing relevant vegetation (bushes and trees) on such structures to encourage animals to use them (this also concerns reinstatement of the original natural infrastructure in the vicinity of the structure).
- Ensuring relevant functional value of animal crossings (height and width of the structure) and a suitable number of crossings, to make sure they meet their main task:
  - in the case of big mammals the width of overpasses should be at least 50 m, and the height of underpasses at least 4 m.
  - the number (density) of crossings depends on: (i) importance of the crossed migration corridor, (ii) the type of the crossed habitat and the forms of protection it falls under (national and landscape parks),

  - the highest density of crossings (every 1 km) should be used within the borders of national parks, Nature 2000 conservation sites and in big, compact forest complexes.
- Ensuring that a structure is not elevated more than 1.0 m above its surrounding area (an animal needs to see the opposing side where it is aiming to).
- Diversifying types of crossings over a given area, so that all species (of different requirements) can cross the road.
- Creating silent area around the ecobridges using noise barriers which deaden noise and interference of light coming from vehicles, especially at night times.
- Ensuring that the functions of animal crossing and crossing for forestry and woodcutting services do not coincide at one structure.
- Paying attention to technology of construction works.
- Undertaking consultations and arrangements of construction solutions as well as land development ideas with due services responsible for supervising a given area of natural environment.

3.3. Design errors in and their influence over the use of a crossing

The most common errors at designing various types of animal crossings are:

- not enough width of a crossing,
- too big angle of inclination of a crossing,
- too steep (lack of gentle exit way from the structure onto the surrounding land) and narrow entrances to the structures (lack of guiding funnels),
- in the case of underway culverts – lack of dry passages for amphibians above flooding level,
- situating additional facilities on the structures, for example road signs, walls, barriers, lighting etc.,
- lack of noise and blinding barriers,
- inefficient composition with the surrounding environment, for instance in the vicinity of human habitats,
- lack of high and medium-high vegetation on the structures and in vicinity,
- incorrect top ground layer on the substructure on entrances to objects,
- using vegetation coming from geographically distant parts.

Animal crossings of the A4 motorway in Poland are good examples of the above presented designing errors. However, despite some transgressions and structural defects, in January and February 2006 (after about five year from its construction) individual trails of deer and wild boars were observed on the snow on animal crossings along the analysed motorway section. The number of game population and its density within the borders of hunting areas where evaluation of environmental changes was held, has increased, which proves that animals have got used to living in the neighbourhood of the motorway. It has also been observed that the ecobridges are mainly used at night times by such animals as deer, hares and foxes. Similar analyses of using animal crossings have been contained among others in the following research papers (Cain et al. 2003; Clavanger and Waltho 2005; Dodd et al. 2004; Mata et al. 2005; Ng et al. 2004; Olsson et al. 2008).

An analysis of using of selected animal crossings situated on the motorway and expressway in Poland (10 overpasses and 10 underpasses) has been also conducted depending on their width (Fig. 7). Above-mentioned observations were done at winter 2006 and 2007. Tracks of the deer, roe deer, marten, hares, foxes and wild boars have been observed at the analysed ecobridges mainly at night times. According to the obtain results in the case of overpasses (the width of passage in range 40–140 m) using by the more eagerly animals (mainly by deer, roe deer, wild boars) has been observed. However in the case of underpasses (tunnels, flyovers) of width within the scope of 10–140 m, the number of animals using them can reach 20 individuals per night, mainly foxes, hares, martens and also wild boars. Generally it has been observed that underpasses are more often used than overpasses. This is probably related to their more natural integration with the surrounding environment – they most often constitute an extension to a migration corridor at the same ground level. In the case of overpasses, for example in the form of a viaduct over road the solution is a non-natural connection between two areas of natural environment. In this case an animal heading the opposite side of a road needs to go up a slope, which always causes anxiety. The similar research of use the overpasses is presented by Jedrzejewski (2007). Neither adaptation of existing culverts for

animal crossing purposes is a good solution. Most often those objects do not meet basic geometrical parameters nor are they located on animal migration trails (Mata et al. 2008).

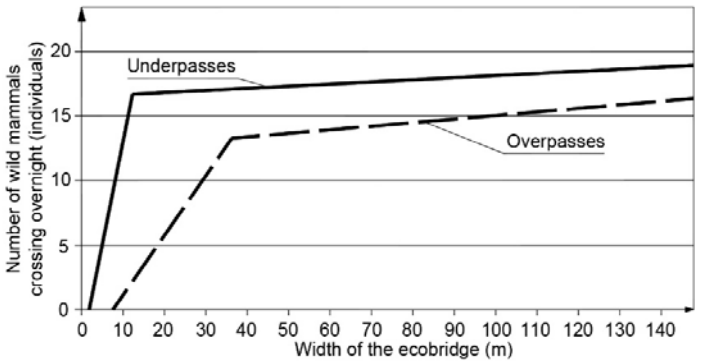

Fig. 7. Frequency rates of using overpasses and underpasses by animals.

4. Discussion

The constantly evolving transportation infrastructure (roads, railways, airports) in Europe, especially in its Midwestern part, on one hand connects, making it easier for people to travel and ship goods, but on the other hand it irreversibly divides and leaves its painful impress on virgin natural areas (fragmentation of the environment). That is why execution of different engineering projects, especially ones of road and railway type requires sensible actions, bearing in mind not only building of impressive road or railway route, but also preservation of the natural environment in its untouched condition to the highest possible extent.

As it results from analyses conducted in paper, animal crossings complemented with suitable fencing weaken the so called barrier effect and accomplish two main functions, namely (i) they create conditions to meet habitation requirements of wild animals, the individual territories of which are cut through by a transportation route. These animals can use both parts of their territory located on the two sides of the road; (ii) they make migration and dispersion of animals migrating on long distance possible.

As it has been proved by the analysis of use of animal crossings, animals use them, even the ones transgressing the rules of good designing and engineering practice. This is caused by the fact that animals have got used to such crossings and to their vicinity, having at the same time no alternative to cross the road. It has also been observed that underpasses tend to be used more often than overpasses by such medium sized animals as hedgehogs, martens, badgers foxes and hares. In the case of both crossings types, the animals tend to use them mainly at night times. It is because at night times the wild animals feel more safely than during daytime (less of light and transportation noise level).

Animal death rates on roads depend also upon the area that the road crosses. For example there are amphibians and medium sized forest and field-forest mammals (e.g. hedgehogs, martens, badgers, foxes, hares) as well as big mammals (e.g. roe deer, wild boars, deer) that get killed on Polish roads. Collisions with elks, wolves, lynxes or even European bisons are very rare. In other European countries the situation is similar with the reservation that many animals species does not die, because already long ago extinct, e.g. lynxes, European bisons. Animal death rates vary depending on a season – they are the highest at the time of intensified spring and autumn migrations and on a time of a day – most accidents happen at dusk. The most threatened by roads are the following animals: amphibians and mammals of high spatial requirements: a wolf, a lynx, a brown bear, an elk, a European bison and a deer.

Based on the presented research, minimization of negative influence of transportation projects on an animal population can be recommended through the following action (Fig. 8):

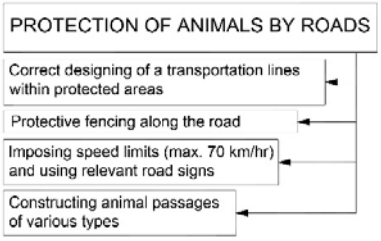

Fig. 8. Scheme of basic animal protection by roads.

- Designing transportation routes in such a way as to avoid collision with animal migration routes (it is necessary to work out a strategy of motorways and express roads development having in mind protection of environmental resources).
- Constructing well developed animal crossings of relevant geometric parameters.
- Using fencing to limit collisions with vehicles and to reduce the negative effect of noise and vibrations from roads.

An important element of environmental protection is compensation of losses, the so called natural compensation. However it appears that building ecological crossings for wild animals is one of the elements of wildlife protection of utmost importance. Structures of this type constitute quite a big technical problem due to its complex nature, therefore, above others, it is necessary to: (i) recognize populations of animal life and their habits, (ii) locate the structure in the correct place – i.e. on animal migration trail, (iii) develop the crossing for animals in an appropriate way (for instance high and medium sized vegetation, blinding screens, suitable paving, etc.), (iv) use environment friendly construction and material solutions, (v) design structures of relevant geometric parameters, this especially concerns the width of a crossing and the clearance between the road level and the animal passage.

Many types of construction materials are used to build animal passages. They are steel, concrete, plastic, but it seems that structures made from corrugated steel plates (CSP) elements interacting with the surrounding soil (so called the soil-steel bridge structures) are the best ecobridges for small and medium sized animals (Fig. 9), due to their natural characteristics, which are among others: (i) soil cover on the structure needs not be artificially created – it constitutes an integral bearing part of the structure; (ii) they compose well with the surroundings (they can be finished off in a freely selected way: grass or gabions on outlets from ecobridges); (iii) they do not cause too much vibration when vehicles run over or under them – the backfill damps it; (iv) they allow possible widening of the animal passage if necessary; (v) they do not require using heavy construction equipments.

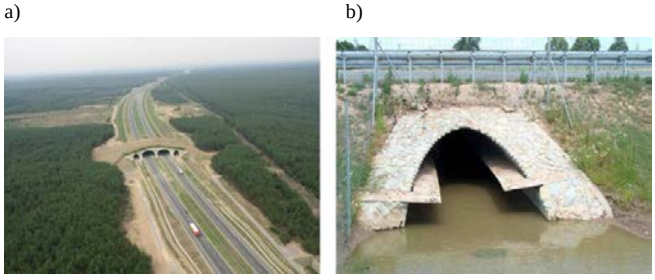

Fig. 9. An example of: (a) an overpass for animals; (b) underpass with shelves for amphibians.

It is also very important to hold constant monitoring of animal crossings which allows to estimate their functional value and can be the source of ideas of increasing and maintaining required quality of land development. It can also be of help at constructing new crossings (Clavanger and Waltho 2005). To this goal thermo-vision cameras as well as the GPS technology can be used.

5. Conclusions

- The animal crossings are built in form of overpasses, underpasses and crossings on the road surface. These types of structures are more and more often built in Poland and Europe, it is results from the Natura 2000 requirements.
- The correct designed and constructed animal crossings should be characterize the appropriate geometrical parameters (width and height of object) adapted to kind of animals as well as it should be made from the environment-friendly materials, e.g. native soil.
- The use of existing animal crossings in Poland is mainly dependent on their width, i.e. the crossings are wider (more from 140 m) the animals more often use them. The use of animals crossings were observed mainly at night times. The animals more willingly used objects built of the materials environment-friendly and equipped with the acoustic screens overgrown with the creepers.
- From conducted observations, it seems that structures made from CSP elements interacting with the surrounding soil are the best ecobridges for small and medium sized animals, due to their natural characteristics.
- In connection with the above, it has been proved beyond any doubt that these types of structures are necessary and unavoidable, because they allow for preservation of genetic diversity of various animal species.

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