The Management of Environmental Bridge Design

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Abstract

The aim of the paper is to characterize the inconsistencies appearing during the bridge design process, maintenance and ecological issues which were caused by lack of proper environmental management system. Several examples of the road and bridge investments carried out in Poland in the last decade have provided the basis to formulate several statements and questions. The difference between the approach of bridge engineers and environmental experts to the concept of animal migrations is shown against the background of technical and environmental standards that were implemented in the investment. The existing problems are of dual nature, the first group being very general issues i.e. concerning the concept of ecology, while the other one involves detailed matters, e.g. the appearance of a bridge. Several questions of great significance have been formulated and addressed to ecologists. The answers are indispensable for bridge engineers to work on technical aspects of proper design of environment-friendly bridges. Last but not least, the suggestion to use bridges as sites to monitor the environment in their surroundings is presented. This research work might be crucial for further good cooperation of bridge engineers and environmental engineers only when a simple and consistent management system embracing different standards is created and put into operation.

Keywords: Bridges, environment management, sustainable development.

Introduction

The article shows the development of environmental proceedings in bridge design in Poland during the last decade and attempts to propose a useful control option for monitoring the environment near rail and road corridors, especially now when hundreds of highways as well as express roads have been built. The starting point was the basis worked out by foreign ecological institutions, the main element i.e. animals migration corridors included (Rochelle, 1999). The turning point was the so called Rospuda River case. In 2008 the road construction works were stopped because of the protest organize by local ecological organizations. The protest had a form of blocking the road construction works.

Many young acting spontaneously people chained themselves to the trees, set up their encampment in the area and commenced regular occupation. The purpose of the planned new road was to alleviate the impact of heavy transport which caused infrastructure damage, noise pollution and even fatal traffic accidents in several small towns. On the other hand, there were some road sections that crossed the selected ecologically sensitive areas marked as Nature 2000. It was a situation, where neither party was absolutely right. The compromise was not reached. In such circumstances a new deal was indispensable.

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Since that time, instead of the semi-environmental approach the real technical-environmental design considerations have taken place.

Rospuda River Casus – Polish Experiences

The beginnings of the ecological movement in Poland was characterized by spontaneous, intuitional but less professional activity. The first action focused on the preservation of old poplars along the roads. This tree system created a typical sight in our landscapes. However, when the tree achieves the age of ca 40 years, its expanded branches tend to fracture, especially under the snow layer and during high winds. Many cars were damaged by falling trees' branches. It was necessary to cut out thousands of old poplars but simultaneously this decision implied an opposition of the old trees aficionados connected with the youth' ecological movement. The final effect of this action was easily predictable, but earlier it was necessary to fight a battle which led to the fundamental conclusion that cutting off a tree is acceptable provided a new tree is planted.

A more spectacular action took place when the construction of the bypass of the small town of Augustów was commenced. In 1992 the decision on the design work of the bypass road was taken. Among dozens of bridges, overpasses and culverts there were also passages designed for small and big animals. All this, i.e. roads and bridges as project elements, was performed strictly according to the Polish (Regulation, 2000) and European standards on nature conservation (Directive, 1985), (Convention, 1998), (Directive, 2001). On the course of the road was the nature reserve on the Rospuda River which was intended to be traversed by means of high road embankments and overpasses as well as bridges in the valley of the river.

It is necessary to emphasize that the life of citizens in Augustów reached the limit of uncomfortable conditions due to heavy transport traffic, high noise, difficulties of pedestrian and bicycle traffic and even dangerous accidents.

The road construction works started in 2007 but soon the works were blocked due to an ecological action which was supported by some TV channels. In 2008 the investment was stopped until 2014, when again after some modifications road works are continued. Till now the slogan Rospuda is recognizable anywhere and anytime in Poland when one thinks of designing roads.

Here a question arises why such a situation occurred. Firstly, there is an analogy to the case of the overpass highway of Pilzno, the Czech Republic. Also there, the young ecological movement blocked the road construction works, and also after ~10 years the construction was continued. Probably here and there appeared the same sociological mechanism. It is worth mentioning that those were the days when both Poland and the Czech Republic joined the European Union and when new circumstances provided a new range for independent criticism and freedom to express personal distrust to government’s decisions. . But 10 years' periods seems to be enough for mature understanding of both road and bridge technical conditions and environmental requirements. This interval enabled to avoid a really dramatic cost of struggle between the two sides of the investment process and allowed time to transform the two opposite sides parties into partners. At present one may quite confidently say that partnership works. However, civil engineers have been still waiting for more detailed and uniform rules related to the environmental requirements for design than those contained in (COST, 2003) for instance.

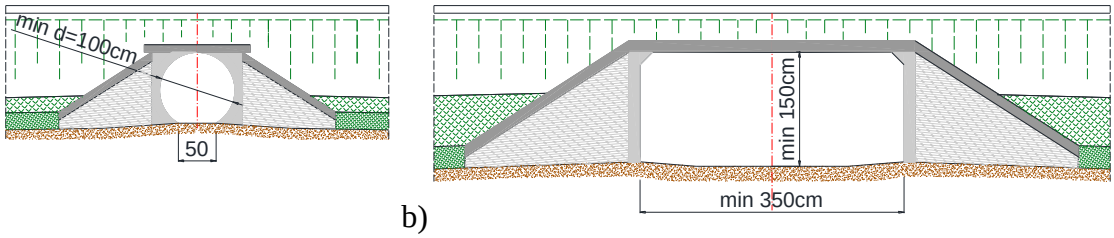
Basic Environmental Requirements Related to Bridges

There are no special technical standards to design bridge structures regarding environmental needs. Instead of standards there are paragraphs in (Regulation, 2000)

where such requirements are formulated in detail and by using very formal provisions. Briefly, they go as follows.

For wild animals a non-collision path ought to be ensured to let them move from one side to the other of higher class of roads in areas of increased animal migration, in particular in larger forest complexes and areas of wetlands and other habitats of rare and endangered species, as indicated by the relevant government authorities or appropriate local government units. This ought to be done as:

- passage in tunnels across the body of the road of a width equal to min 10m,
- viaducts over the road with entrances equipped with a screening fence in the approach to the facility, off-axis crossing at an angle close to 60 deg, and connecting with the green surrounding - in order to provide guidance to animals.



a) b)

Figure 1. The clearance gauge a) for small animals b) medium-sized animals [3]

In the case of large animals we practically have to deal with full-size viaducts. The rectangular clearance gauge under the viaduct has a minimum height (H) of 4 m. The clearance width (B) is set using the following formula

$$B \geq \frac{N \cdot L}{H} = \frac{3}{2}\frac{L}{H} \qquad (1)$$

where N is the measure of narrowness of min value $N=1.5$; H - the height; L - the length of the passage. Another, more comfortable, parameters are proposed in (COST, 2003).

Basically the bridges were located over the rivers, while the viaducts over existing roads, agricultural fields or meadows. The aim was to integrate the new passages with migration paths, as shown on figure 2.

a) b) c)

Figure 2. Animal passages a) for medium-sized animals b), c) for big animals

There were three groups distinguished - small animals, medium-size ones and big ones respectively. In short - for small animals, like frogs or foxes for instance, for which it is necessary to build passes in form of circular tube culverts of a min diameter 100cm (0,8m^2)

[3] wild boar, roe deer for example

and walking paths of a min breadth 50 cm, see figure 1-3, also in culverts along water courses.

Outside of the culvert, the surface of the passage should be designed according to the existing ground surface. In the case of water-courses additional side benches running along the passage near the culvert walls should be constructed. The surface of the benches has to be placed above the average water level. To protect animal migration along roads or railway lines an appropriate fencing system should be introduced to direct small animals to the safety zone where the culvert passage is located. The above mentioned fences could be made from different materials (like steel shields) but in practice they are made of green color plastics.

Finally, even though it is not written down in any technical or administrative document, the local stone, ground and vegetation are recommended for use.

a)  b) 

Figure 3. River culverts a) built in 2006 b) constructed in 2013

In figure 3 the culverts present their beauty as elements of the river's landscape. Also the photos show differences occurring within the range of environmental approaches. In the first photo, figure 4.a, there are no side paths for small animals. In figure 4.b such a side bench was made. The slope protection is made by use of openwork precast concrete heavy plates which start being overgrown by grass. Technically it is a typical and well verified solution, whereas the concrete stiff elements are extraneous in the natural river bed system.

a)  b) 

Figure 4. The bridge over the Lopa River in Lopiennik; transition for medium-sized animals a) just after construction b) after 2 years

Now, the dominating solution is to use more environmental-friendly gabion mattresses which are filled with crushed natural stones, appropriately to the mesh size, figure 4.a. The gabion mattresses protection easily becomes overgrown by meadow grasses, figure 4.b.

Long Span Bridges - Small Ones

Large river or even a medium-sized river always has a wide floodplain. Additionally, high water levels are significant because the height of the clearance gauge is large. Designing a long span bridge means to obey hydraulic and hydrologic criterions for easy flow of high river water. This automatically fulfills the conditions for minimum clearance gauge for big animals. Also, bigger distances from the carrying-deck to the ground level result in a more quiet solution considering road traffic but also, increasingly for new rail bridges. This positive ecological impact was for a long time countered by extensive damage to surrounding area caused during construction of long bridges. Nowadays however, building technologies limit very strongly bad influence on bird habitats, especially during the breeding season (Garniel, 2010).

Existence of biotopes in the surrounding of long bridges is a challenge for both environmental and bridge engineers. Locally, during erecting a bridge the previously existing biotope is destroyed. Figure 5.a shows a change of vegetation occurring during the replacement of the existing old RC[4] bridge with a new composite of steel-concrete one. According to the environmental rules the previous condition of vegetation should be reconstructed in the coming 18 months after finishing the construction works. As it is clearly visible, it is not possible in practice, as shown on figure 5.b. Here arises a question of options i.e. which solution is right - a meadow, bushes or a forest ?

Figure 5. The bridge in Neple over the Bug River a) an old bridge b) the new one

Also here two additional views encounter. In a technical sense for instance if the empty meadow clearance is perfect for the water flow, than from the environmental point of view shall we go back to the choice between a meadow, bushes or a forest ? Here, bridge engineers are still waiting for the answer.

Small span bridges, up to 20 m, were not so automatically designed as long span ones. From time to time it happened that the leading rules for small bridge design come from environment needs. Mainly the height of clearance gauge, which has to be proper for medium or big animals migration, influences road and bridge gradeline. Finally, a small bridge may be more expensive than a bridge of average size one due to environmental conditions.

Animals - People

While creating the environmental surrounding for animals it was forgotten that the human - in a sense - is an animal too. Many rainwater reservoirs near the highways were practically immediately populated by amphibians, even when vegetation was not fully grown. Reservoirs were designed for two reasons: first to collect the water and the second to

[4] RC - reinforced concrete

shelter amphibians. On the other hand, a water mirror, a green slope of highway embankments, an easy access i.e. in the vicinity of a city, all these were elements which attracted people for camping, barbecuing, fishing, bird watching - in general - for relaxation, figure 6. This is a new role for reservoirs which was not predicted earlier.

Let us notice that the noise of highway traffic at the foot of the road embankment is relatively not high and the car movement plays a similar role to a TV series. This provides the unity of nature and home for people around. Also, while building highways many secondary service roads are provided were necessary. This service net discloses many interesting nature places. When one thinks 'environment', the human is excluded. This sounds like a very popular idea i.e. to separate nature from human activity or at least to limit the contact between them. This is the basic concept accompanying the foundation of national parks, for instance.

a)  b) 

Figure 6. On the S17 road a) nature refuge b) place of recreation

From the authors' point of view, the contact between the human and the nature is an elementary organic relation; (Karas, 2011). It ought to be organized properly for both of them. To do this, the more commercial approach is necessary. At the design level the parking places must be taken into consideration. The administrator of such areas has to introduce clear rules of behavior, entry fee, etc.- so in short all the elements which are in use in countries like Belgium or the Netherlands.

Here appears another mental barrier which should be broken through. This should become be obvious to non-environmentalists and bring about discussion among ecologists.

Questions that are Waiting for Discussion

Building a bridge structure proceeds according to proven, almost typical rules which correspond to those given in the Eurocodes. The possible variation is only in terms of details. Environmental engineers have repeatedly raised questions the impact of the appearance of a bridge on the behavior of large animals but so far there is no one good answer. Actually, there are two approaches, not congruent at all, see figure 7.

For example, the cones[5] of road embankments at bridge abutments may have at least two forms. The cone may be surface-enhanced by means of semi-rigid elements made of concrete blocks of 15cm thickness. The expression of such a solution is a strong color image corresponding to the geological rock formation occurring in the rock mountains, figure 7.a. The other option is a solution used not so long ago, in which the cones of embankments were reinforced with laying turf, figure 7.b. In this case, the image is characteristic of the lowland meadow views. Which one is better ? The point is that one can get the answer in two variants.

[5] Actually, in the sense of geometry, it is a quarter of truncated cone.

a)  b) 

Figure 7. Bridge cone veneering a) natural grass b) concrete blocks

In terms of maintenance both discussed solutions are correct and equivalent. Therefore the question mentioned above arises, which of these solutions is more environmentally friendly? There is also a similar question: how large animals perceive color or the color intensity? So far as coloring is concerned bridges are designed only in the context of acceptance by man.

Both questions are reasonable in a much broader context, namely: *what is the psychology of large animals* ? This question is so broad that the problems of shaping bridges constitute its small fraction.

Another issue is the cost of engineering and road bridges. Based on the Polish experience of the past 10 years, it is estimated that construction costs of passages for small, medium and large animals, noise screens, planting of trees and shrubs were from 10 to 20% of the total investment costs (Madaj, 2012). This is a significant sum. The most expensive are green bridges for large animals, which amount to the cost of normal overpasses over the highway, figure 8.

a)  b) 

Figure 8. Animal overpass a) made of RC b) integrated of ground-steel shell type

Another reasonable question arises concerning the effectiveness of these expenses. Currently monitoring of the use of these structures by animals is commonly conducted. The answers are partial, but positive. The material collected from the observation includes animal trails and single images of passing animals, which indicate that the animals use the newly built passages. However, so far no conclusions can be drawn in terms of statistics. Probably, animals need a generation or more to get used to the new situation. The answer to this question is very important, as the cited 10 to 20% of costs represent a significant compromise and may impede achievement of the objectives necessary to the people, (Karas, 2011).

Although the road and bridge standards in the field of ecology were formulated long ago and are precise and clear, the environmental criteria laid down in the relevant documents are not. In the field of environment there is an exponential growth in various regulations and instructions, which means that the goals are not clearly defined. Hence,

their implementation may cause technical troubles. This is a major difficulty, which in the opinion of the authors, results from not enough professionalism of environmentalists.

Numerous mishaps show clearly that this area requires a significant cognitive and technical discipline, (COST, 2003).

As an example, reference is made to a temporary stop in design and consequently a holdup of construction of the airport in Swidnik (eastern Poland). The area destined for the runway proved to be inhabited by the spackled ground squirrel - in Poland, briefly called gopher - (Spermophilus suslicus), which is a protected species.

The problem has become popular because of its extensive coverage in the mass media.

After a thorough examination it turned out that the existing colony of gophers was the result of release of a few individuals from a breeding home. Due to unfavorable natural conditions and degeneration within the group colony the gopher disappeared.

The above example shows that good intentions must be supported with solid research.

Here is therefore another question. Our perception of ecology is dominated by human perspective but is this a right approach? What about animal's perspective? The above question is related to yet another issue of nature - the problem of locally favored conditions; (Gałaś, 2004).

Can We Protect the Nature?

The symbol of the last conference on environment and road construction[6] was a stork preying at a guiding fence. Another recorded picture was of a snake hunting along the guide fence. Hence comes a question - to what extent are human activities appropriate to protect nature ? And to what extend are the protecting processes leading to the imbalance of the whole system of fauna? Since nature is governed by the primary rule of survival and human standards create a feature of predation and ruthlessness, every facility that benefits certain animals raises an increased risk for others (Bohatkiewicz, 2014). From the point of view of a road and bridge engineer this problem is of minor significance, but every road and bridge engineer is also an ordinary man for whom the idea of equality, justice, etc. is crucial.

a)  b) 

Figure 9. Effects of the beavers activity

For several years, beavers in Poland have been under strict protection. These animals are not very timid in the neighborhood of man. Their nature is to build systems of dams using trees growing along the rivers. Following the introduction of protective provisions

[6] VIth International Conference on Environment and Aesthetics in the Road Construction, which was held in Kazimierz Dolny, this year on 23-25 April; organized, among others, by the Road and Bridge Chair of Lublin University of Technology [online]. Available from: http://wbia.pollub.pl/pl/o-wydziale/struktura-wydzialu/katedra-drog-i-mostow/konferencja-kazimierz-2014. [Accessed 1 August 2014]

there was a significant growth of the population of beavers. Hence there was clearly a greater range of their activities which was manifested by fallen trees, figure 9, and significant damage (sometimes up to 100%) to population of fishes in rivers. Here and there a new flood plain river areas occurred, even coming to the surface of ca 5 hectares. There was a visible change of the image of woodlots after some poplars, ash and alder trees has disappeared. There were problems with availability of grassland, maintenance of riverbed profiles, uncontrolled damming of the water. In the case of bridges and culverts the problem strongly appeared during the high water flow when the water carried logs of trees blocking the clearance gauge of the bridges, causing additional stacking water and often blurring the bottoms of the rivers.

Conclusions

Poland is a young, 10 years, EU member state, where in the last 5 years ca 1,800 km of highways and expressways were constructed, creating a new transportation network. Simultaneously conflicts the with environmental organisations of different types – official and social - arose. Currently the environmental control system is in its infancy. Professional management system does not work properly. It is especially badly felt by constructional engineers. But also in old member states such as Germany and Austria some deficiencies are visible. The environmental management system which will govern in the field of different aspects of human activity, especially in the field of road and bridge design, maintenance and monitoring of nature is a nowadays a dire need. The postulated management system should be related to technical standards as for instance the Eurocodes and others.

In Poland, animal migration corridors on a local and continental scale, have been changed due to construction of a systems of highways. The road construction works have not been completed yet. The next step in modernisation of the country will be a similar process, but now connected with rail transport.

Now truly exists the awareness of the necessity to protect the environmental system, which also requires additional remedies resulting from infrastructure development. The only way to do this will be when qualitative recognition is completed through research based on quantitative considerations. Such processes have to be transparent and understandable for any group of people i.e. be in accordance to (Directive, 2003).

Bridges are cutting points for roads and railways on the one hand side and a provide continuity of animal migration paths on the other. On this basis existing bridges should be supplemented by monitoring systems which will be able to record continuous or selected ecological events in the surrounding of bridges. Also temperature, moisture, air pollution and noise level have to be added to the recorded elements.

Monitoring of bridges, although is not common, works in special cases. Lots of suspension or cable-stayed bridges are supplied with facilities to observe strain, stress or displacement processes. The archiving could be done on a disk or in cloud. As it is seen – nothing is to discover. Some general concept and some examples of monitoring were included in (COST, 2003), however those suggestions do not form a typical technical solution i.e. solution which would be easy to apply into bridge design procedures. The only action is to develop and to unify the existing systems and adopt them to environmental needs. With a good database it will be easier to find reliable solutions to challenges that occur in road and bridge design practice.

References

Bohatkiewicz J., Gałaś S., 2014. The use of checklists in environmental studies in the field of road construction, *Construction and Architecture*, No. 1, Vol. 13, 295-304.

Gałaś S., Gałaś A., 2004. Evaluation of the environment from the point of view of optimal use of its potential. *Polish Journal of Environmental Studies*; vol. 13 suppl. 3, 255–258.

Garniel A., Mierwald U., Ojowski U., 2010. Arbeitshilfe Vögel und Straßenverkehr. *Bundesministerium Für Verkehr, Bau und Stadtentwicklung, Abteilung Straßenbau, Kieler Institut für Landschaftsökologie*, [online]. Available from: https://mvi.baden-wuerttemberg.de/fileadmin/redaktion/m-mvi/intern/dateien/PDF/Arbeitshilfe_Voegel_ im_Strassenverkehr_BMVBS.pdf [Accessed 1 August 2014].

Karas S., Leniak-Tomczyk A., 2011. Roads and sustainable development. *In*, W Rawski, eds. *Conference Proceedingsod IVth International Conference on Environment Protection, Esteheticks and raod Infrastructure Developement, 25-26 May, Zamość, Poland.* Lublin: Print for Association of Engineers and Technicians of Road Engineering, 149-161.

Madaj A. and Bednarek B., 2012. Animal passages over the A2 motorway, Nowy Tomysl-Swiecko section, in Poland. *In:* A. Madaj and I. Jankowiak, eds. *Conference Proceedings of 2nd European Conference on Buried Flexible Steel Structureas, 23-24 April 2012, Rydzyna, Poland.* Poznan: Archives of Institute of Civil Engineering, 167-174.

Rochelle J.A., Lehmann L.A., Wisniewski J., 1999. *Forest Fragmentation: Wildlife and Management Implications*. Printed in Netherlands, ISBN 90 04 11388 6.

COST, 2003. *Habitat Fragmentation due to Transportation Infrastructure*. *Wildlife and Traffic*. A European Handbook for Identifying Conflicts and Designing Solutions [online]. Available from: http://www.iene.info/wp-content/uploads/ COST341_ Hand book.pdf [Accessed 1 August 2014].

Convention, 1998. *On Access to Information, Public Participation in Decision-Making and Access to Justice in Environmental Matters*. Denmark: 25 June 1998 Å rhus, Fourth Ministerial Conference, "Environment for Europe" [online]. Available from: http://www.unece.org/fileadmin/DAM/env/pp/documents/cep43e.pdf [Accessed 1 August 2014].

Directive, 1985. *On the assessment of the effects of certain public and private projects on the environment.* (85/337/EEC) of 27 June [online]. Available from: http://www.energy-community.org/pls/portal/docs/36294.Pdf [Accessed 1 August 2014].

Directive, 2001. *On the assessment of the effects of certain plans and programmes on the environment*. 2001/42/EC of the European Parliament and Council of 27 June 2001 (No. 2001/42/EC, O.J. No. L 197, 21 July 2001 P. 0030 – 0037) [online]. Available from: http://www.environ.ie/en/Legislation/DevelopmentandHousing/Planning/ File DownLoad,14420,en.pdf [Accessed 1 August 2014].

Directive, 2003. *On public access to environmental information and repealing*. 2003/4/EC of the European Parliament and Council of 28 January Council Directive 90/313/EEC [online]. Available from: http://www.elaw.org/system /files /EU. 20034 ECDirective. pdf [Accessed 1 August 2014].

Regulation, 2000. *Regulation of the Minister of Transport and Maritime on the technical conditions to be met by traffic engineering objects and their location* (in Polish), Dz.U. 2000 nr 63 pos. 735, [online]. Available from: http://www.abc.com.pl/du-akt/-/akt/dz-u-00-63-735 [Accessed 1 August 2014].