RESEARCH PROJECT ON THE ENVIRONMENTAL IMPACT OF ENGINEERING STRUCTURES

FORSCHUNGSPROJEKT ZUR BEWERTUNG DER UMWELT-AUSWIRKUNGEN VON INGENIEURBAUWERKEN

PROJET DE RECHERCHE SUR L'IMPACT ECOLOGIQUE D'OUVRAGES DU GENIE CIVIL

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SUMMARY

The Environmental Life Cycle Assessment is a common method for the assessment of effects on the environment. Some experiences regarding environmental life cycle assessment of bridges will be presented. The methodology will be described and associated problems will be discussed. Using an example, it will be shown what type of results could be obtained from a comparison of different designs, and ways to reduce environmental effects will be indicated.

ZUSAMMENFASSUNG

Ökobilanzen sind gängige Methoden zur Bewertung von Auswirkungen auf die Umwelt. In diesem Bericht werden einige Erfahrungen mit Ökobilanzen von Brücken präsentiert. Die Methode wird beschrieben und bestehende Probleme werden diskutiert. An einem Beispiel werden die erreichbaren Ergebnisse dargestellt und Wege zur Verringerung von Umweltbelastungen aufgezeigt.

RESUME

L'analyse de cycles de vie est un procédé commun pour l'évaluation des influences sur l'environnement. Ce rapport décrit quelques expériences avec des analyses du cycle de vie se rapportant à des ponts. La méthode est décrite et les problèmes associés sont discutés. A l'aide d'un exemple, les résultats obtenus pour différents concepts sont démontrés, ainsi que des possibilités pour réduire l'incidence sur l'environnement.

1 INTRODUCTION

In this report, some experiences from an ongoing research project will be presented. This project has the objective to assess the effects of engineering structures on the environment. Preliminary results and associated problems as well as unanswered questions will be discussed in the following pages.

The described research work is carried out as a part of an interdisciplinary research group which has been formed at the University of Stuttgart. The objective of this group is to formulate a methodology for the description and assessment of the quality of engineering structures from an integral point of view. From the start of this project on, ecological as well as formal, structural, social and economical aspects are to be investigated. The topic regarding the ecological questions is under investigation at the Institute of Construction Materials at the University of Stuttgart. The study covers not only the influence of materials, but also includes structures with special emphasis on bridge structures.

2 METHODOLOGY

Regarding methodology, some guidelines are available in literature [CML, 1992; Umweltbundesamt, 1992; Consoli, 1993]. In the aforementioned papers environmental effects are assessed by comparison of the ecological relevance of products with similar functions. Furthermore, there exists an agreement to divide the assessment in several steps. The inventory analysis of environmental interventions should be carried out first, based on uniform rules (Inventory Analysis). Secondly, environmental effects caused by interventions should be investigated (Classification) and finally a conclusion on ecological relevance could be derived (Evaluation). The concept of comparison of products with similar functions and the gradual assessment are used in the described project.

Some differences between bridges and residential or office buildings, with respect to environmental effects, should be discussed. If someone wants to assess

the effects on environment of buildings where people live and work, they need to study first the influences on human health. This influence is normally not relevant for bridges. Furthermore, there are no heating and ventilating systems which have a great share on the sum of environmental interventions for a residential or office building [Ankele, 1993; Kohler, 1994]. That is why in engineering structures, other life cycle stages (for example production of construction materials) are considered to be more important.

3 INVENTORY ANALYSIS

One of the main points of this work is the inventory of environmental interventions caused by bridges. The inventory analysis is based on life cycle stages. A distinction is made between interventions connected with bridge structure and interventions caused by traffic. The following life cycle stages are investigated: production of construction materials, execution, usage, maintenance, demolition and waste disposal. For every stage, the consumption of energy and raw material, the use of space, as well as the pollution and the waste were determined. However, it has been extremely difficult to obtain these data for the following reasons:

- Life cycle stage - production of construction materials:
  The industry is most of the time not willing to give information on their production, since they fear direct effects on their marketing power.
- Life cycle stage - construction (execution):
  Better conditions are found here: data to energy consumption can be obtained from estimating engineers. Normally they know the energy consumption of construction works (electricity, fuel, gas etc.) exactly, since it is a part of the cost estimate. The problem here lies in the great variety of possible construction methods. Additionally, the estimating engineers often do not know more about environmental interventions than about energy consumption. However, a

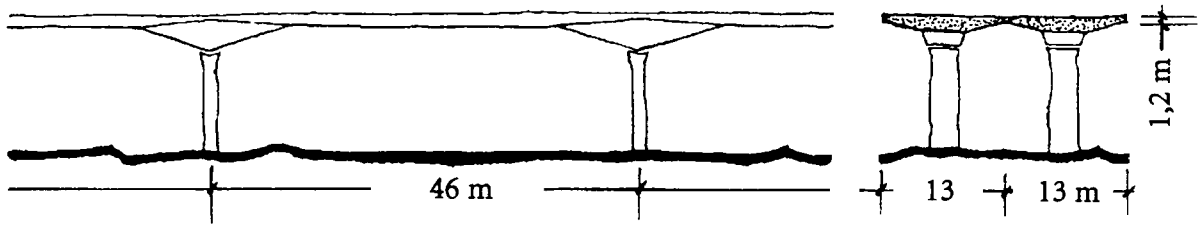
large part of environmental interventions is known, when depletion of raw materials and emission caused by energy consumption are calculated.

- Life cycle stages - usage, maintenance, demolition, waste disposal:
  These life cycle stages take facts into account which belong to the future. That is why scenarios and prognoses are required (for example scenarios regarding maintenance). Experience shows that it is difficult to foresee the evolution in the future. Who would have suspected, for example, at the beginning of the concrete era, the maintenance necessary to upkeep concrete structures today? A further problem lies in the determination of environmental interventions of technical processes, which could be caused by more advanced techniques perhaps used in the future. It is of course possible to get some current data, often on the energy consumption, but it is questionable whether these data represent the future development.

In spite of the problems discussed above, inventory analyses for several bridges were performed. Tab. 1 presents for example the energy consumption of two different bridge designs (length = 628 m) [Lünser, 1994]:

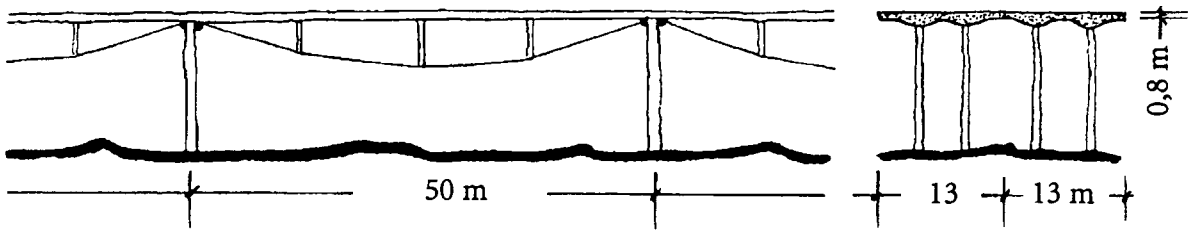
Tab. 1: Energy consumption (10^{12} J)

	Design No. 1	Design No. 2
production of construction materials	78,8	56,5
construction	13,7	9,9
maintenance	39,1	44,0
demolition and waste disposal	11,1	7,3
total	142,7	117,7



- superstructure: prestressed concrete slab (with haunches)
- substructure: concrete pillars

Fig. 1: Alternative Design No. 1 (as built)



- superstructure: external prestressed concrete girder
- substructure: steel pipes filled with concrete

Fig. 2: Alternative Design No. 2

These results show that:

- There are differences between the two designs in all life cycle stages.
- The high value of the production of construction materials is remarkable. In both cases, it is nearly half of the total sum of the whole life time energy demand.
- The need for maintenance is less, but depends strongly on the life time. A life time of 80 years was assumed in both cases.
- Construction, demolition and waste disposal have got smaller shares, but they are not negligible.

Similar conditions were found for other environmental aspects [Lünser, in preparation]. Which conclusions could be drawn from all this? The first thing that needs to be mentioned is that a comparison of different designs seems to be useful. A difference of $25.5 * 10^{12}$ J was found between the two alternative designs. Otherwise, this difference is nearly negligible, when compared with the yearly energy consumption of Germany (around $15 * 10^{18}$ J in 1992). Therefore, the results of such comparisons and the influence of a single bridge should not be overvalued.

4 CLASSIFICATION

The aim of the classification is to analyze the effects of the environmental interventions which have been determined in the inventory analysis. This leads to a concentration of data.

Cause-effect-models are used to analyze these effects. Creation of such models normally exceeds the competence of civil engineers. But in literature [CML, 1992; Consoli, 1993] several cause-effect-models for global effects (for example influence on greenhouse effect) are available. Models like these are used in the described research project. It is more difficult to investigate the effects of a bridge on the surroundings. These could be influences on flora, fauna, microclimate caused by space use, separation, emissions, noise etc. The effects on the surroundings depend strongly on the local conditions. That is why extensive investigations are necessary. As these investigations have to interact with other disciplines (e.g. biology), it is imperative to work with other specialists from these disciplines.

Experience shows that there is a large interest in the effects on the surroundings, often larger than in the global effects. Therefore, a co-operation with other scientists, especially ecologists, is planned for all future work.

In spite of the importance of the effects on the surroundings, the determination of global effects is also useful. It is known from experience that the differences in different bridge designs hardly has any effect on the surroundings. These effects will be interesting just for comparison of different routes.

5 EVALUATION

To evaluate the effects determined in classification, several known methods could be used. However there is no generally accepted method. Within this research project the evaluation of the effects is necessary, as the interdisciplinary group wants to give a condensed statement about the quality of a structure. Statements about environmental effects have to be confronted with other aspects (design, robustness, safety etc.). That is why a general evaluation concept is used in taking the following steps:

- formulation of aims
- determination of how these aims are to be achieved (grade of achievement)
- aggregation to a single parameter

In principle, this concept is similar to use-value-analysis known from literature (e.g. [Beckmann, 1978]) and hence will not be discussed here.

6 CONCLUSION

To reduce the effects on the environment in the construction of bridges the following possibilities are derived:

- The production of important construction materials, used for the erection of bridges (concrete and steel) has got a large share in the sum of environmental

interventions. If the interventions of production were to be reduced, the environmental effects of structures would be less.

- Planning engineers are able to influence the environmental interventions through their choice of materials, structure types and construction works. To achieve this, suitable instruments are necessary, which make the environmental effects of different designs visible and assessable. Kohler [Kohler, 1994] gives some guidelines for buildings, which could also be used for engineering structures.
- Construction works may have large influences on the surroundings. These depend on one hand on the choice of construction works, and on the other hand on the care of the contractors.
- Effects on the environment during usage depend mainly on traffic. The choice of routes could possibly influence these effects, but maintenance also could have similar effects. Here, the design engineer could plan a robust structure (concrete cover etc.) which does not require frequent maintenance.
- Whether the materials or the structural elements are re-usable depend on one hand on the material choice, on the other hand on the possibilities to dismantle the structure at a later date, as well as on the economic questions. The last two things are difficult to foresee.

7 REFERENCES

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