DESIGN OF CONCRETE STRUCTURES – ENVIRONMENTAL ASPECTS

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Optimizing task formulation for concrete structure design is stated.

1. Introduction

There is no doubt that environmental aspects of the concrete industry will be important in the future. This is partly due to direct environmental factors (reduced resources, greenhouse effect, etc.) and partly to economic effects as a consequence of the latter (e.g. increased taxes, increased prices of scarce resources etc.).

The proposal from C3.6 FIB group is based on the argument that the total environmental impact only can be understood correctly. The activities be priority-ranked correctly - if the products and the designed structure are considered over their whole life cycle.

Design of concrete structure with checking of environmental impacts of designed structure could be made on some levels:

- ***Environmental reading.*** An environmental reading is a mapping and a survey of a structure's environmental impacts, i.e. the consumption of

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energy, materials and water and output of solid waste, waste water, and emissions to air. Furthermore, the amounts of produced concrete products are mapped.

- ***Environmental management.*** Environmental management is a systematic and planned effort in a building design with the purpose of reducing environmental impacts in an economically justifiable way. An environmental management system is a total description of how to build, organise, perform, report and follow up on the building's environmental efforts.

- ***Life cycle assessments.*** A life cycle assessment (LCA) is a systematic and quantitative mapping of relevant environmental impacts during the lifetime of a structure. The phases in the life cycle of concrete structure are often defined as:

    - Extraction and processing of raw materials,
    - Concrete production,
    - Construction and re-building/extension of buildings and structures,
    - Operation and maintenance of buildings and structures,
    - Demolition and waste treatment/recycling.

  The first step in an LCA is to perform a life cycle inventory (LCI). The result of an inventory is a list of all environmental impacts in the life cycle. An LCI is the basis of every LCA. Several impact assessment methods can be applied to the same LCI data. Some are bound in scientific models (for instance calculations of greenhouse effects), and others are bound in political decisions (as for instance weighting of different environmental impacts).

- ***Environmental communication.*** Often, the purpose of dealing with environmental aspects is chiefly to show that the design company and/or future owner of built structure are concerned about the environment, secondly to show specific environmental data (for instance the total CO2 emission). This is often for competitive reasons, and can also be necessary in order to show authorities etc. that specific requirements are fulfilled.

2. Design of concrete structures

Design of a construction is a wide set of the architecturally engineering actions. All these actions are interconnected, they influence each other and in result they determine the quality of a realised construction. This complicated action has to combine structural, aesthetical, functional, energetic, economical and environmental aspects. However, the structural requirements (selection of the type of a structure and of the materials) aesthetical (features of a construction, composition into the environment), functional (function, reliability and durability), economical (initial cost, maintenance and repair cost, modernization and regeneration cost) and ecological (ecological load relating to the construction life cycle) are for the most part contradictory. To make the investment effective, it is necessary to adopt the method of optimised design.

It wouldn't be much practical to optimise the initial cost only. Far more appropriate is to minimize the total cost, i.e. the cost referring to the life cycle of a construction. It is possible to take into account the environmental impact of the structure too.

Design of a construction is the problem in which a set of parameters defining it (shape, materials, boundary conditions) is divided into two disjunctive subsets: predefined parameters (they are constant in the course of the design), design variables (they change in the predefined boundaries in the course of the design). The design variables have to meet the restrictive conditions sequent on the physical principle of the solved problem (conditions of equilibrium, reliability, etc.), or on the structural restriction (constructive principles of corresponding standards, spatial restrictions and others). The design propriety is evaluated by the predefined criteria of which the design endeavours in the extreme. These criteria determine a form of the target function (scalar or vector) by which is the design "quality" assessed.

3. Environmental aspects of design of concrete structures

The optimisation problem of the concrete structure “sustainment” may be, e.g. by [9], expressed by the target function:

$$\{f(\{A_s\})\} = f(\min E_{tot}, \min C_{tot}, \max S_{tot}) \,, \qquad (1)$$

where E_{tot} is the gross environmental impact, C_{tot} is the gross cost and S_{tot} is the gross social-cultural quality.

3.1. Environmental impact

The magnitude of the environmental impact of the structure E_{tot} may be expressed

$$E_{tot} = \sum p_i \; E_i \tag{2}$$

where p_i is the probability of incidence of i-th environmental impact E_i. Relation (4) may be explicated as

$$E_{tot} = E_{ini} + E_{oper} + E_m + \sum p_f \, E_{repair} + \sum p_{renov} E_{renov} + E_{demol} + E_{recycl}, \tag{3}$$

where the individual environmental impacts represent: E_{ini} the impact connected with the materials and members production and to the design and realisation of the construction, E_{oper} the impact connected with the operation of the construction, E_m the impact connected with maintenance, E_{repair} the impact connected with the repair of failures, E_{renov} the impact connected with the reconstruction, E_{demol} the impact connected with the demolition, E_{recycl} the impact connected with the recycling and p_f , p_{renov} are the referring probabilities of possible failures origin and reconstructing interventions.

These partial environmental impacts (generally denoted E_i) related to the individual phases of the concrete structure life cycle should include every important environmental impact that correspond to the decisive environmental criteria and are expressed as

$$E_i = \sum w_j \; Q_j \, , \tag{4}$$

where $\{w_j\} = (w_1 \; ... \; w_m)^T$ is the weight vector expressing importance of the individual criteria, $\{Q_j\} = (Q_1 \; ... \; Q_m)^T$ is the vector of embodied values relating to the individual criteria, m is the number of criteria.

3.2. Cost of construction

The quantity cost of construction C_{tot} is expressed as a function expressing the construction cost during its life cycle, i.e.

$$C_{tot} = \sum r_i \; C_i \tag{5}$$

or in the more detailed form as:

$$C_{tot} = C_{ini} + C_{oper} + C_m + \sum r_f \, C_{repair} + \sum r_{renov} C_{renov} + C_{demol} + C_{recycl} \; , \tag{6}$$

where C_{ini} is the construction initial cost (i.e. a sum of the costs of materials, transport, design and construction), C_{oper} is the operating cost, C_m is the maintenance cost, C_{repair} is the repairs cost, E_{renov} is the accidental reconstruction (renovation) cost, C_{demol} is the demolition cost, C_{recycl} is the recycling cost and r_f, r_{renov} are probabilities of the possible failures origin and reconstructing interventions.

3.2. Social and cultural quality

The specification of this function and quantification of the individual criteria represents very soft problem. It is possible that its introducing could lead to the confusion and devaluation of the optimisation results performed on the criteria according to 3.1.1 or 3.1.2, and to 3.2.1, 3.2.2.

Conclusion

The purpose of prepared guidelines in frame of FIB C3 working group is to provide the principles and procedures for designing concrete structures considering environmental aspects. The members of FIB commission C3 hope that prepared guideline will be helpful for standardization bodies and code writers when introducing environmental aspects in their standards and codes.

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