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Design strategies for low embodied carbon and low embodied energy buildings: principles and examples

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Abstract

The paper is based on recent work within IEA EBC Annex 57. It describes building design strategies for reduction of embodied energy and embodied carbon emissions and presents them on five examples of design optimizations of building elements, subsystems and whole buildings. The first example shows environmental optimization of curtain wall façade elements leading to utilization of bio-based materials. The second example present a family house, which has been rebuilt form foundations, whilst some of the original materials were reused in the new structure. The third example presents an optimized subtle structural system made of ultra high performance concrete. The fourth example presents a case study of variant designs of structural system of a residential house in Prague. The last example shows an alternative design of a family passive house in Prague, based on hybrid construction of light prefabricated concrete elements and timber-based external walls.

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1. Introduction

European countries have in the last years significantly improved standards and legislation related to energy performance of new buildings [1]. When studying a life cycle of a building, such move means that environmental

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impacts and resource use of the use stage of a building life cycle (B1-7 according to EN 15978 [2]) becomes less significant, whereas proportion of impacts of product stage and construction process (A1-5) in the life cycle increases [3]. These stages, where energy and carbon emissions are being embodied into buildings, are intensively studied in an ongoing Annex 57 of the International Energy Agency's Energy in Buildings and Communities Programme (hereafter referred as Annex 57). The main objectives of Annex 57 are: i) to collect existing research results concerning embodied energy and carbon dioxide emissions due to building construction, to analyze them and to summarize into the state of the art; ii) to develop guidelines of the methods for evaluating the embodied energy and $CO_{2,eq.}$ emissions due to building construction; and iii) to develop guidelines of the measures to design and construct buildings with less embodied energy and $CO_{2,eq.}$ emissions [4].

This paper focuses on the third objective and describes strategies for reduction of embodied energy (EE) and embodied carbon emissions (EC) and provides examples of design optimizations of building elements, subsystems and whole buildings.

2. Design strategies for reduction of embodied energy and embodied carbon

Subtask 4 of Annex 57 formulated design and construction strategies for reduction of EE and EC through three steps:

- Reduction of amount of needed materials throughout entire life cycle
- Substitution of traditional materials for alternatives with lower environmental impacts
- Reduction of construction stage impact

The strategy of reduction of amount of needed materials is further broken into the five sub-strategies:

- Optimization of layout plan
- Optimization of structural system
- Low-maintenance design
- Flexible and adaptable design
- Components' service life optimization

The strategy of substitution of the traditional materials with alternatives includes the six sub-strategies:

- Reuse of building parts and elements
- Utilization of recycled materials
- Substitution for bio-based and raw materials
- Use of innovative materials with lower environmental impacts
- Design for deconstruction
- Use of recyclable materials

3. Examples of utilization of various design strategies

The presented examples intend to show examples of application of the above-listed strategies on real designs, escalating from building elements (Examples 1 and 2) through load bearing systems (Examples 3 and 4) to whole buildings (Example 5). To achieve the maximum environmental benefits, in most of the examples several design sub-strategies are combined.

3.1. Example 1: Bio-based curtain wall façade elements

In the national Czech research project *Intelligent Buildings* has been developed a new environmentally friendly curtain wall façade system [5][6] by utilization of the design strategies: components' service life optimization;