Parametric modelling to improve sustainability in design

Eloïse Denis, Stef Feyers, Simon Van Gompel
BESIX Engineering Department, Brussels, Belgium

Contact: eloïse.denis@besix.com , stef.feyers@besix.com , simon.vangompel@besix.com

Abstract

Nowadays, a structural design does not only need to be feasible and cost-effective, but it also needs to limit the environmental impact. Environmental regulations are more and more to be considered. This paper presents a workflow in which the complete calculation process is considered as one parametric model. The result obtained is a summary table of the possible design solutions, including the embodied carbon calculated according to a life cycle assessment (LCA). This enables the designer to optimise the sustainability in design. This workflow is then applied to a case study on Schijnpoorttunnel, part of the Oosterweel project.

Keywords: parametric design; sustainability; LCA; embodied carbon; Schijnpoorttunnel

1 Introduction

BESIX Engineering Department adds value to the design of a project using the latest trends in calculation methods, one of which is parametric modelling. This is a design approach where the calculation model is defined as a set of pre-defined rules which describe the correlations between the different elements of a model. By doing so, when one of the input parameters is changed, the complete model will adapt accordingly, including the automated set of calculations performed in different software. This enables the designer to examine different possible solutions and optimise the design according to specific design requirements.

One of the requirements that is becoming increasingly important, is to include sustainability aspects in the design choices. A calculation method that can be used to evaluate the environmental impact of a project throughout its entire life cycle, is a Life Cycle Assessments (LCA). In an LCA, the quantities of the used materials are multiplied by its environmental impact factor.

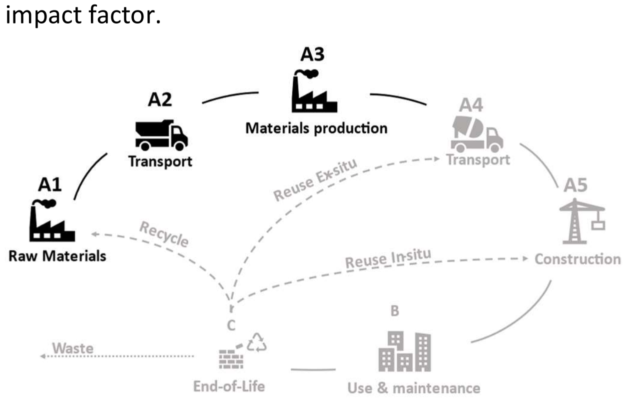

Figure 1-1: Life Cycle Assessment

2 Workflow

In this article, a workflow is presented where the complete calculation process is considered as one parametric model. This workflow is translated into a Grasshopper script, which allows to connect the different steps of a design in an automated manner.

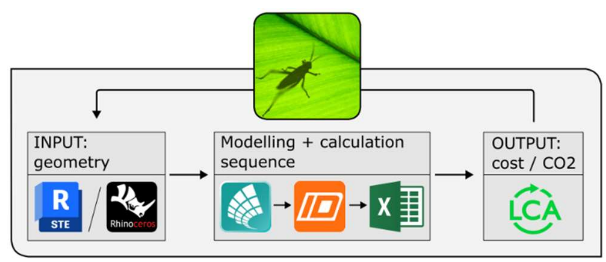

Figure 2-1: Workflow

The first step is to obtain the geometry, either by extracting it from a Revit model or by building it in Rhino. This geometry is then translated into a FEM-model and the additional information, such as loads and supports, is defined. The governing results are extracted and copied to an IDEA Statica file, where different reinforcement layouts are tested. All possible solutions are summarized in Excel and the required quantities are calculated.

These quantities are multiplied by their environmental impact factor and their price factor. The last step is to assess the obtained solutions.

For the sustainability parameter, the focus in this workflow is embodied carbon included in steps A1 to A3 of the LCA. These steps are linked to the material selection and are considered as the most determining one's with reliant information available at the design stage.

3 Case study – Schijnpoorttunnel

3.1 Description of the project

This case study focuses on the post-tensioned roof of Schijnpoorttunnel, a part of the Oosterweel project in Antwerp. Currently, feasibility and sensitivity analysis are ongoing, considering all the geometrical boundary conditions in a dense urban environment.

3.2 Analysis and results

For this analysis, three governing cross-sections CS1 – CS2 – CS3 (as shown in figure 3-1) have been considered. A 1D isolated model of the roof is used to withdraw the internal forces, considering as well geometrically feasible post-tensioning lay-outs. These are checked and then implemented in de template IdeaStatica files.

For every section the following parameters are considered as a variable: concrete thickness, reinforcement configuration, amount and the eccentricity of the post-tensioning strands.

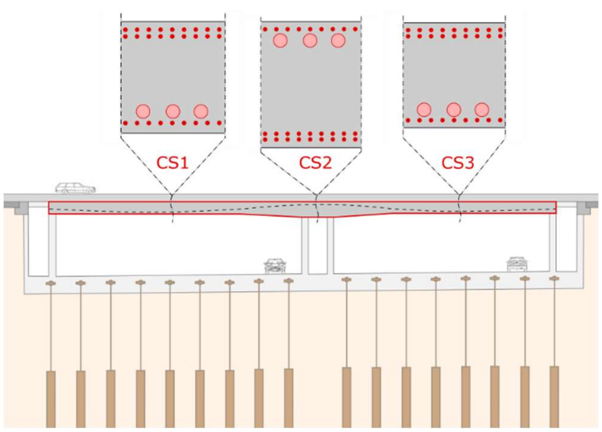

Figure 3-1: Roof of Schijnpoorttunnel

Adopting this workflow leads to an improved understanding of the structure. For example, analysis shows that increasing the eccentricity of the strands allows to reduce the number of strands, but also requires more passive reinforcement (as accidental explosion loads are to be considered). The results of the workflow reveal the relative importance and influence of the different parameters.

The results of the analysis show that it is not possible to have the best option for every investigated section, as the post-tensioning cables need to be installed over the full width of the tunnel. As a result, the number of strands has to be the same in all sections.

In figure 3-2, a graph is shown with the results for cross-section CS1. It gives the amount of CO_2 and the relative increase of the direct construction cost for different configurations. We see that the best options are having a thickness of 1,5 m.

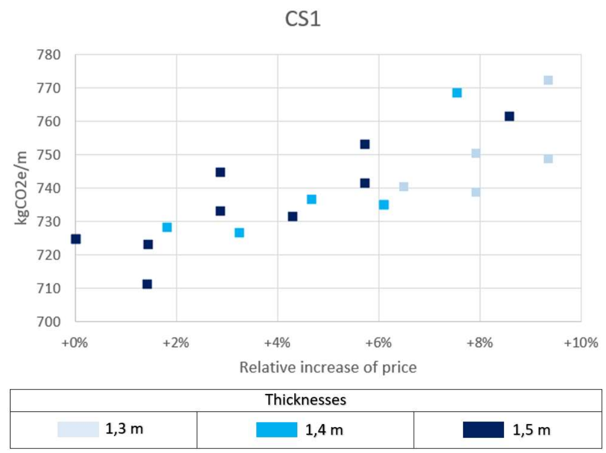

Figure 3-2: Carbon footprint and cost impact for the results of CS1

3.3 Integral design

The presented sensitivity analysis considers only the roof structure of the tunnel, of which each cross-section is analysed separately. This allows to determine the most optimal configuration within the pre-defined set of parameters. However, to obtain the complete design of the tunnel, the design choices should be made integrally, by considering all boundary conditions and requirements into account.

The insights from the sensitivity analysis reveal the governing parameters and their relative influence. This allows the designer to make further design considerations in a well-founded and fundamental manner.

4 Conclusions

The workflow is an innovative manner of incorporating the fundamental steps of a structural design, as well as the new environmental constraints that are slowly emerging via regulations such as the RE2020 (France) and MPG (The Netherlands).

This methodology gives the designer the ability to make well-founded and responsible design choices to optimize the design. It can be implemented for other (sub)structures by adjusting the script of the parametric model with the project specific boundary conditions.

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