Design Optimization of Composite Road Bridges using Genetic Algorithms
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Abstract

Steel bridges today are mostly constructed in traditional carbon steel, with corrosion as a common issue leading to high maintenance costs and a limited service life. This problem can be minimized by using stainless steel as it is less prone to corrode. However, stainless steel is more expensive leading to a higher investment cost. The aim of the thesis is therefore to develop a design optimization program of concrete-steel composite road bridges. The program, written in Python, is based on the Eurocode design procedure and optimized with the use of a genetic algorithm with the option to optimize towards minimum life cycle cost (LCC), environmental impact (LCA) or steel material usage. The life cycle performance tool used is developed in a parallel master's thesis by Nissan and Woldeyohannes (2022).

A case study is conducted where the program is set to redesign an existing bridge with flat web girders of carbon steel S355. The optimization is run for two concepts: girders of carbon steel grade S355 with flat webs and Duplex stainless steel girders with corrugated webs. The main study is on minimizing the life cycle cost, where sub-studies are performed to see how the result is affected by limitations of the web height, the amount of traffic, and the material price. Additionally, the program is run to minimize the environmental impact (CO_2 equivalents) and steel material mass to better understand the design choices of the program.

The results shows that the optimization program reduced the material use with 20 % for the carbon steel concept and with 30 % for stainless steel concept, compared to the original design. The first concept design also gave a life cycle cost reduction of 6 %. Comparing the two concepts with each other, the results showed that when allowing a web height of up to two meters, considering today's steel prices (60 SEK/kg for Duplex steel and 20 SEK/kg for S355), the stainless steel alternative is 9 % more expensive. However, when allowing a web height of up to three meters, the stainless steel alternative is 3 % cheaper. Further, with decreased material prices and increased amount of traffic, the stainless steel alternative could be proven even more competitive.

Lastly, an important conclusion is that the optimizations against mass and minimize life cycle cost gave similar results for the stainless steel alternative, showing it enough to optimize against mass. However, for the carbon steel alternative, where the maintenance aspect is highly important, a life cycle cost optimization is required.

Keywords: Composite Bridge, Corrugated Web, Stainless Steel, Optimization, Genetic Algorithms, Life Cycle cost (LCC), Life Cycle Assessment (LCA)