A low-carbon, funicular concrete floor system: design and engineering of the HiLo floors

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Abstract

This paper reports on the integrated computational design, engineering and construction of the concrete, rib-stiffened funicular floors of the HiLo research & innovation unit, built on the NEST platform in Dübendorf, Switzerland. These floors represent the first application of this innovative technology in a real project. The lightweight structural floors significantly reduce environmental impact and embodied carbon emissions, when compared to common reinforced concrete slabs, both by minimising material needs and by using a large percentage of recycled construction waste, thus additionally contributing to a circular economy in construction.

Keywords: concrete floors; slabs; rib-stiffened funicular floor; compression-only; embodied emissions; global warming potential; sustainable construction.

1 Introduction

Population growth combined with urbanisation will pose huge challenges to construction in the next decades. Most of this construction has historically happened in reinforced concrete, causing tremendous environmental issues, particularly towards global warming, due to the large greenhouse-gas emissions of cement and steel, but also accelerating the depletion of natural resources and virgin materials. Considering that for medium high-rises of ten to twenty floors, an average of 40% of the building mass is in the floors, this structural element is thus one of the most significant carbon emitters [1]. With billions of floors expected to be built by 2060 [2], this research developed an alternative, sustainable structural slab solution in concrete and implemented it for the first time in a real-scale office building.

This paper is structured as follows. In the first part of this section, a brief overview of the funicular floor system is provided, along with the main references for an in-depth review. Following, the HiLo unit and its two funicular floors are introduced. In Section 2, the design process is presented, from the form finding to the structural analyses. Section 3 shows the fabrication and construction of the floors. A comparison with more traditional structural floor systems is offered in Section 4. Finally, Section 0 presents a summary of the research and provides future outlooks.

1.1 Funicular floors background

Inspired by vaulted masonry structures, specifically those resulting from the tile-vaulting technique of Rafael Guastavino [3], the *funicular floor* is a structural slab system studied by the Block Research Group (BRG) since 2010. By using the principles of *strength through geometry* and *material effectiveness*, this system is able to reduce material and mass, promote the use of more sustainable materials, and improve longevity and circularity [4].

In a funicular floor the loads are transferred to the supports through arch action: a thin vault is

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