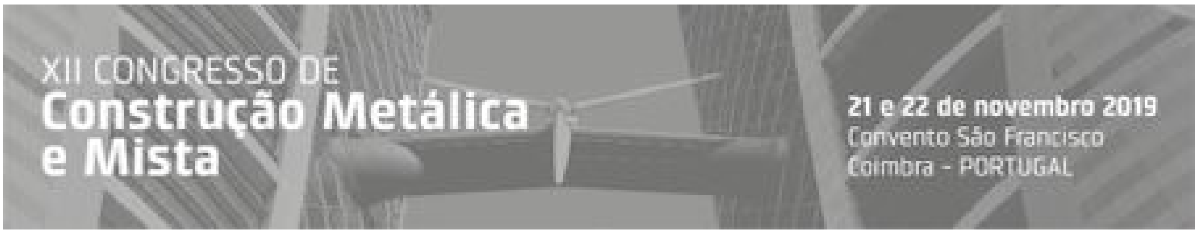

INCREASING SUSTAINABILITY WITH SLIM FLOOR STRUCTURES

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Abstract: Slim floor structures greatly increase the sustainability. Height of the buildings will be lower, while commercially available connections can help to design structures that can be dismantled later for re-use. Choosing products that utilise recycled raw materials and building methods that accommodate low emission materials such as wood will result in even lower CO_2 emissions.

1. Introduction

The building industry is responsible for 40% of total energy use and 30% of the global amount of waste. The concrete business accounts a large proportion of this.

Using slim floor structures can lower the environmental impact of building business and concrete in particular. In this paper, four ways to achieve this are presented along with recent case studies and new, innovative products.

2. Height of the building

By reducing the height of the building while keeping the amount of floors, significant savings can be done in terms of both ecology and economy.

In a 6 storey example (Fig. 1), the height of the building is 27,87 meters with conventional structure. The same building designed with a slim floor structure is 25,43 meters, translating into 2,44 meters lower height and 50,000 m^3 lower volume. Less cladding and lower columns, walls, elevator and stair shafts, pipes and ducts all translate into savings and a more sustainable structure. As the building envelope is smaller, heating and cooling needs are lower during the whole lifespan of the building.

A slim floor structure can also save man hours significantly, as the HVAC installation is easier with a ceiling with no obstructions.

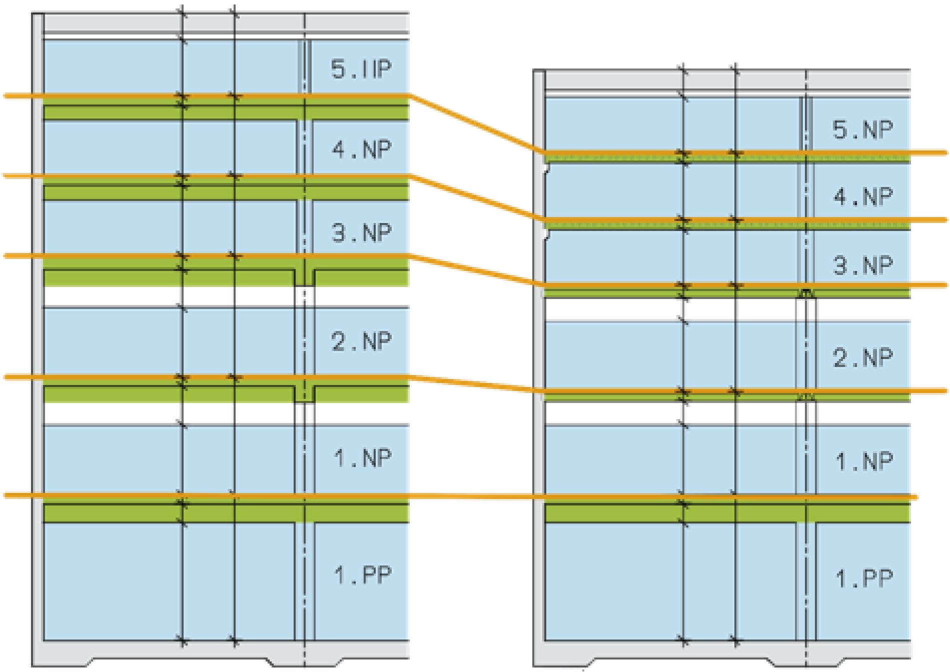

Fig. 1 Height and building envelope difference between a slim floor structure and conventional structure

2.1. Reduction of height and 500 truck deliveries

Capella is a new seven-story biosciences laboratory at Cambridge University, UK built at the Addenbrookes Hospital site.

The project brief had a very high demand for a very low response factor – floor vibration. Normally this would have been achieved by building an extremely rigid cast-in-situ concrete structure.

For this project the initial designs resulted in a 700 mm (28 in) overall floor depth. However, it was quickly realized that a fully cast-in-situ solution had significant difficulties due to a shortage of local ready-mixed concrete supply, the number of construction workers, and the amount of construction plant required. The large number of vehicle deliveries as well as the overall program would have caused serious disruption and noise to the already congested hospital area.

The main contractor wanted to consider options to find a solution that would result in a faster build program and reduced on-site activities, create less need for in-situ concrete works, and be more eco-friendly.

Initial calculations were carried out with various combinations of DELTABEAM®s, hollow-core slabs, and topping depths. The calculations indicated that it was possible to find a structural solution that meets the stringent vibration specification requirements and gives the required construction advantages.

Finally, a detailed FEM analysis revealed that the required low response factors would be achieved with D32-500 DELTABEAM®s, 300 mm (12 in) deep hollow-core slabs, and 200 mm (8 in) of structural concrete topping. The end result was a hybrid frame, which combined the benefits of both precast and cast-in-situ techniques.

The use of DELTABEAM® facilitated a 200 mm slimmer floor compared to in-situ casted floor (Fig. 2).

According to the main contractor's estimation, the offsite engineered hybrid solution reduced over 500 truck deliveries to the site and the dead weight of the building was more than 3,000 tons (3,307 US t) lower compared to the original in-situ frame solution.

The onsite construction program was 20 weeks faster and saved over 2,500 man weeks in comparison with the envisaged in-situ solution.

Additionally, the overall carbon footprint was significantly reduced with fewer truck deliveries and high-quality offsite production of the steel DELTABEAM® and precast concrete units.

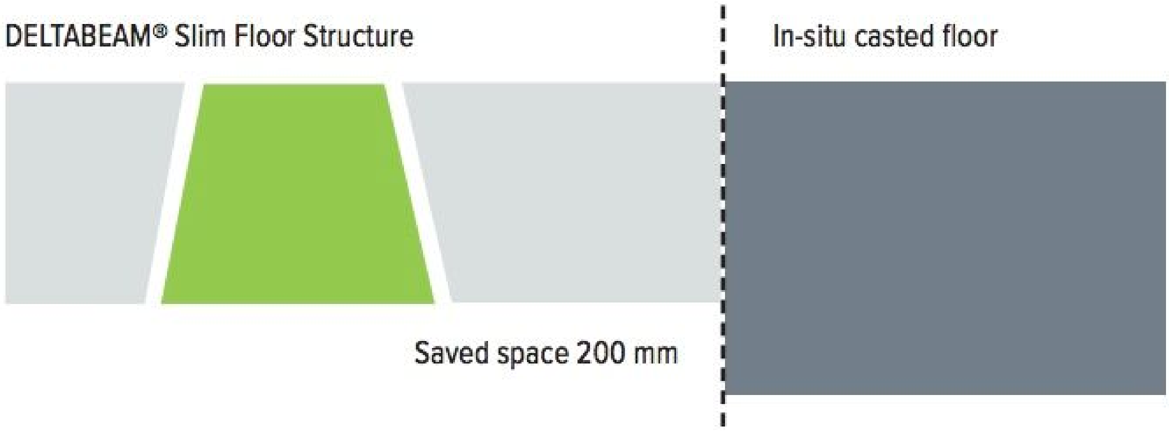

Fig. 2 The overall slab thickness was reduced by 200 mm and the dead weight of the building was more than 3,000 tons (3,307 US t) lower compared to the original in-situ frame solution.

3. Adaptation of circular economy principles in construction

The current economy is based on "take, make, waste" model of production. It is a concept where precious and finite raw materials are claimed and made into products. At the end of their use, they are disposed of as waste. In this economy, all materials will at some point end up with little or no value. This is inherently unsustainable.

A circular economy is a closed-loop resource system in which there is no waste – all materials are conserved and are in some way used as inputs for new production. This can be achieved by designing, maintaining, reusing, remanufacturing, refurbishing, and recycling products with appropriate care and thought.

In order to do this, design for disassembly is an important tool. The basic idea is to design each product so it can easily be stripped down to individual components or material fractions, making it easier to reuse either the component in similar products or materials in a new product. This ensures that value and resources are always maintained and kept away from landfills.

Unlike in the traditional linear economy, in circular economy the amounts of renewable and reused non-renewable resources are maximized, thus further minimizing the use of natural resources and negative environmental effects.

3.1 DELTABEAM® and dismountable connections made buildings circular

Dismounting and re-using precast buildings had sounded more or less theoretical, until a large-scale test bed for a new kind of a sustainable and circular city was built in Buiksloterham – an old industrial neighborhood in Amsterdam.

The larger of the two residential buildings has four floors with eight apartments, while the other comprises of three townhouse apartments. The buildings are connected by a roof garden above a shared parking garage.

In order to create a dismountable precast frame, choosing the right kind of connections for the elements was crucial.

Structural designers suggested a full set of Peikko precast connections to go with DELTABEAM® Composite Beams. In the finished buildings, these mechanical connections ensure that the buildings can be easily dismantled when the time comes (Fig.4 & Fig. 5).

Fig. 3 The wall connections installed

As normal grouting would make dismounting next to impossible, rockwool and non-shrink mortar were used for protecting the connections from fire. When re-cycling the buildings, thin layers of mortar can be removed to get access to the bolts. After that, it's an easy job to unbolt the connections to separate beams and columns (Fig. 5).

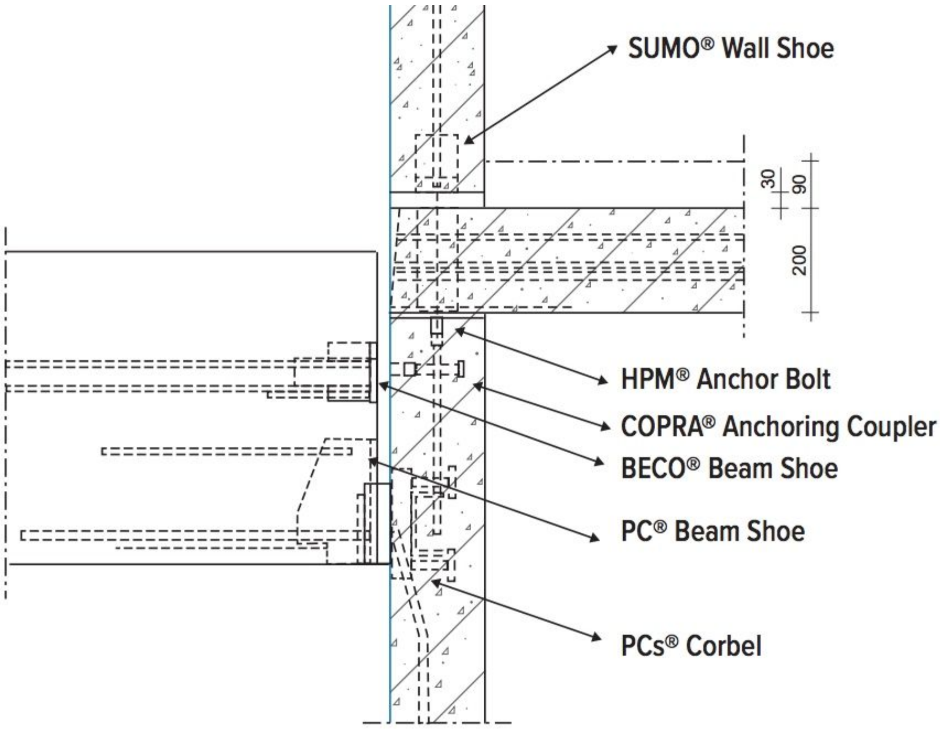

Fig. 4 The wall and beam connections designed for disassembly

Fig. 5 The rebars connecting the floor slabs through the web holes can be disconnected later on, and then the DELTABEAM® will function as a concrete beam.

4. The origin of steel used in frame components

Optimizing material usage is a step to the closed-loop economy.

In composite frame manufacturing it is a question of lowering the amount of virgin steel material used. The best case scenario is that at the end of their life cycle, all materials would be separated and reinserted into the circular process as raw materials.

Steps missing from the complete circular building model are steel and concrete separation and the ability to insert reused steel and concrete in large scale production (Fig. 7).

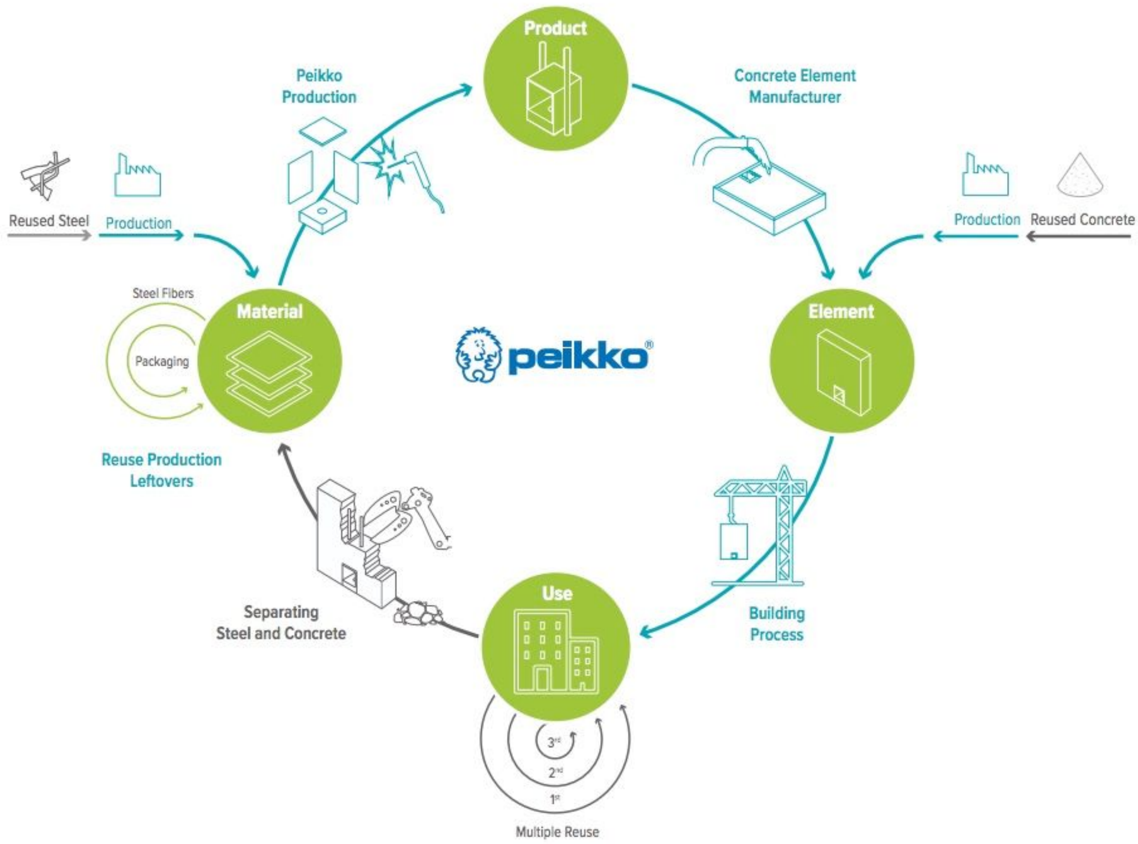

Fig. 6 A complete circular model

4.1 DELTABEAM® amount of used recycled steel

In order to lighten the environmental footprint, Peikko has taken steps to increase the use of recycled steel in DELTABEAM® slim floor structures not only by optimizing design with composite action. This will also help to achieve LEED and BREAM certificates in the future.

Table 1. DELTABEAM® benefits and future development

BENEFITS	DELTABEAM®	
Usage of recycled steel / CE		x
Minimised use of steel	x	x
Sustainability with prefabrication	x	x
Faster speed of construction	x	x
Better space utilisation with flexible open spaces	x	x
Long spans	x	x
Integrated fire-proofing	x	x
Expanded life span of the building	x	x

5. The type of slab matters

A slim floor structure is inherently sustainable as it uses less concrete and steel when compared to cast-in-situ solutions. But even lower environmental footprint can be achieved by choosing environmental slab solutions (Fig. 7).

Fig.7 DELTABEAM® mates with any kind of slab, including wood and wood composite.

5.1. Lasting quality and sustainability called for a hybrid structure

Legero united is an Austrian shoe manufacturer with a strong emphasis on quality and sustainability. That's why architects Dietrich/Untertrifaller decided to use DELTABEAM® in their new headquarters in Feldkirchen, Austria (Fig. 8).

In addition to the frame consisting of DELTABEAM®, wood composite slabs and columns, recycled concrete is used wherever possible. Also the insulators are made of sustainable materials such as wood fibers, hemp, linen and wool.

Fig. 8 According to architects, the wooden structure is aesthetic, economical and sustain-able.Client: legero united campus GmbH, Architecture: Dietrich | Untertrifaller

6. Conclusions

The main conclusions are:

1. Using slim floor structures can significantly lower the environmental impact of concrete buildings.
2. Commercially available solutions can be used to build according to circular economy principles.
3. Using recycled steel is structural components is an effective way to lower CO_2 emissions further.
4. Tried and true precast building methods can be used in combination with low emission materials such as wood.