Floor systems - key elements for sustainable multi-storey buildings

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Summary

In the design of floor systems a wide range of various aspects of sustainability have to be taken into account in parallel. The present report analyses selected floor systems regarding these criteria and outlines new developments for improving the sustainability of floor systems. The mechanical properties are enhanced by using composite effects or pre-stressing. These solutions have to be combined with the integration of a piping system to create thermo-active building components for energy efficient heating and cooling, acting mainly via the ceiling. For flexible installations openable cavities (access mainly from the floor) are needed. The integrated approach of these systems requires a high degree of prefabrication.

Keywords: floor systems, sustainability, multi-storey buildings, DGNB

1. Introduction

In the design of floor systems a wide range of various aspects of sustainability have to be taken into account in parallel: A flexible building use asks for long spans with minimized number of columns or massive walls, for low-exergy heating and cooling systems the large surface is beneficial, the mass of the slabs is the only relevant thermal inertia in modern office buildings. Additionally, acoustic aspects have to be considered, the floor system should provide a flexible routing to cover future demands concerning building services and IT and the quality and the quantity of the used materials referring the environmental impact (eco-balance) is of interest, too.

The multiple impacts on the sustainability assessment of the flooring systems will be shown exemplary based on the german DGNB system to point out the advantages and disadvantages of the different solutions in this context.

2. Floor systems and sustainability

2.1 Relevant sustainability criteria for floor systems

The definition of what “sustainability” is, has become more precise and more common during the last few years. Sustainability covers the three areas “ecology”, “economy” and “social/functional”. The existing sustainability assessment methods are based on criteria lists, which ask for details for describing the main areas.

Floors are important in this context because they are responsible for about 60 to 80 % of the building mass. According to the german DGNB-label, floor systems are involved in 20 criteria of 34 criteria in total; due to different weighting factors they influences 56 % of the overall result [1].

The following criteria are of particular interest within this context:

Ecology:

- Eco-balance (production, use-phase, end of life)

Economy
- Life-cycle costs
- Flexibility in use

Social / functional
- Thermal comfort (impact by thermal inertia)
- acoustics

2.2 Developments for improving sustainability of floor systems

Improving sustainability of buildings is in general a task for the whole building design and not for a single element. Nevertheless, key elements for a whole building like floor systems have an substantial impact on the sustainability, therefore it is valuable to look at these elements in detail.

Combining several aims in one technical solution offers good opportunities on this way. Two examples illustrate this way of thinking:

a) Composite decks with profiled steel sheets
Composite decks based on profiled steel sheets combine the following effects (beneath others): The use of profiled steel sheets reduces the mass of concrete, depending on the shape of the steel sheet (Fig. 1). Furthermore, longer spans can be realised and a third benefit is given by the fact, that the effective thermal inertia is higher due to the enlarged surface. This leads to better thermal behaviour, in particular in the summer case. Advantages in the three main areas of sustainability can be ascertained.

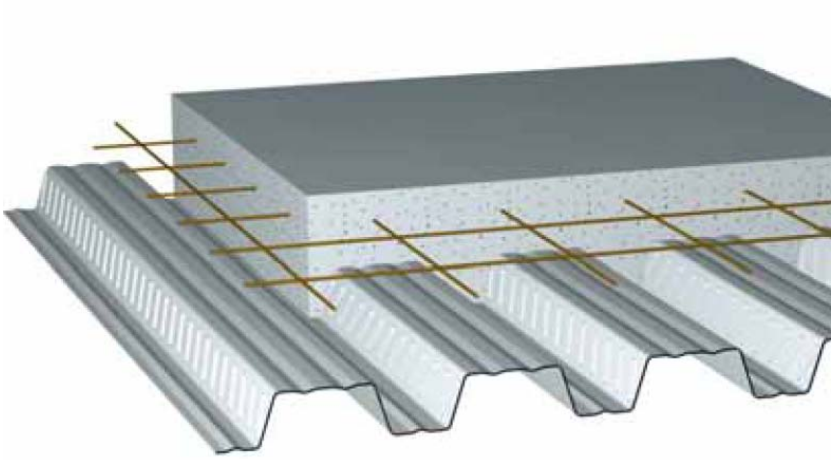

Fig. 1 Composite deck [2]

The effective thermal inertia was studied in detail for various profiles available on the market (Fig. 2 – Fig. 4). For these deck systems the effective thermal inertia was determined based on an FEM-simulation and compered with the results of a conventional flat concrete slab. The simulation uses a sinusoidal temperature curve in the room below the deck element (T_{min} = 18 °C, T_{max} = 26 °C=. The heat, that is stored in the deck element in a quasi-stationary state (after 10 periods), was determined.

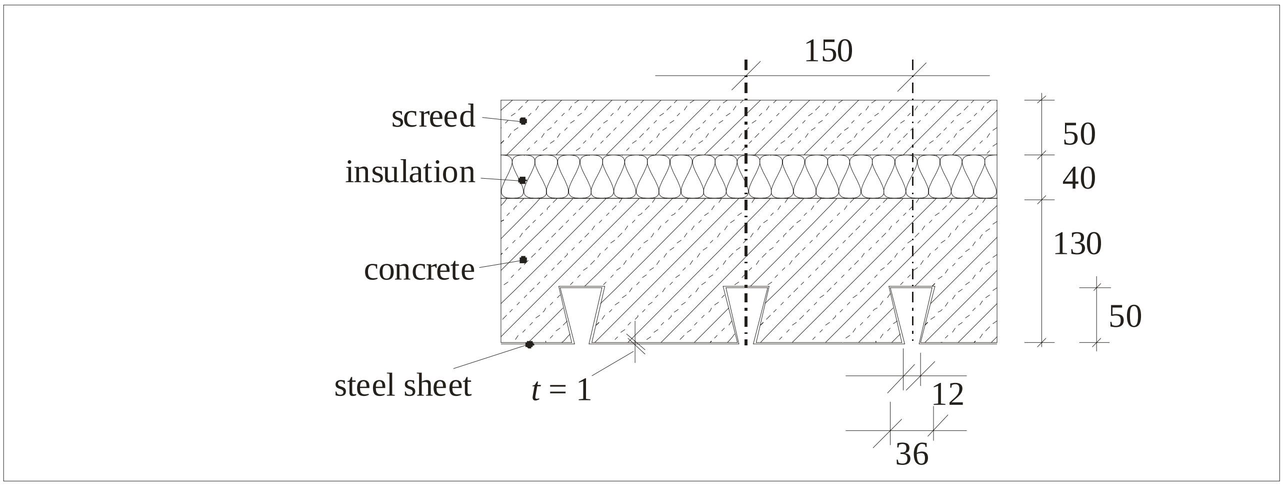

Fig. 2 Holorib deck [3]

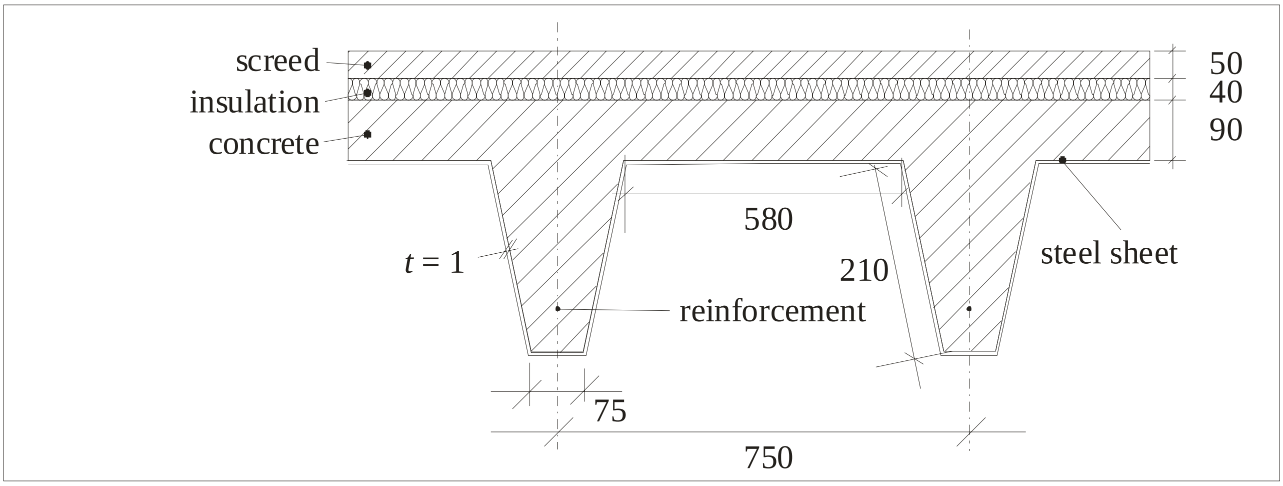

Fig. 3 Hoesch additiv deck [4]

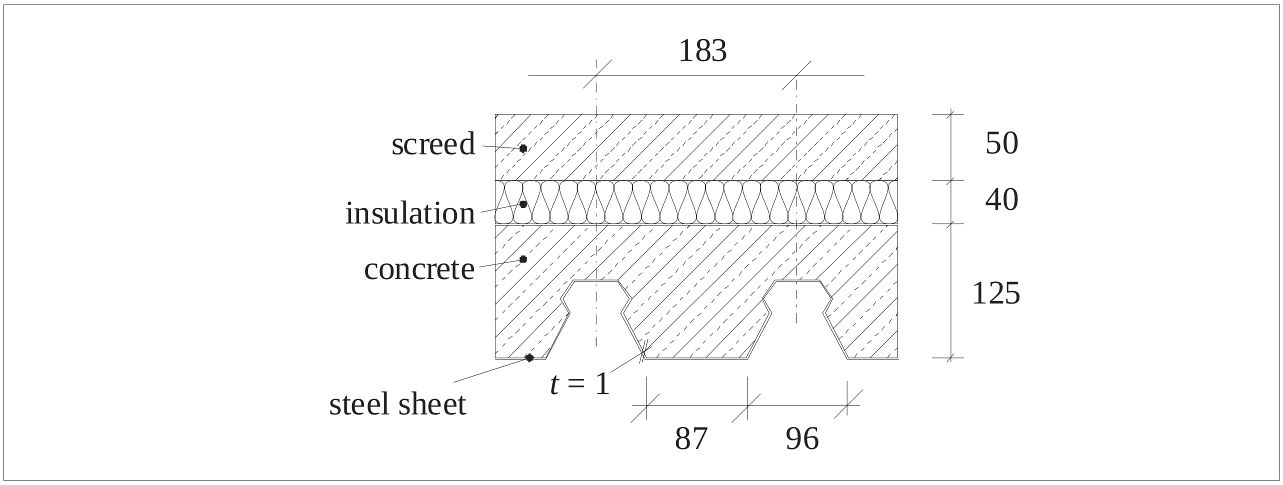

Fig. 4 ArcelorMittal Cofrastra deck [2]

Fig. 5 compares the maximum heat flux q_{max} into the different composite deck systems (and for comparison: a massive concrete deck of 10 cm, at which there is no remarkable difference in the thermal behaviour between 10 cm and 20 cm, e.g.). Additionally, the total heat per m² (q_k) is shown.

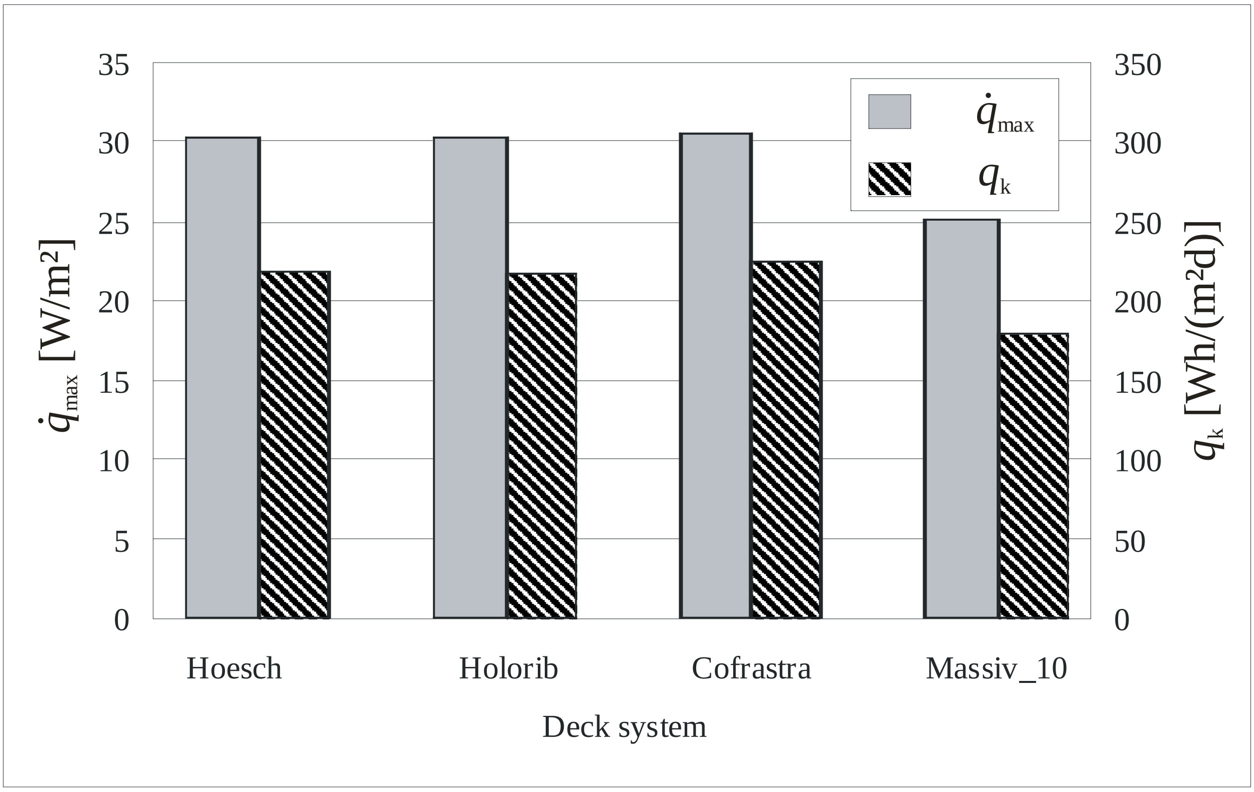

Fig. 5 Comparison of thermal performance – composite decks and massive concrete slab

This diagram shows, that the effective thermal inertia is about 20 % higher for the profiled composite decks. The load bearing capabilities of these floor systems are considerable higher, thus a positive effect on the whole building assessment can be expected [5].

b) Thermo-active pre-stressed hollow core slabs

Pre-stressed hollow core slabs have large spans and reduced mass. Pre-stressing leads to a higher utilization of the capabilities of concrete. The combination with thermal activation by an integrated pipe system gives added value: The deck element becomes an energy efficient an low cost heating and cooling system.

Fig. 6 Fabrication of thermo-active concrete slab (on site)

Fig. 7 Fabrication of thermo-active hollow-core slab (in shop)

Fig. 7 shows the fabrication of thermo-active pre-stressed elements in shop. Numerical investigations (Fig. 8) and practical testing (Fig. 9) of these elements verified, that the thermal performance of these elements is positive: the thermal intertia is sufficient for typical use of office buildings, the thermal resistance from the pipe to the surface and the equability of surface temperature are sufficient for an energy efficient use of these elements.

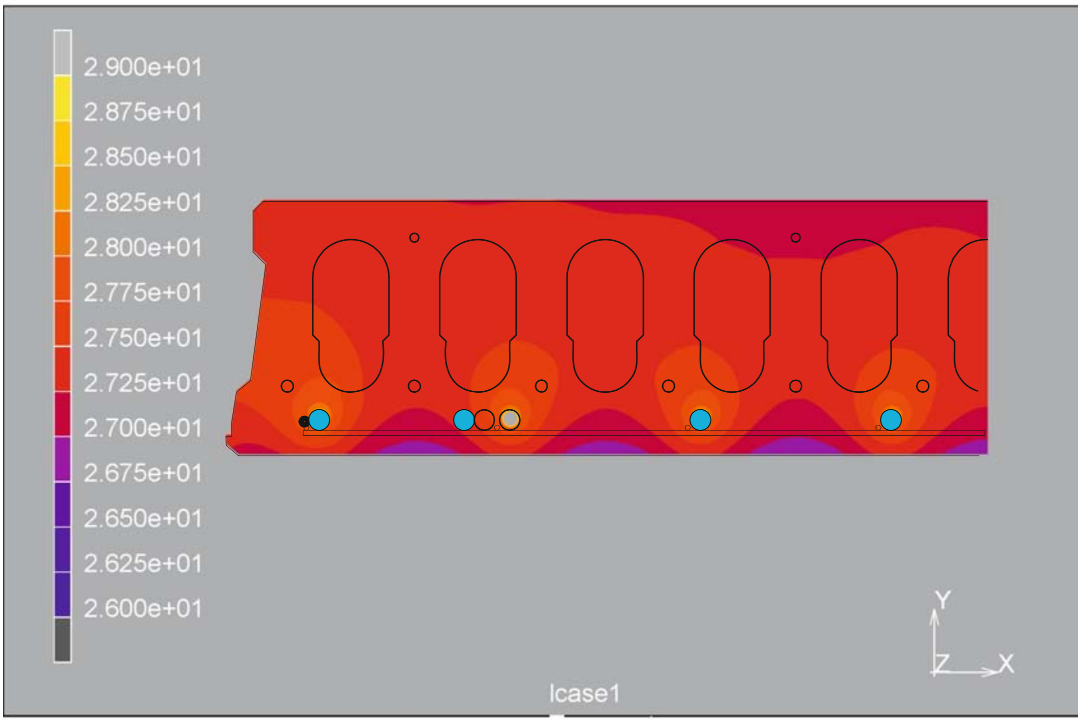

Fig. 8 Thermal performance of thermo-active hollow core slab (FEM-result)

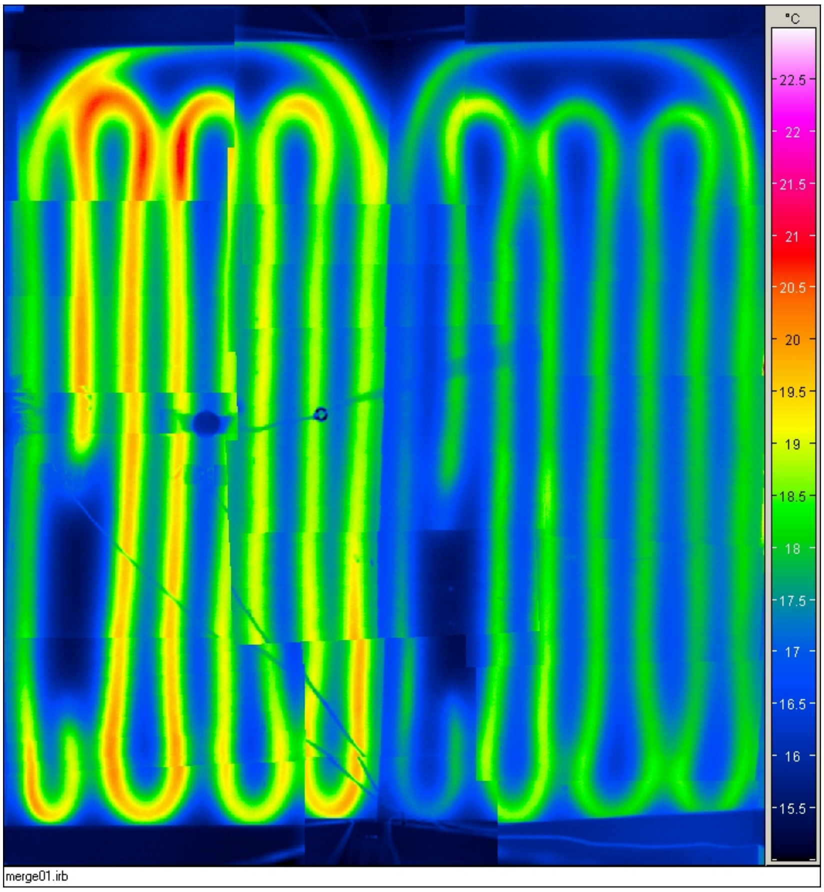

Fig. 9 Infra-red survey of thermo-active hollow core slabs in test rig.

Finally, also for this floor system advantages in the three main areas of sustainability can be ascertained: Improvement of span and load bearing capabilities, reduced need of natural resources and positive impact on the energy efficiency.

3. Discussion

Perhaps it is not directly obvious, that floor systems have a significant impact on the sustainability assessment of a building, but it can be shown that floor systems are relevant for a wide range of sustainability criteria.
Remarkable progress is possible, if improved performance in different areas can be realized in parallel. The two examples combine larger spans with reduced need of material and a positive effect concerning thermal and energetic behaviour.

4. References

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