Ecological and economic potentials of point-supported flat slabs in concrete construction

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ABSTRACT: This master thesis provides insights into the sustainable use of different concrete strength classes for point supported flat slabs in concrete construction. One possible variant is to apply massive component cross-sections and use a concrete grade of lower strength class. While this means that a larger amount of concrete is used, it still causes less economical costs per cubic meter and additionally has a smaller environmental footprint compared to concrete with higher-strength classes for the same quantity. The counterpart to this is the use of very slender components with a high-strength concrete. The central research question of this master's thesis is to determine which one of the two design options is more attractive in terms of ecology and economy.

KEYWORDS: TIM, BIM, Project Management, Construction Management

1 Introduction

The current situation of rising global warming not only represents a major new challenge for the entire world population, but at the same time demands rapid and active action by all sectors of economy and life. The global goals of climate neutrality by 2050 call for a significant reduction in climate-damaging greenhouse gases [1]. The construction sector is responsible for a significant share of global energy related carbon dioxide emissions and makes a major contribution to global warming [2]. Therefore, the construction industry is challenged to deal with the issue of sustainability, to rethink existing manufacturing processes and to use existing building materials in a resource-saving way.

2 Application to the ATP project

The fundamentals for the investigations in this master's thesis are the documents of an integral project by ATP-Innsbruck. This is a building construction project consisting of two underground parking levels in the basement, a 6-storey base building with predominantly office use and a 10-storey residential tower with a final technical floor. The construction is executed as a skeleton structure in concrete. The floor plan is based on the usual grid dimensions of 8.10 m x 8.10 m used in office buildings. In these grid points, the flat slab is hinged by square concrete supports. The total area of the ceiling is approx. 2575 m². For the investigations, one storey is considered as an independent ceiling. Fig. 2-1 shows the modelling in the finite element method program RFEM.

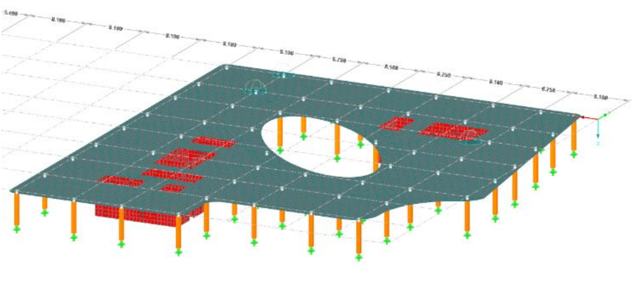

Figure 2-1: Modelling

2.1 Ecological and economic assessment

The assessment of ecological sustainability is derived from the life cycle assessment. The basis for the calculations of carbon dioxide emissions refers to the "Ökobaudat" database provided by the German Federal Ministry of Housing, Urban Development and Construction. The equivalent carbon dioxide values of the global warming potential (GWP) are used for this purpose. Fig. 2-2 shows the life cycle stages according to ÖNORM EN 15978. For the comparison of variants, the life cycle stages A1 to A5 are considered. In the stages of use (B1-7) and disposal (C1-4), equal wear and tear, renovation measures and recycling costs are assumed for all variants and are therefore not included in the analysis.

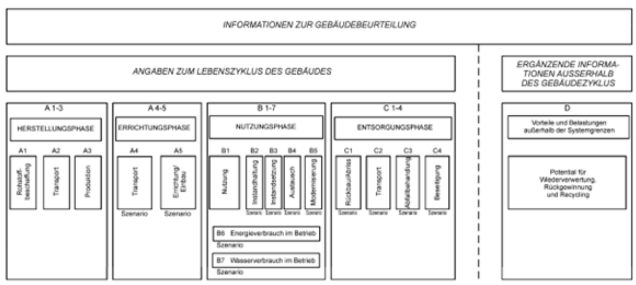

Figure 2-2: life cycle stages [3, S. 23]

For the analysis of the economic aspects, the relevant factors are considered. It should be noted that this is not a complete detailed calculation. The cost comparisons are based on assumptions of characteristic values from the service items of similar reference projects and on the comparison of the current list prices of the suppliers. For the construction of the concrete floors, the cost factors from Fig. 2-3 are considered in principle. Due to the equality of the floor plans, there are no differences for the formwork surfaces and therefore no costs are recorded.

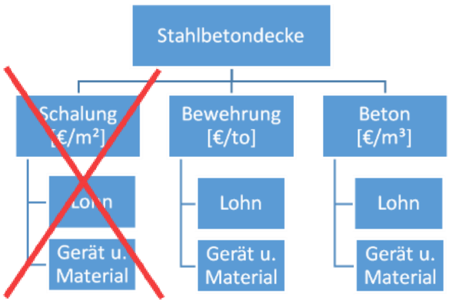

Figure 2-3: calulation overview concrete slabs

3 Results

The course of greenhouse gas emissions shows a global increase over the compressive strength classes of the concrete. Referenced to the planned variant (slab thickness 30 cm; concrete grade C40/50), the concrete slab with a lower concrete strength (C30/37) can be realised with approx. 10% lower emissions. With an increase to C50/60, the emissions increase by approx. 10%. The equivalent carbon dioxide emissions of all variants of strength class C30/37 are below the lowest value of strength class C40/50. The same conclusion is reached by comparing the results of the concrete grade C40/50 with C50/60, showing a gradual increase of the values outside the same strength classes.

The comparison of the economic aspects shows with an average deviation of 2-4% smaller differences than the ecological. comparison. A gradual increase over the concrete strength classes is also recognisable here (except for the variants 2.0 and 2.1). These two variants show that laying the elevated reinforcement areas in approx. 50% of the edge fields is associated with lower emissions, but with higher costs. This means that reinforcement levels up to 170 kg/m³ in the edge areas are not problematic in terms of costs and GWP. The driving factor is therefore the strength class of the concrete.

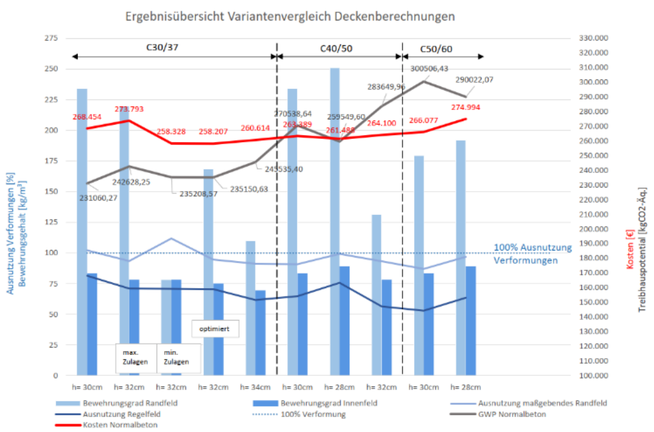

Figure 4: Overview of variant comparision

4 Conclusion

The decisive factor in dimensioning the parameters of the slabs is compliance with the differential deformations in the centre of the field of the border areas. The amount of reinforcement bars required from the bending design does not change with a variation of the slab thickness to a significant extent.

Therefore ∅10/15 is a reasonable reinforcement specification for the edge fields in all variants. However, the limit values of the deformations cannot be complied within certain areas. An increase of the reinforcement bars reduces the occurring deformations in these areas. In conclusion the results show that independent of the slab thickness and the amount of reinforcement bars, the sum of the equivalent carbon dioxide emissions increases significantly with an increase of the concrete quality.

In addition, about 80% of the greenhouse potential of the floor slab is attributable to the concrete and the steel has little influence on the equivalent carbon dioxide emissions. The driving factor is therefore the strength class of the concrete. The variant differences regarding the economic aspects are with an average deviation of 2% lower than the planned design variant. Reinforcement levels up to 170kg/m³ in the edge areas of the slab are therefore unproblematic in terms of costs and GWP.

5 Outlook

In summary, the progressive standardisation and further development of the current carbon dioxide-reduced concrete contributes significantly to the reduction of the greenhouse gases. The more these emissions can be reduced, the greater the relevance of the steel quantities for the GWP consideration for point-supported flat slabs.

The economic studies are based on assumptions of current market prices in 2023. Especially steel prices have subjected to very strong fluctuations in recent years due to the pandemic and the state of war in Eastern Europe. In addition, politics and its groundbreaking decisions with regard to the 2050 climate targets lead to a significant influence on the market. An analysis at a later point in time may deliver different results due to changed boundary conditions.

6 References

[1] *Paris Agreement*, 2015.

[2] United Nations Environment Programme, *2022 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector.*

[3] *Nachhaltigkeit von Bauwerken — Bewertung der umweltbezogenen Qualität von Gebäuden — Berechnungsmethode*, 15978, Austrian Standards Institute, Okt. 2012.