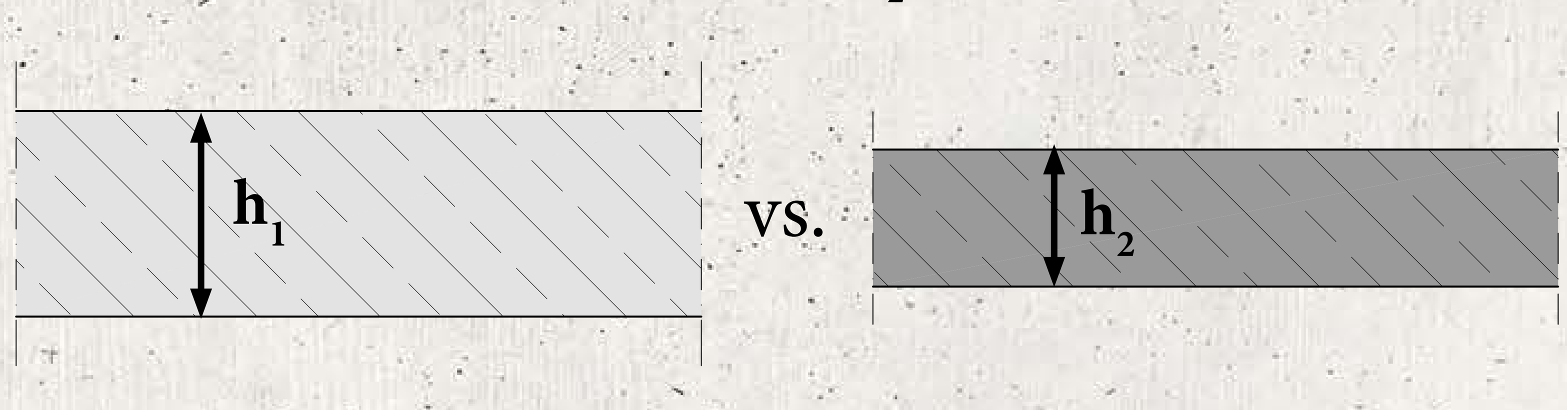
ECOLOGICAL AND ECONOMIC POTENTIALS

OF POINT SUPPORTED FLAT SLABS IN CONCRETE CONSTRUCTION

RESEARCH QUESTION:

This master thesis provides insights into the sustainable use of different concrete strength classes in concrete construction and leads to the follwing research question: How should point supported flat slabs be designed in order to minimise costs from both an ecological and economic point of view? Is it better to apply massive component cross-sections and use a concrete grade of lower strength class? This means that more concrete is used, but it causes less economical costs per cubic meter and has a smaller environmental footprint than concrete with higher-strength classes for the same quantity. Or is the use of slender components with a high-strength concrete the better option. And how does a CO_2-reduced concrete effect the results?



GWP | concrete standard (acc. to „Ökobaudat")

[kg CO_2e/m^3]	A1	A2	A3	A4	A5	TOTAL A
Concrete strength	Raw material supply	Transport	Manu-factoring	Transport	Construction-installation process	GWP (A1-A5)
C30/37	219			4,5	1,08	224,58
C35/45	244			9,1	1,08	254,18
C40/50	265			19,1	1,08	285,18
C45/50	286			29,1	1,08	316,18
C50/60	300			28,8	1,08	329,88

-23,3%

GWP | concrete CO_2-reduced

C30/37	166,2			3,34	2,66	172,20

economic costs | concrete standard

Concrete strength	wages [€/m³]	Material & equipment [€/m³]	total [€/m³]
C30/37	15,25	154,87	170,12
C40/50	15,25	169,87	185,12
C50/60	15,25	194,87	210,12

+5%

economic costs | concrete CO_2- reduced

C30/37	15,25	163,27	178,52

APPLIED PROJECT

The fundamentals for the investigations in this master's thesis are the documents of an integral project by an architects' and engineering office operating in Europe. 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 8.10m x 8.10m 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. 1 shows the modelling in the finite element method program. RFEM.

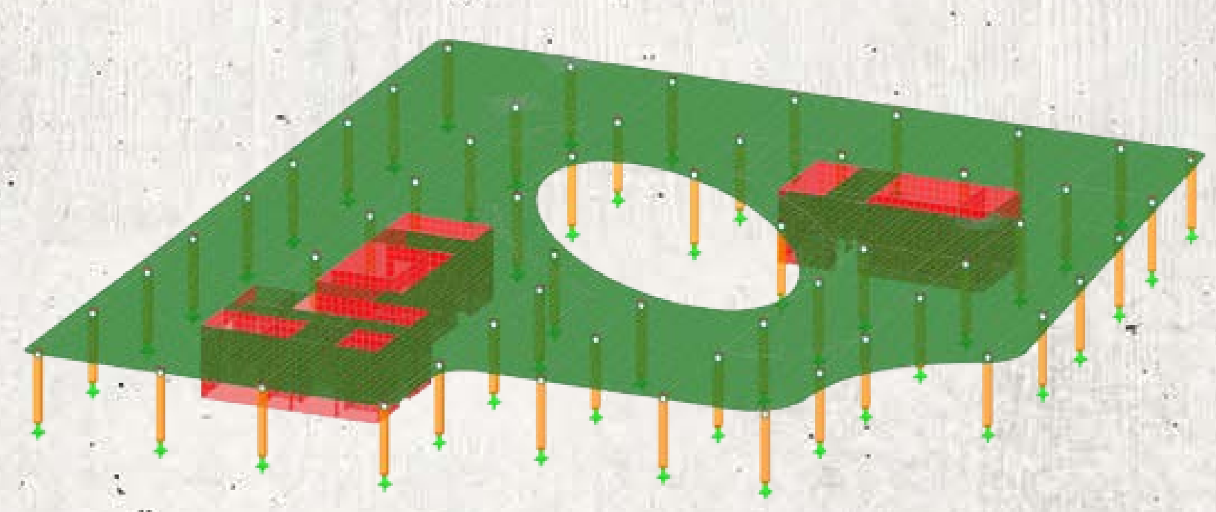


Figure 1: static model

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" data base 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 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.

The economic 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. In principle cost factors of concrete and reinforcment steel are considered. Due to the equality of the floor plans, there are no differences for the formwork surfaces and therefore no costs are recorded for this service item.

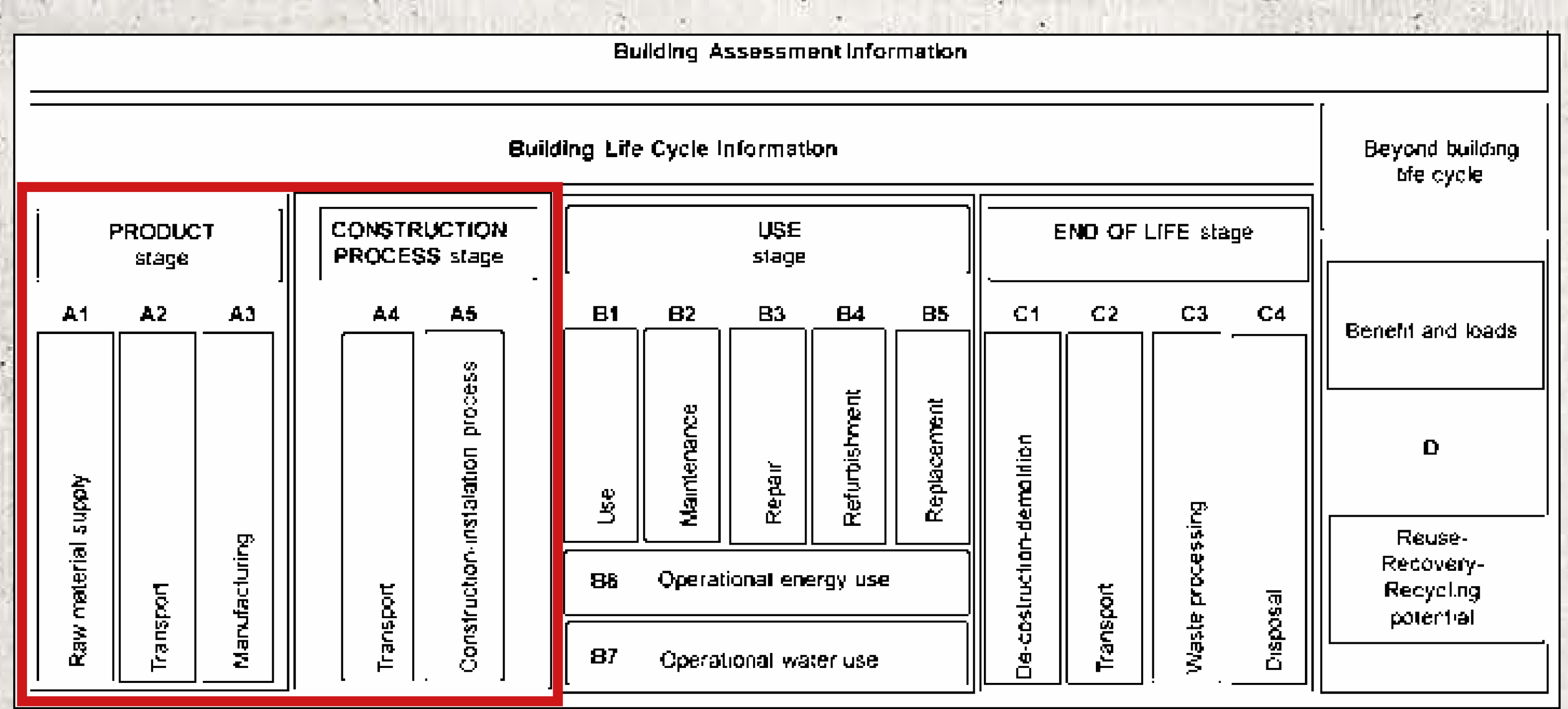


Figure 2: life cycle stages [1]

CHALLENGES / DIFFICULTIES

A key factor in the dimensioning of concrete floors is the proof of deformations. One aim is to prevent neighbouring components from being damaged by deformations, which are occuring during the period of use. According to EC2, the difference between the final deformation ($t=\infty$; incl. creep and shrinkage) and the deformation after completion of the construction phase ($t=0$) must be limited to 1/500 of the span. As the interior construction is predominantly made of glass and drywall elements, it is therefore advisable to adhere to these limit values. As can be seen in Figure 3, the edge fields are the decisive areas. The size of the deformations can be controlled with the parameters of ceiling thickness, amount of reinforcement and concrete strength.

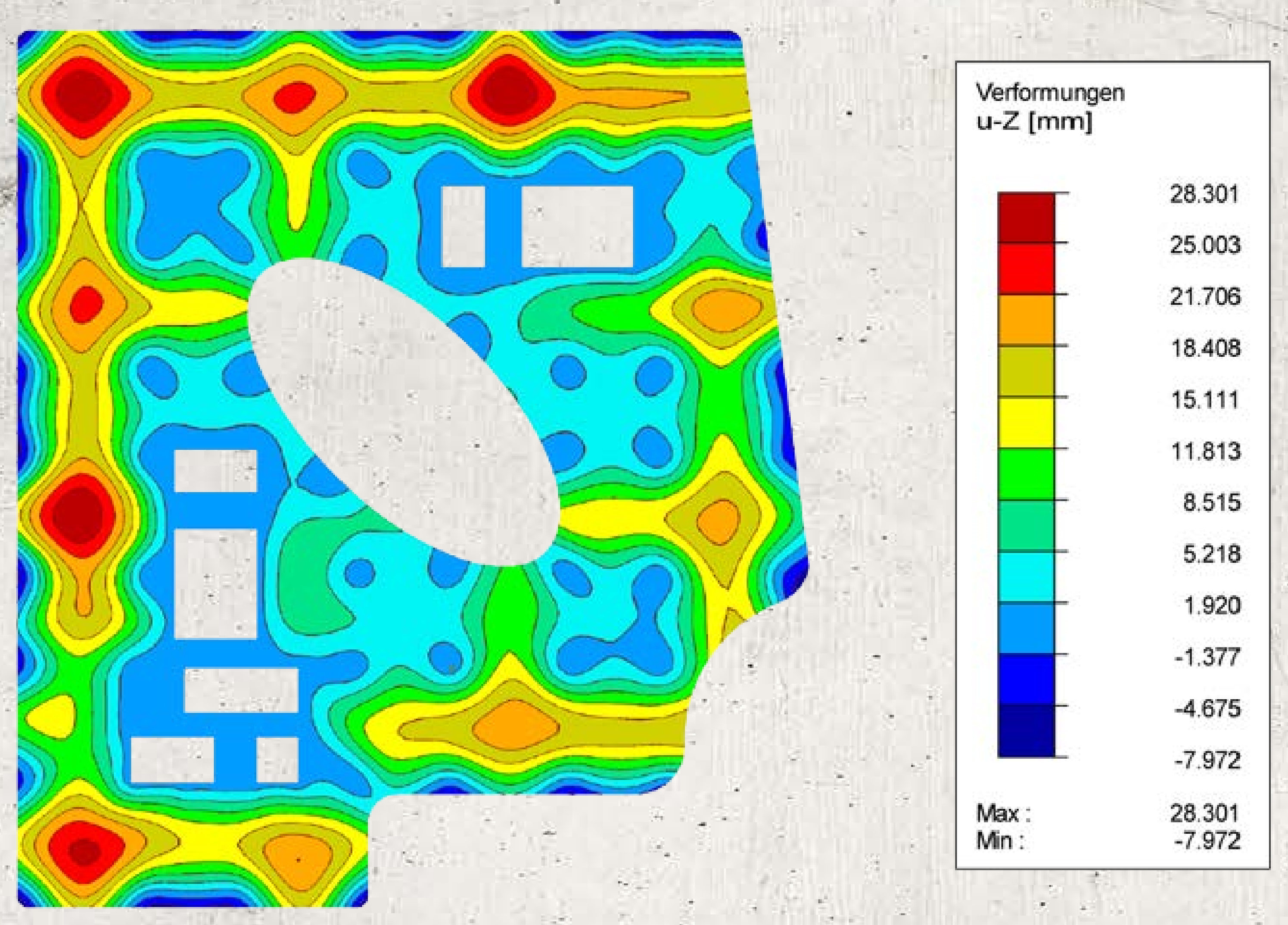


Figure 3: Deformations

RESULTS

As shown in figure 4 the course of **greenhouse gas emissions** shows a global increase over the compressive strength classes of the concrete. Referenced to the variant with slab thickness 30 cm and concrete grade C40/50, the concrete slabs with lower concrete strength (C30/37) can be realised with approx. 10% lower emissions. With an increase to C50/60, the emissions rise by approx. 10%. Approx. 80% of total emissions are caused by concrete. By using CO_2-reduced concrete, approx. 25% of greenhouse gases can be saved (yellow line). The characteristic values represent the arithmetic mean of the CO_2-reduced concretes currently available on the market in Germany.

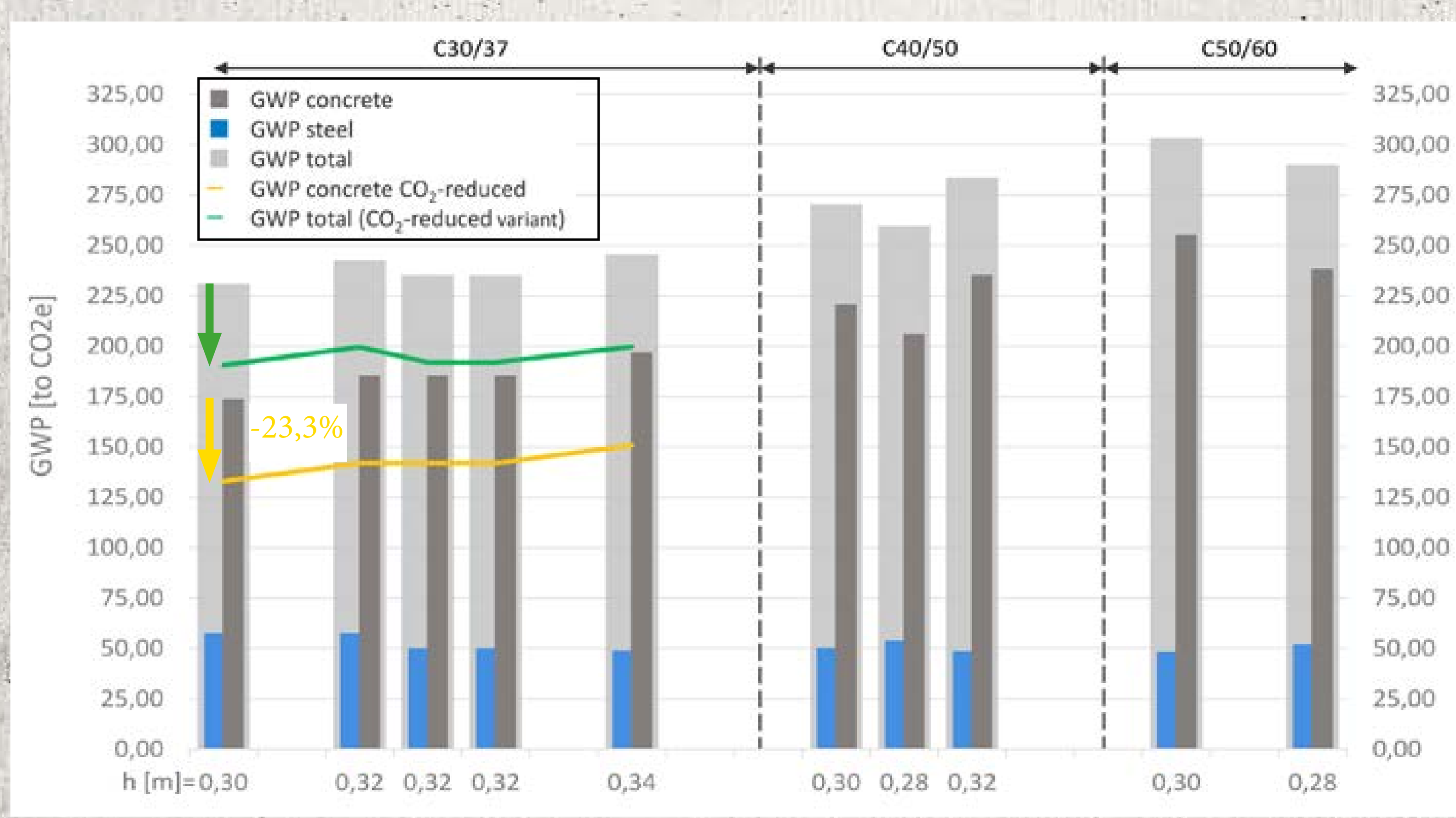


Figure 4: Distribution of equivalent CO_2-emissions

The comparision of the **economic aspects** is illustrated in figure 5 and shows no significant differences between the variants. While variants with higher concrete volumes incur more costs for concrete, they proportionally keep steel costs low. Consequently, all variants result in nearly similar total costs, with a deviation of about 2-4%. The prices of CO_2-reduced concrete are on average 5% higher than those of standard concrete.

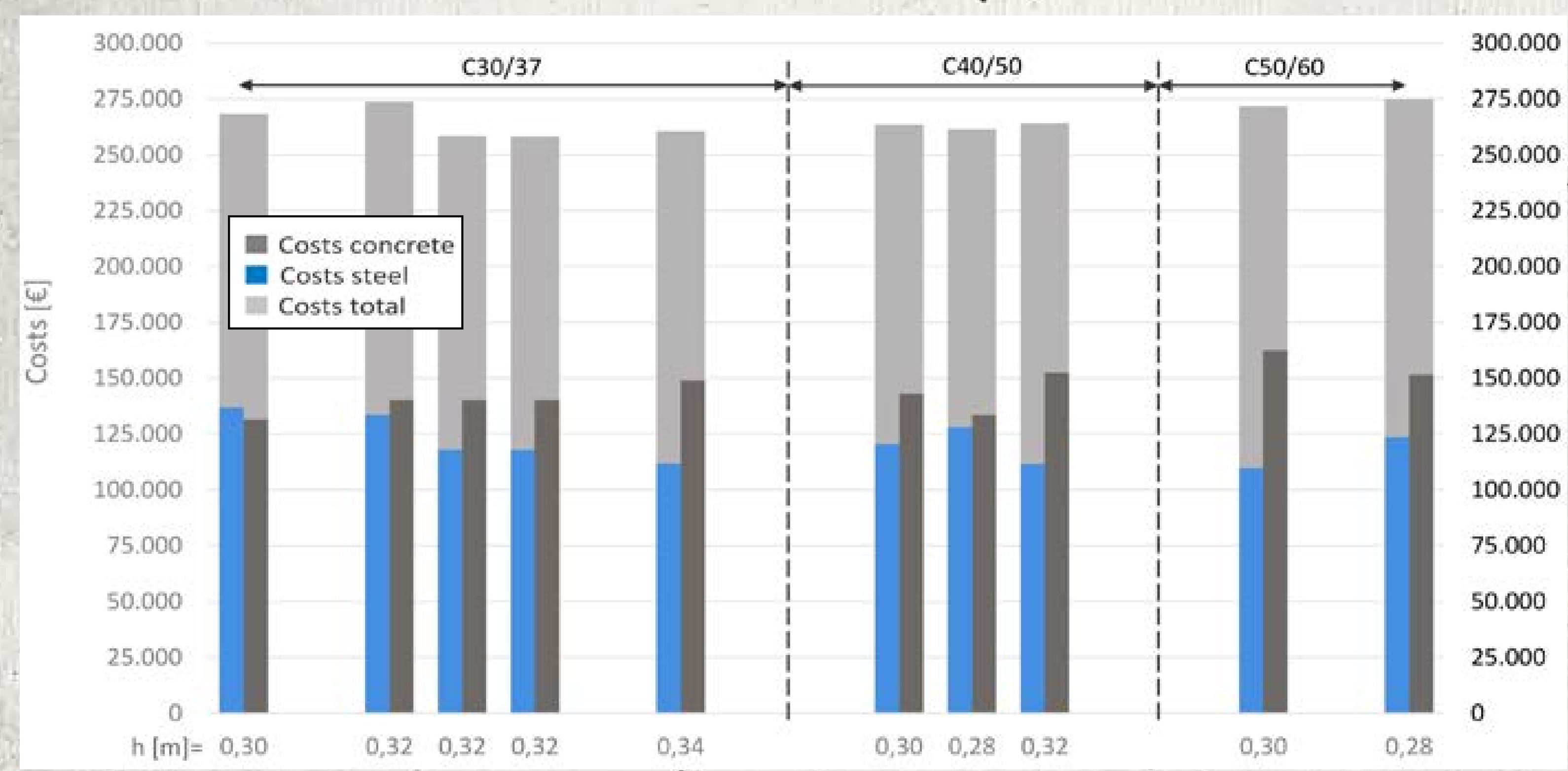


Figure 5: Distribution of economic costs

CONCLUSION

In conclusion the results show that regardless 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 strength. Mainly 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 of the concrete decrease, the greater the relevance of the steel quantities for the GWP consideration for point-supported flat slabs. An increase of the reinforcement bars reduces the occurring deformations in the relevant areas. This is associated with lower emissions, but with higher costs. However reinforcement levels limited to 170 kg/m^3 are not problematic in terms of costs and GWP. So the driving factor is therefore the strength class of the concrete.

OUTLOOK AND BENEFITS FOR SOCIETY

The construction sector is responsible for roughly 37% of global energy-related CO_2 emissions and thereby is causing a significant portion to global warming [2]. The implementation of the taxonomy aims to assess economic activities and steer capital and investors towards sustainable ventures. In the future, CO_2-certifications for sustainably designed buildings will be crucial for loan interests and subsidies. Specifically, interest rates on loans will be determined by the levels of certification. Through intelligent construction planning, a better certification level and thus more favorable conditions can be achieved. These benefits will not only apply to the financing of concrete decks themselves but also to the overall costs of the building.

REFERENCES

[1] EN15978-1: Sustainability of construction works, Assessment of environmental performance of buildings
[2] United Nations Environment Programme, 2022 Global Status Report for Buildings and Construction