

PARAMETRIC OPTIMISATION OF TWO-WAY SLABS ON BEAMS FOR EARLY-STAGE LOW-CARBON DESIGN

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Floor systems account for nearly 75% of embodied carbon (EC) emissions in building superstructures, highlighting the critical need to identify early design parameters that can effectively reduce EC emissions while ensuring full compliance with structural standards and safety regulations. This study explores the potential to minimise EC in reinforced concrete two-way slabs using a parametric grid search approach, analysing the intricate relationship between code-compliant design and EC. MATLAB scripts were employed for a comprehensive parametric analysis, with grid sizes ranging from 4 m to 10 m and slab thickness variations in 1 mm increments to accurately assess their impact on carbon emissions. Concrete grades from C20/25 to C40/50 were considered, and all designs were thoroughly checked against Eurocode 2 for flexural capacity, serviceability, and detailing requirements.

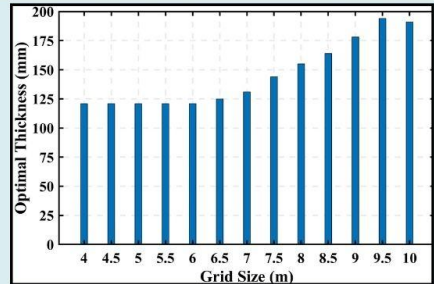
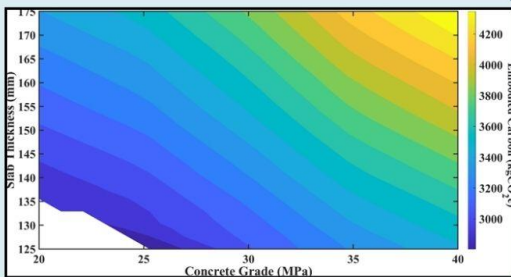
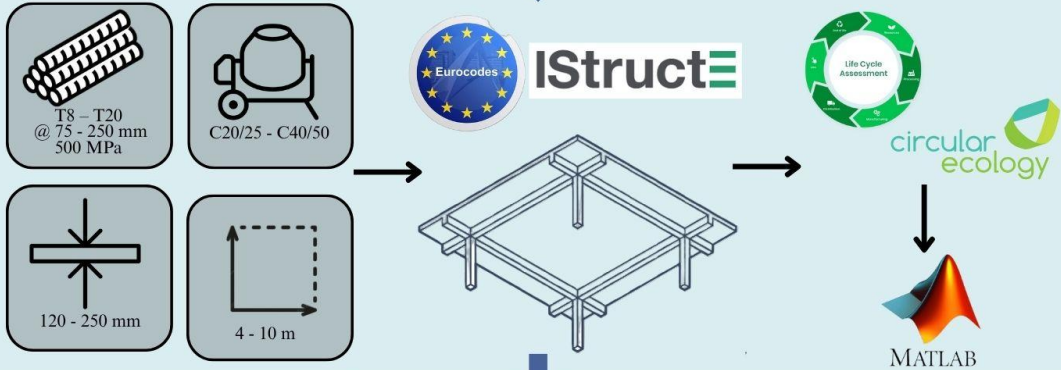
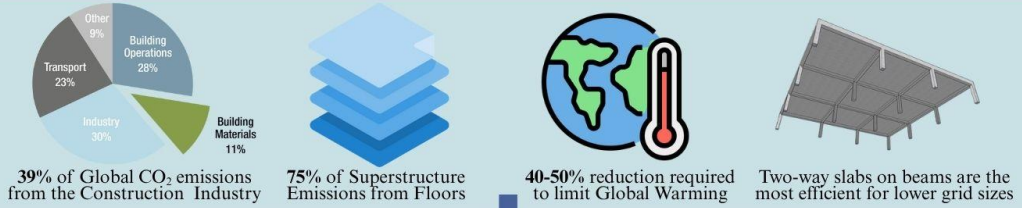
From thousands of design permutations, those with the lowest cradle-to-gate carbon emissions were selected for detailed and focused analysis. The results show significant carbon savings of 3-50% compared to conventional Eurocode-based designs, with larger reductions observed for longer spans. Lower concrete grades (C20/25–C25/30) consistently resulted in the lowest EC across all grid sizes, even when factoring in thickness reductions with higher-strength concrete. The increased carbon intensity and additional reinforcement needs of higher grades outweighed material savings. For smaller grid sizes (4-6 m), slab thickness was primarily driven by fire resistance requirements, effectively eliminating any benefit from higher grades. Reinforcement analysis revealed optimal main reinforcement ratios between 0.15% and 0.35%, with larger grid sizes requiring higher ratios to maintain structural performance. The study found that concrete's strength-to-carbon ratio is significantly less favourable than steel's, explaining why thinner slabs with slightly higher reinforcement ratios are often more sustainable.

The research also assessed the sensitivity of results to variations in emission factors. Even with a 100% increase in concrete emission factors, the optimal design parameters remained unchanged, though total EC rose by about 45%. This suggests the robustness of low-carbon solutions under different carbon accounting scenarios. Practical outcomes include early-stage design tables specifying optimal slab thicknesses for various loading conditions and grid sizes. Compared to standard code recommendations, the optimised solutions achieve carbon reductions of 24.3-49.1% versus Eurocode span/depth ratios and 2.9-29.6% versus Concrete Centre guidelines. This study provides designers with both a methodological framework and practical tools for creating sustainable two-way slab systems that reduce EC while ensuring structural performance and code compliance, offering clear guidance for decarbonising concrete construction.

Keywords: Embodied carbon, Life cycle assessment, Parametric design, Reinforced concrete, Sustainable structural design

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Thinner slabs & lower grades of concrete lead to most sustainable designs
Optimum reinforcement ratio lies in the range of 0.15%-0.35%
3-29% savings in Embodied Carbon compared to the cost-based design method
At least 24% savings compared to using the span-depth ratios suggested in Eurocode 2

