

Summary

The stress field method, which is based on the lower bound theorem of plasticity, provides an unlimited number of solutions allowing to carry the applied loads to the supports for a given structure. This possibility which gives a large freedom to designing, it raises the question of which is the most suitable stress field for the analysis of the structure.

The present research provides further contributions to the generation and the optimisation of strut-and-tie and stress field models. Different automatic and manual methods are generalised and developed. Regarding the design of structures, manual methods are based on the graphical statics and on consideration about the structural behaviour, while for the analysis of existing structures they are based on the upper bound theorem of plasticity. When using automatic methods, firstly the optimisation criteria are evaluated. Different optimisation criteria can lead to different layouts of the steel bars in the structure. Thus, the selection of the optimal structure can be defined according to several criteria, which can meet one of the requirements of the structure while the remaining may be fulfilled at least partially.

For automatic analysis, the criterion of minimum strain energy is selected as the most suitable amongst those investigated. This criterion is firstly applied in the linear optimisation of an initial truss, and then it is applied using the proposed algorithm which is based on the displacement method respecting also compatibility conditions. According to this algorithm, the optimal solution but also others close to the optimal are obtained. Finally, an algorithm is proposed which allows to transform the optimal strut-and-tie model obtained into a discontinuous stress field.

The proposed algorithm, which is based on displacement method, considers not only the equilibrium of the structure but also compatibility conditions. Therefore it can be equally used for the optimisation of continuous stress fields that are based on non-linear finite element analysis. In that way, the position of the required ties and the development of discontinuous stress field models can be easily obtained. The results obtained are compared to classical solutions and to examples recently proposed in the scientific literature.

The actual behavior of structures is also assessed by means of both continuous and discontinuous stress field analyses. The main concerns are the need for reducing the concrete strength and the analyses of the different phenomena which influence the structural behaviour. The conclusions withdrawn from this study were verified for the particular case of a corner joint cast in lightweight aggregate concrete which was tested in laboratory during the thesis and analysed with the stress field method. Additional structures containing discontinuity regions, were included in this study.

The behaviour at service load is finally studied by selecting the cracking zones in the structures which were previously identified using the stress field method. In addition, tension zones outside the tie zones are analysed in detail. At these regions, it is necessary to ensure the propagation of the tie cracks in order to limit crack openings. Suggested values for the minimal reinforcement and the maximal distance between reinforcement bars are finally proposed.

Keywords: stress field models, strut-and-tie models, design, analysis of the structures, optimisation, algorithms, conception, topologies, finite elements, strength, spalling of concrete cover, lightweight concrete, cracking, service load behavior, minimal steel