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Simplified method to nonlinear analysis of reinforced concrete in pure flexure

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ABSTRACT

The use of the finite element method in the design of reinforced concrete slabs and beams has become a generally accepted practice in recent times and when designing structural members, both ultimate and serviceability limit states are required to be considered in the consequent analyses. The nonlinear analysis of reinforced concrete, using plates and shells, may be defined into two broader categories with the first being the layered approach and the second being the effective stiffness approach.

Common commercial finite element software do not all provide the facilities for the nonlinear analysis of reinforced concrete beams and slabs. Although there are currently nonlinear models provided through literature these can be seen as complex to certain engineers and only applicable to the specialist engineer able to understand and implement the theory correctly.

The more complex methods are also aimed at predicting the wider range of failure mechanisms. Unless carrying out forensic engineering, the design engineer might not be interested in the actual failure load but rather, dependant on design philosophy, a cautious yield line load or similar.

This report presents a simplified method, based on an effective stiffness approach, to the nonlinear analysis of reinforced concrete slabs and beams for serviceability and ultimate limit states. The method allows for the use of simple design equations familiar to all structural engineers undertaking reinforced concrete designs.

Using the finite element method, plate elements and simplified constitutive properties a nonlinear algorithm is developed which results in the accurate estimation of the displacements during loading as well as a design ultimate loading. The proposed method is intended for reinforced concrete beams and slabs under transverse loading leading to bending with no axial forces present.

The proposed model and nonlinear algorithm is validated against four experimental case studies which show the accuracy and relevance of the given nonlinear solution. The results provide evidence that the proposed nonlinear model is valid for all loading and boundary conditions considered. The application can be for displacement serviceability checks or the ultimate load design of a slab or beam. The nonlinear model and algorithm presented can be easily integrated into a commercial finite element package, with API capabilities, for use in the design of reinforced concrete slabs and beams.