MINIMUM REINFORCEMENT DESIGN OF REINFORCED CONCRETE SLABS

by

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To my father

Late Mr. MOHAMMAD ZAHIR-UDDIN AHMAD

CERTIFICATE

This is to certify that the thesis entitled "MINIMUM REINFORCEMENT DESIGN OF REINFORCED CONCRETE SLABS" being submitted by Mr. Mohammad Zahoor-uddin Ahmad to the Indian Institute of Technology, Delhi, in fulfilment of the requirements of the degree of Doctor of Philosophy, is a record of bonafide research work carried out by him under my guidance and supervision.

To the best of my knowledge, the thesis has reached the requisite standard. The matter presented in this thesis, has not been submitted in part or full to any other University or Institute for the award of any degree or diploma.

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Mohd. Zahoor-uddin Ahmad

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ABSTRACT

The present study is concerned with the minimum reinforcement design of rectangular slabs in which reinforcement is placed parallel to the edges of the slab. Two types of slabs namely, slabs supported all along their edges and typical interior panels of flat slab system are considered in the study. Three different types of boundary conditions are considered for the slabs supported all along their edges (i) all edges fixed, (ii) two longer edges fixed and other two simply supported, and (iii) two shorter edges fixed and other two simply supported. Three different minimum reinforcement solutions are presented for these slabs. The first solution obtains a minimum volume of straight reinforcement for rectangular slabs in which bottom reinforcement is curtailed near the edges. The solution is based on the theory of optimal plastic design for piece-wise constant reinforcement which uses Prager and Shield's optimality criterion. The second solution obtains the minimum volume of uncurtailed reinforcement based on the lower bound analysis (limit state) of the slab. The solution is obtained by choosing a statically admissible (twistless) moment field which minimizes the moment capacity volume of the slab. The minimum moment capacity volumes of the slabs obtained by this solution are nearly same as those obtained by Rozvany's static-kinematic solution for rectangular slabs with uncurtailed reinforcement. The third solution provides an economic reinforcement solution based on yield line theory. The work is an extension of Wood's economic reinforcement solution for simply supported square slab. The analysis considers curtailment of bottom reinforcement near the edges of the slab. The solution is achieved by obtaining a distribution of plastic moment capacities within the slab which will allow two modes of collapse to occur simultaneously. The results indicate that the moment capacity volumes of the slabs obtained by the present solution are about 5-35% less than those obtained by conventional yield line approach. The solution is, however, found to be less economic compared to the **first** solution mentioned earlier.

The enhancement in the load carrying capacities of the minimum reinforced slabs (laterally restrained at the edges) due to compressive membrane action is then studied both theoretically and experimentally. For the theoretical analysis, rigid plastic strip theory proposed by Park is used. The load carrying capacity of the slab is taken as the load corresponding to the central deflection of 0.5 times the overall depth of the slab. The results of the study show that the enhanced load carrying capacity of the minimum reinforced slabs are quite substantial and the serviceability behaviour of the slabs at the working load is satisfactory. Further, a parametric study shows that the coefficient of orthotropy (in the lower range $\simeq$ 0.25 to 3.0) influences considerably the enhanced load carrying capacity of the slab due to compressive membrane action.

For flat slab panels, two minimum reinforcement solutions are presented. The first solution considers the slab panels on point supports. The minimum reinforcement solution is based on Prager and Shield's optimality criterion for piece-wise constant reinforcement. For the solution, two systems of load transmission are considered; the first system transmits the load through strip action to the second system which carries the load to the point supports with a moment field in which twisting moment is present. The second solution considers the flat slab panels to be supported on rectangular columns of finite dimensions. For the analysis, a twistless moment field is assumed within the slab. The moment field is so selected that it minimizes the moment capacity volume of the slab.

Based on the minimum reinforcement solutions presented for rectangular slabs supported all along their edges and flat slab panels, tables for design moment coefficients have been prepared which can be readily used in practice.

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