ABSTRACT

In order to study the behaviour and ultimate strength of RC slabs having a single opening, 78 square slabs and 9 rectangular slabs have been tested to destruction by either applying uniformly distributed load or central concentrated load that was gradually increased. The size of the square slab was 914mmx914mmx30mm (thickness) and that of a rectangular slab was 914mmx686mmx30mm. The ratio of size of the opening to the size of slab varied from 0.1 to 0.25. In the square slabs the opening was either square or circular. The square slabs had opening either at centre, or at a corner, or at the middle and tangential to an edge, or along a line of symmetry, or along a diagonal line. Openings were provided by cutting the reinforcement at corresponding locations. Of these 87 slabs, two square slabs and two rectangular slabs were solid (without opening). Simply supported edge conditions were maintained for all the slabs.

Deflections at selected points were measured and plotted to study the deformed profile of the slab. Load vs deflection curves have also been plotted for all slabs. The first cracking loads and the ultimate loads were recorded. After the testing was over, yield line patterns of the slabs were photographed.

Virtual work equations based on yield line theory have been derived to find the ultimate load carrying capacity of orthotropically reinforced rectangular concrete slabs that have either a non-central opening, or an opening at a corner, or opening either along a shorter or longer edge and subjected to uniformly distributed load. Also, virtual work equations for RC slabs with an opening either at a corner or tangential to either a shorter or longer edge and subjected to a concentrated load have been derived. For slabs that were subjected to uniformly distributed load, the yield line patterns (failure modes) that have been assumed are of seven types for a non-central opening inside, four types for an opening at a corner, four types for an opening along a shorter edge and three types for an opening along a longer edge. For slabs that are subjected to concentrated load, the yield line patterns assumed are of two types. The equations thus derived are so general that they are applicable to RC slabs with any boundary condition and irrespective of the size and location of the opening. Such a general approach is not available in any of the works of earlier researchers.
The theoretical ultimate loads of slabs as per the virtual work equations thus derived in this investigation have been compared with the observed experimental results of the tested slabs. It has been found that as the size of the opening present in the slab increased, the predicted ultimate loads were closer to the experimental values. The reason for this is, as the size of the opening increases, the load carried by membrane action of the slab decreases and hence the yield-line theory which is based on the bending action is able to predict ultimate loads which are closer to the experimental values.

Twenty square slabs that had a square opening either at centre, or at a corner, or at the middle and tangential to an edge, or at a line of symmetry, or at a diagonal line were strengthened internally. Strengthening was done by providing additional number of steel bars equal in number to those bars that were cut across by the opening. The strengthened slabs were tested to destruction by gradually increasing uniformly distributed loads. The ultimate loads of the slabs have been compared with those of un-strengthened slabs and the solid slabs. It has been found that a minimum of 89% strength of solid slab could be achieved by this technique.

Finite element models have been developed for all the experimentally tested square slabs that had either a square or circular opening at various positions and subjected to either uniformly distributed load or central concentrated load. The mid-node deflections or deflections at a corner of the openings obtained through FE simulation have been compared with those of the corresponding experimental deflection values. The commercially available FE package, ANSYS was used for this study.