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Behavior of lightweight reinforced concrete beams with openings in shear zones**Mohamed Ahmed**
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The construction of modern buildings requires many pipes and ducts to accommodate necessary services such as air conditioning, electricity, telephone, and computer network. Passing the required service through web openings in these beams is more desirable than passing it underneath the beams to keep of building aesthetics, also decrease the total height of building as well as decreases the total construction cost. Many researches were prepared to investigate the effect of openings on strength and stiffness of the reinforced concrete beams under different conditions to get suitable solutions to avoid or reduce these effects. Also, this research has been prepared to study the effect of a rectangular opening on the behavior of simply-supported lightweight, mixed and normal reinforced concrete beams with rectangular cross section using a nonlinear finite element program (ANSYS 17.2). For this purpose, a set of fifty one beams were analyzed to study the behavior of beam with opening under different conditions. All tested beams were simply supported beams with 4050 mm long, 3750 mm span, and cross section of (200 mm width and 500 mm total depth). Main parameters were: opening length (l), opening height (h), position of the opening along the beam axis (X), type of concrete, ultimate compressive strength (f_{cu}) and reinforcement arrangement around opening. The wide range for these parameters was taken as follows: $W=(0.42 d, 0.65 d, 0.85 d \text{ and } 1.30 d)$, where d is the beam effective depth; $h=(0.28 d, 0.45 d, 0.56 d, \text{ and } 0.67 d)$; $X=(0.50 d, 0.75 d, 1.0 d, \text{ and } 1.25 d)$; $f_{cu} = 21 \text{ MPa}$ for Lightweight, 41 MPa for normal weight, and 26 MPa for mixed concrete. The reinforcement arrangement around the opening at top and bottom chord $A_{s1} = (0.64 A_s, 0.36 A_s, 0.12 A_s, \text{ and without RFT})$ where A_s is the main longitudinal reinforcement of the beam. Spacing between main stirrups equal to 200 mm and spacing between stirrups around opening equal to 50 mm. Based on these conditions the study revealed that, provision of openings in lightweight reinforced concrete beams at shear zone changes the behavior of beam. The ratio of reduction in ultimate load increased from 8% to 23%, when the ratio of opening depth to beam effective depth (h/d) increased from (0.28 to 0.67). While it increased from 5% to 18%, when the opening length to beam effective depth ratio (W/d) increased from 0.42 to 1.30. The effect of opening location becomes more significant when opening is located close to support or at a distance equals to half beam depth. When the opening is located at a distance equal to half beam depth, the cracking load and the ultimate load were reduced by 16%, and 13%, respectively. Also, when the opening is located at a distance equals to beam depth, the cracking load and the ultimate loads were reduced by only 9%, and 7%, respectively. Increasing the ultimate compressive strength from 21 to 41 MPa decreases deflection and increases cracking and ultimate loads by 36%, 33%, and 37%, respectively. In addition to, increasing the reinforcement around the opening with certain arrangement helps to recover the loss in ultimate load of beam with openings.

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