



## Strength and Serviceability of Reinforced Concrete Deep Beams with Large Web Openings Created in Shear Spans

Waleed A. Jasim <sup>a</sup>, Abbas A. Allawi <sup>a\*</sup>, Nazar K. Oukaili <sup>a</sup>

<sup>a</sup> University of Baghdad, College of Engineering, Department of Civil Engineering, 10071, Baghdad, Iraq.

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### Abstract

Deep beams are used in wide construction fields such as water tanks, foundations, and girders in multi-story buildings to provide certain areas free of columns. In practice it is quite often occurring to create web opening in deep beams to supply convenient passage of ventilation ducts, cable channels, gas and water pipes. Experimental studies of ten 10 deep beams were carried out, where two of them are control specimens without openings and eight with large web openings in the shear spans. The variables that have been adopted are the ratio of the shear span to the overall depth of the member cross-section, location and dimensions of the opening. Test results showed that there was a decrease in the load carrying capacity of deep beams with openings compared to the control deep beams. This reduction may reach 66% in particular cases. It is clear that, the position of opening in shear span has less effect on the performance of structural concrete deep beams at different serviceability stages. Only 11% increase in load capacity at failure was observed in specimens with openings adjacent to the interior edges of shear spans in comparison with specimens with openings at the center of shear span because the discontinuity of the load path is less. Also the midspan deflection at service load level of the reference beam in specimens with openings adjacent to interior edge of shear spans was less than the midspan deflection of reference specimens by 10% - 33%. Evaluating all these advantages facilitates to recommend, if it is very required, the creation of openings at the interior edges of shear spans of the structural concrete deep beams.

*Keywords:* Deep Beam; Large Web Openings; Shear Span; Load Carrying Capacity.

### 1. Introduction

Deep reinforced concrete beams are quite often used in multistory buildings, bridges and marine structures. There is frequently a need for creation openings in these beams to provide passage for electrical and mechanical ducts. Web openings reduce the load carrying capacity of structural concrete members, specifically the shear resistance. Mansur and Tan (1996) were classified the web openings in reinforced concrete beams as small and large openings [1]. They suggested that the web opening could be considered small when the ratio of the circular opening diameter or web opening depth to overall depth of the deep beam is less than or equal to 25%. Otherwise, web opening could be classified as large web opening. For large web opening, this ratio is limited to 40%. Several studies were conducted to determine the effect of openings on the shear resistance of deep beams [2-4].

Kong and Sharp (1977) conducted experimental work to evaluate the effect of the size and location of opening on the performance of reinforced concrete deep beams. According to their experimental results, series of empirical expressions were proposed to consider the effect of these parameters on the shear strength [5]. The influence of web openings on reinforced concrete deep beams were estimated experimentally and analytically by Yang et al., (2006) [6]. Thirty-two reinforced high-strength concrete deep beams with or without openings were tested under two-point static

\* Corresponding author: [a.allawi@uobaghdad.edu.iq](mailto:a.allawi@uobaghdad.edu.iq)

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