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0BEHAVIOUR OF REINFORCED CONCRETE BEAM WITH WEB OPENINGS

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ABSTRACT

In construction of modern buildings it requires many pipes and ducts in order to accommodate essential services such as air conditioning, electricity, telephone and computer network such that openings in concrete beams enable the installation of these services. It also provides substantial economic savings in the construction of a multi-storey building. Various studies have been conducted with regards to reinforced concrete beams which contain web openings. This paper shows the work on the behaviour, analysis and design of Reinforced Concrete (RC) beams with web openings. A various aspects have been discussed including the classification of openings, guidelines for opening location in the beam, and the structural behaviour of RC beams with web openings. In various design approaches will also be detailed, for example the American Concrete Institute (ACI) approach, and in the Architectural Institute of Japan (AIJ) approach method. Finally directions for the future research based on the gaps which exist in the present work are presented.

Keywords: RC beam, classification of web opening, design approach, failure of beam.

INTRODUCTION

In modern building constructions transverse openings in reinforced concrete beams are often provided for the passage of ducts and utility pipes. These ducts are necessary in order to accommodate essential services such as water supply, electricity and telephone lines. These ducts and pipes are usually placed underneath the soffit of the beam, are covered by a suspended ceiling thus creating a dead space. In each floor, the height of this adds dead space to the overall height of the building depending on the number and height of ducts. Therefore the web openings enable us to reduce the height of the structure thus leading to a highly economical design. The presence of openings will transform simple beam behaviour into a more complex behaviour, as we induce a sudden change in the dimension of the beam's cross section. The ultimate strength, crack width shear strength and stiffness may also be seriously affected. Furthermore, the provision of openings produces discontinuities or disturbances in the normal flow of stresses, thus leading it to stress concentration and early cracking of the beam around the opening region. Similar to any discontinuity, special reinforcement or enclosing of the opening and close to its periphery, it should therefore be provided in sufficient quantity to control crack widths and prevent failure of the beam.

Classification of openings

The classification of Reinforced Concrete (RC) beams with web openings is based on the opening's size and position. Openings are classified as small or big openings and the best position of the opening is decided based on its size. Web openings are found to have many shapes such as circular, rectangular, diamond, triangular, trapezoidal and even irregular shapes. However, circular and rectangular openings are the most commonly used.

According to Somes and Corley, a circular opening may be considered as large when its diameter exceeds 0.25 times the depth of the web. The author however feels that the essence of classifying an opening as either small or large lies in the structural response of the beam. When the opening is small enough to maintain the beam-type behaviour, or in other words, if the usual beam theory applies, then the opening may be termed as small. When beam-type behaviour ceases to exist due to the provision of openings, then the opening may be classified as a large opening. By assuming the prevalence of Vierndeel action and considering the fact that failure occurs after the formation of a four-hinge mechanism.

According to Mansur, recommended certain criteria with which to classify the size of an opening as either large or small. It can be assumed that hinges form in the chord members at a distance of h/2 from the vertical faces of the opening. where h is the overall depth of a chord member, and the subscripts t and b refer to the top and bottom chords,
respectively.

- Small opening- lo ≤hmax
- Large opening- lo >hmax

Mansur and Tan illustrated the selection of the size and location of web openings as, For T-beams, openings should preferably be positioned flush with the flange for ease in construction. In the case of rectangular beams, openings are commonly placed at mid-depth of the section. Openings should not be located closer than one-half of the beam's depth D to the supports. This is in order to avoid critical region for shear failure and reinforcement congestion. Similarly, the positioning of an opening closer than 0.5D to any concentrated load should be avoided. Depth of openings should be limited to 50% of the overall beam depth. When the opening becomes bigger, it is preferable to use multiple openings providing the same passageway instead of using a single opening. When multiple openings are used, the post separating two

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adjacent openings should not be aforementioned less than 0.5D to ensure that each opening behaves independently. Based on the review, it is clear that openings can take many shapes and sizes. The actual type and location of an opening must be clearly decided before the design specification stage.

Small openings design approaches

These type of design approaches which are been used for RC beams with small openings. Mansur and Tan recommended that a circular, square, or nearly square opening may be considered a small opening provided that the depth (or diameter) of the opening is in realistic proportion to the beam size, that is, less than approximately 40% of the overall beam depth. In such a case, beam action may be assumed to prevail. Therefore, the analysis and design of a beam with small openings may follow a similar course of action to that of a solid beam.

Traditional design approach

In the case of pure bending the concrete there would have cracked anyway in flexure the placement of an opening completely within the tension zone does not change the load-carrying mechanism of the beam. As long as the minimum depth of the compression chord, hc, is greater than or equal to the depth the ultimate moment capacity of a beam is not affected by the presence of an opening of the ultimate compressive stress block, that is,

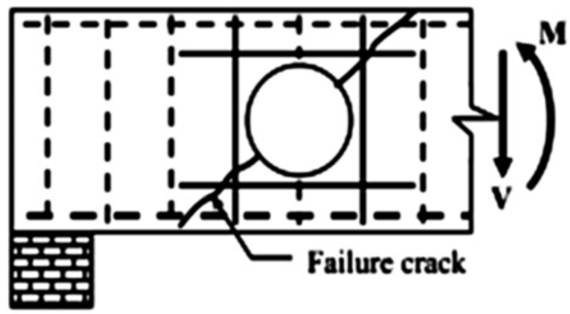
$h_c \leq A_s f_y / 0.85 f_c' b$

where, A_s is the area of flexural reinforcement, f_y is the yield strength of flexural reinforcement, f_c' is the compressive strength of concrete and b is the beam width.
Tests have been conducted with a small opening enclosed by reinforcement and introduced into a region subjected to predominant shear. The beam may fail in two distinctly different modes. The first type is labelled beam-type failure which is typical of the failure commonly observed in solid beams except that the failure plane passes through the centre of the opening. Conversely, in the second type labelled frame-type failure, the formation of two particular diagonal cracks, one in each member bridging the two solid beam segments, leads to the failure. It was suggested that these types of failures require separate treatment for complete design. Similar to the traditional shear design approach, in both the cases it may be assumed that the nominal shear resistance, V_n, is the sum of two components V_c and V_s (attributable to concrete and shear reinforcement across the failure plane)

$V_n = V_c + V_s$

Beam-type failure

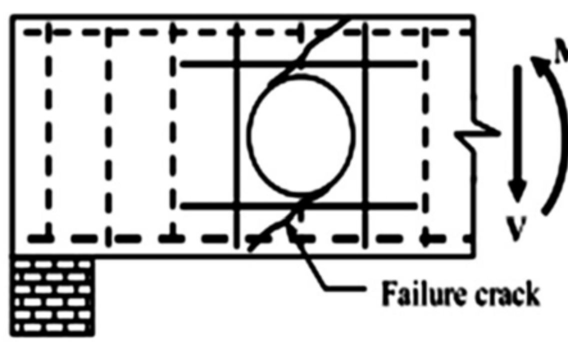
Similar to a solid beam, a 45°inclined failure plane may be assumed when designing for beam-type failure, in which the plane being traversed through the centre of the opening, as shown in Fig. A simplified approach namely the American Concrete Institute (ACI) is been followed to estimate the shear resistance V_c provided by the concrete: where b_w is the web width, d is the effective depth and do is the diameter of opening.



(a) Beam-type failure

Frame-type failure

This type of failure occurs due to the formation of two independent diagonal cracks, one on each of the chord members above and below the opening. Each member behaves independently similar to the members in a framed structure. Design reinforcement is recommended for this mode of failure and it was also suggested that the chord member requires independent treatment. Let us consider the free-body in which the applied factored moment, M_u, at the Centre of the opening from the global action is resisted by the usual bending mechanism by which compressive and tensile stress results, Nu, in the chord members above and below the opening.



(b) Frame-type failure

Plasticity method

In beam with openings it is difficult to develop an arch mechanism, and consequently, the applied shear is transferred by means of a truss mechanism. A beam has a circular opening only when the beam is reinforced transversely by vertical stirrups. Note that us is the angle of concrete compression strut in the upper and lower chord members. The horizontal arrows show bond stress and the vertical arrows represent forces acting on the concrete due to the forces in the stirrups. The unshaded portion shows the zone where the diagonal compressive stress field is not formed. The diagonal compressive stress in concrete

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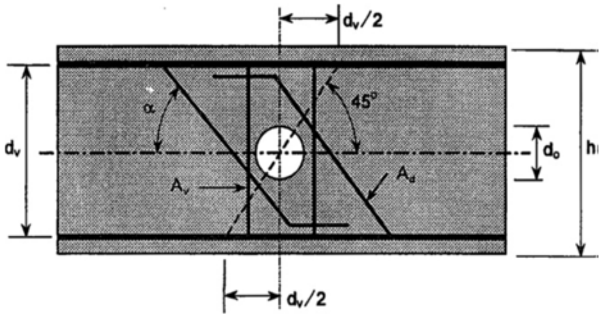
around the opening becomes larger as the unshaded portion widens or as the opening become large.



Large opening design approaches

The presence of large openings in reinforced concrete beamsrequires special attention in the analysis and design phase because of the reduction in both strength and stiffness of the beam and excessive cracking at the opening due to high stress concentration. This section presents existing approaches which have been used for the design of RC beams with large openings. The plastic hinge method, with its three revisions, is presented as well as the plasticity method.

CONCLUSION

Thorough the study about behavior of reinforced concrete beam with web openings by referring some journals. to investigate about the openings design approach of the beam, failures of beam and frame, plasticity method of beam has been revealed.

REFERENCES

Mansur MA, Tan KH, Weng W. 2006. Analysis of concrete beams with circular web openings using strut-and-tie models. Malay J Civil Eng. 18(2):89-98.

Tan KH, Mansur MA. 1992. Design procedure for reinforced concrete beams with large web openings. ACI Struct J. 93(4):404-10.

Hasnat A, Akhtaruzzaman AA. 1987. Beams with small rectangular opening under torsion, bending and shear. ASCE J Struct Eng. 113(10):2253-70.

Somes NF, Corley WG. 1974. Circular openings in webs of continuous beams. Shear in Reinforced Concrete. Special Publication SP-42. Detroit: American Concrete Institute. pp. 359-398.

Mansur MA. 1998. Effect of openings on the behavior and strength of RC beams in shear. Cement Concr Compos. 20(6): 477-486.

Shri, S. Deepa, and R. Thenmozhi. 2012. "Flexural behavior of hybrid ferrocement slabs with microconcrete and fibers." Int. J Emerg Trends Eng Dev. 4(2): 165-177.

Mansur MA, Tan KH. Concrete beams with openings: analysis and design. Boca Raton, Florida, USA: CRC Press LLC; 1999. p. 220.

Tan KH, Mansur MA, Huang LM. Design of reinforced concrete beams with circular openings. ACI Struct J 2001; 98(3):407–15.

Mansur MA, Tan KH, Weng W. Effects of creating an opening in existing beams. ACI Struct J 2001; 98(3):407–15.

K. Ramadevi and S. Deepa Shri. 2015. “Flexural Behaviour of Hemp Fiber Reinforced Concrete Beams”, ARPN Journal of Engineering and Applied Sciences, 10: 1819-6608.

Pa. Ganeshwaran and S. Deepa Shri. 2015. “A Solid Waste Management in Coimbatore City”, Journal of Engineering and Applied Sciences, 10(14): 6177-6183.

Hanson JM. 1969. Square openings in webs of continuous joists. PCA Research and Development Bulletin RD 100.01D. Portland cement Association. p. 1-14.

Weng W. 1998. Concrete beams with small openings under bending and shear. MEng Thesis, National University of Singapore. p. 92.

Mansur MA, Tan KH, Weng W. 2006. Analysis of concrete beams with circular web openings using strut-and-tie models. Malay J Civil Eng. 18(2): 89-98.

Siao WB, Yap SF. 1990. Ultimate behavior of strengthened large openings made in existing concrete beams. J Inst Eng. 30(3): 51-7.

Mansur MA. 1988. Ultimate strength design of beams with large openings. Int. J Struct. 8(2): 107-25.