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Review on Beam with Web Opening

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Abstract : The research highlighted the impact of web openings on load-carrying capacity, crack widths, and stiffness of the beams. Various reinforcement techniques, including hybrid fibers and carbon fiber-reinforced polymers (CFRP), were examined for enhancing the performance of these beams. Experimental tests, analytical models, and numerical simulations were employed to analyze the behavior and develop design methodologies. Factors such as opening size, shape, and location, as well as moment-shear ratio and reinforcement rates, were identified as significant parameters affecting the structural response. The findings contribute to improving the understanding of beams with web openings, facilitating the design and reinforcement strategies for these structural elements.

***IndexTerms* - Web Openings, Beams**

I. Introduction

Beams with web openings are structural elements that possess apertures within their webs, serving various purposes such as accommodating services, reducing weight, or providing access. The presence of these openings can significantly influence the behavior and performance of the beams, affecting factors such as load-carrying capacity, stiffness, crack propagation, and failure modes. Understanding the behavior of beams with web openings is crucial for engineers and designers to ensure the structural integrity and optimize the design of such elements. This introduction provides an overview of the research conducted on beams with web openings, highlighting the importance of investigating their behavior, exploring reinforcement techniques, and developing design methodologies to enhance their performance.

II. LITERATURE REVIEW

Smarzewski [1] shows the results of an experimental and theoretical study of the behaviour of hybrid steel-polypropylene fiber-reinforced high-performance concrete deep beams with and without holes. This study showed that using composite threads as web support has a good effect on deep beam crack widths and makes deep beams with holes stronger so they can hold more weight.

Makki et al. [2] looked at the behaviour of UHPC deep beams with carbon fiber-reinforced polymer (CFRP) strips that were joined on the outside. Using a carbon fibre reinforced plastic (CFRP) system as an external strengthening method had a big effect on how the tested beam models responded as a whole.

Allawi et al. [3] looked at how 18 deep beams performed in terms of breaking, distortion, and being able to hold weight. As a test, two deep logs were built without any holes or extra support. Eight deep beams with openings but no reinforcement were put in place first. Then, eight deep beams with openings in shear spans and CFRP sheet reinforcement around opening zones were put in place. The results of the experiments showed that the building of openings in shear spans changes the load-carrying capacity. Compared to control beams without openings, specimens with openings but no strengthening can have a failure load that is 66% less than specimens without openings.

Using ten deep beams, Jasim et al. [4] did an experiment to find out how big web holes affect stress lengths. The results of the tests showed that deep beams with holes could not carry as much weight as deep beams without holes. In some cases, this cut could be as high as 66%.

Elsayed et al. [5] did an experiment to find out how UHPC shallow boards with holes behave when sheared. The quantity of steel strands and the form and location of the holes were the factors that were looked at. Their results showed that holes in the web in the shear region made UHPC shallow beams 33.7% less strong in the shear direction. Because of this, there have been a lot of worries about the main factors that control how UHPFRC deep beams with web openings behave in shear.

Lam [6] says that since the 1940s, all research on parts made of both steel and concrete has looked at mechanical connections. As an example, a set of tests were done at the University of Lehigh in 1943. In this case, several tests were done on stiff connections that looked like hooks, swirls, and other shapes. Viest did some pushout tests and found that this kind of link is good for tensile strength because it is flexible.

Chapman and Balakrishnan [7] did pushout tests so that the results could be compared with the results of bending tests on composite beams. This was done to figure out how the height and width of the joints and a different device for vertical mounting affected the beams. During the tests, the writers used the relationship between force and slip to describe how flexible the head bolt connection was. Shear strength, on the other hand, was not known and wasn't looked into until much later [8].

Ollgaard et al. [9] looked at the resistance and behaviour of head stud connections in standard and low density concrete. Experiments with pushouts were done to figure out how well they worked. In this study, the authors came to the conclusion that the compressive strength of the concrete had the most effect on the tensile strength of head studs in both standard density and light density concrete.

Clawson and Darwin [10] came up with a way to estimate the strength of composite boards without support that have rectangular holes in the web, taking into account the bending strength of the concrete floor. The suggested model estimated the resistance capacity of the opening region by using moment-shear interaction graphs.

Roberts and Al-amery [11] stressed how important it was that the connections could be taken apart. An mathematical model that can predict the shear strength of these structure parts was made by using the results of tests. Experiments, such as the behaviour of slabs with a typical shear failure mode, the breaking of the web post of the girder, and the Vierendeel mechanism, were used to develop this method.

Shanmugam et al. (12) did tests with hybrid steel-concrete girders that had square and round holes in the web. In this study, both the height and the size of the holes were changed. The end result of the tests was that the concrete surfaces broke in diagonal lines and formed plastic joints. The results showed that the shear strength goes up as the height or width of the opening goes down. After that, the writers used the finite element method to make a computational model that included non-linear analysis. This model had shell elements in the steel profile, solid elements in the slab and flex joints, and contact elements between the steel and concrete surfaces. Experiments showed that the model was correct.

Chen et al. [13] looked at how cantilever composite beams with holes in the web behave. Tests and nonlinear analysis were done to find out what effect the size of the hole, the reinforcement plates, and the moment-shear ratio had. The study's results showed that the initial fracture stresses of composite beams with web openings are lower than those of composite beams without web openings, and that the mechanical behaviour of composite beams under negative moments can be greatly improved by putting reinforcing steel plates around the opening.

Li et al. [14] tried continuous steel-concrete hybrid beams with holes in the web. The writers then used the software ANSYS to look at the effect of block thickness and reinforcing rate using geometrical nonlinear studies. The study found that the holes made the structure less rigid; the failure mode was controlled by stress in the concrete slab near the opening; and the increase in concrete slab thickness and strengthening rate added to the structure's final strength and flexible behaviour. Also, the writers' computer model was the same as the models that were checked. In this study, the first flaws in the geometry were not taken into account.

Gizejowski and Khalil [15] showed what happens when a negative moment is put on a hybrid cellular beam. In all of these cases, the writers saw warping in the web because border conditions make this bad thing worse. When a negative moment is put on a composite beam, the bottom edge of the profile is compressed, but it is not forced to stay in the beam's plane. This causes the web to deform.

Redwood and Wong (16) studied composite beams made from composite slabs that had bigger rectangular holes in the web. At high moment ratios, the writers saw that flexure was the most common failure cause. The Vierendeel mechanism was caused by a local displacement of the upper and lower ends, which became more obvious as the moment shear ratio went down. When the moment-shear ratio was low, the failure mode was controlled by the Vierendeel mechanism, which caused bending cracks in the concrete block.

Donahey and Darwin (17) did tests with composite blocks that were placed both perpendicular to and parallel to the steel profile's lengthwise axis. Experiments were set up to look at the effects of the link between moment and shear, the number and position of shear connections, and the direction and position of steel formwork.

Darwin and Donahey [18] showed how to figure out the strength of composite beams without support that have rectangular holes in the web. Moment-shear models are used in the process, and the resistance of the hole to bending, straight shear, and mixes of bending and shear are all taken into account. In this method, the pure moment and shear resistance capacities are calculated separately. A cubic interaction graph is then used to show how the moment and shear capacities work together.

Djebli et al. [19] came up with a mathematical model for figuring out the total displacement of composite cellular beams that are loaded evenly or in a few places. Unlike previous models, this one takes into account whether or not the hole is in the middle of the span.

Chung and Lawson [20] showed how to build composite beams with square or round web openings for use with EC4. These steps gave general information about how the size of holes depends on shear and bending strength, as well as how these holes affect deflections. The writers say that even though there are design methods like Lawson13, the main reason for the release was that the EC4, which hadn't been made yet, was put on hold. Because of this, there were no ways to make composite wood with holes of different shapes and sizes.

Lawson and his friends [21] did tests on mixed woods with square holes in the web. The goal of these tests was to find out how longitudinal stiffeners affect global and local bending, local web buckling by compression and bending, shear transfer through the concrete block, resistance to the formation of the Vierendeel mechanism, and the increase in deflections caused by holes. The tests showed that the concrete was flexible, with no cracks, stress, or twisting of the web. The development of the Vierendeel process determined how well the tests could stand up to force.

III. CONCLUSION

In conclusion, the presented data from various studies highlight the behavior of beams with openings and the effects of different strengthening techniques on their performance. The use of hybrid steel-polypropylene fiber-reinforced high-performance concrete and carbon fiber-reinforced polymer (CFRP) strips as reinforcements have shown positive impacts on crack widths and load-carrying capacity. However, the creation of openings in shear spans without strengthening measures has been found to significantly reduce the load-carrying capacity of beams. The behavior of composite beams with web openings has been found to be influenced by factors such as moment-shear ratio, boundary conditions, flexure, Vierendeel mechanism, and web distortion. The design methodologies and procedures for composite beams with openings have been evolving, with a focus on shear and bending strength, deflections, and various shapes and dimensions of openings.

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