Securing the implementation of openings in deep concrete beams

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***Abstract* - Many times it can be needed to make an opening in the shallow beams, for example, works of air conditioning pipes and the transgression of electricity cables. But it was more complicated in deep concrete beams because the large size of the beam can accommodate the dimensions of the openings and different use may be a door for people to cross or ventilation window may be up to the corridor in the garage and so. Therefore, it should be paid attention to the openings in the deep concrete beams, not only for the large dimensions of the opening but also for the safety of the deep beam means the safety of the whole building because it usually carries more than floors. This, unlike shallow beam which carries loads from one roof. Hence, researchers began to conduct studies of deep beams with openings on both sides design as a new structure and strengthen the openings to increase durability. In this paper, we will study the effect of opening on a deep concrete beam and develop a practical solution to compensate for the shortage in the resistance of the beam. Eight beams were saluted by using the associated program, one of them was solid, one of them was with two opening and six beams with strengthening with steel jacket at the tie area. The results of this paper are that the selected opening reduced the resistance of the beam by an approximate 20% and we proposed a suggestion to make up for this shortfall of resistance to make it easier to create opening in deep concrete beams safely.**

***keywords* - Deep beams, opening, strengthening, steel jacket**

I. INTRODUCTION

In the late of the seventy of last century, the great Kong [1,2] began researching the openings in deep concrete beams. Together with others, he conducted a study of the effect of size and place of openings on deep lightweight concrete beams. In the other article, they developed solutions to reinforce the beams with holes based on the shape of the cracks that appeared on the beams in the first article. Not only that, but they matched the results with large-size beams and set an equation to calculate the shear strength of the deep concrete beams with holes. In addition to the impact of different solutions to these beams they concluded also that If the opening is reasonably clear of the natural load path, the ultimate shear strength may be calculated as though there were no openings.

In the mid, the eighty of last century and with the advent of fibers additives for reinforced concrete scientists began to study deep concrete beams made of concrete with fibers. M.A.Mansur* and W.A.M.Alwis [3] through 12 deep beams they studied the influence of both volume fraction of fibers, opening location, shear span to effective depth ratio and the amount of web reinforcement. They concluded that the volume of web reinforcement and location of opening are the two principal parameters that affect the behavior and strength of deep beams with web openings. The effect of an opening on the behavior and strength of deep beams depends primarily on the degree of interruption of the natural load path joining the loading and support reaction points. N.E.Shanmugam and S.Swaddiwudhipong [4] studied the effect of fiber content, positions of openings, and different types of loadings on the behavior of deep beams. They are noted that the increase in strength with the increase of fiber content. The significance of the natural load path joining the edge of loading and supporting plates is exemplified through a drastic reduction in strength when it is intercepted by the opening.

Finally, in the new millennium, the effort of scientists in the study of deep beams focused on two points. First one how does expect the truss form which consists of struts and ties to move the load from load point to the support point in the presence of the openings.The solutions proposed to solve that truss and therefore design and calculation of shear strength of the beam is the calculation of the forces in all members of the truss and consider that the struts which subjected to pressure curried by concrete and reinforce the ties with steel bars. In most of these researches, the internal truss is carried out inside the beam in the manner that was mentioned then tested in the laboratory and clarified the results)Brian S. Maxwell and John E. Breen [5], Brian S. Chen, et al. [6], K. H. Tan, K. et al. [7], Hong Guan and Jeung-Hwan Doh [8] and Sergio F. Breña and Micah C. Morrison [9](. The second point was the behavior of deep beams with the change of the dimensions of the holes and their places, the number of rows for longitudinal steel and the strengthening of deep beams. For example, Ashraf F. Ashour and G. Rishi [10] studded reinforced concrete two-span continuous deep beams with web openings. They concluded that The vertical web reinforcement had more influence on the beam capacity than the horizontal web reinforcement. Keun-Hyeok Yang et al. [11] studied the influence of inclined web reinforcement on reinforced concrete deep beams with openings they concluded that shear strength of beams tested improved beams having effective inclined reinforcement factors of more than 0.15 had higher shear strengths than that of the corresponding solid beam. O. E. Hu and K. H. Tan [12] studied the behavior and shear strength of large reinforced-concrete deep beams with web openings. They fabricate six large scale beam but during casting two specimens were lost . they Test results show that a web opening can reduce the ultimate strength of a large deep beam significantly if the web opening intersects the force path between the load point and the support. The observed crack patterns clearly illustrate a strut-and-tie system in large pierced deep beams. An improved strut-and-tie approach is also presented in the current paper to predict the ultimate shear strength. Tamer El-Maaddawy and Bilal El-Ariss [13,14] showed reinforced concrete beams with web openings strengthened in shear with externally bonded carbon fiber reinforced polymer (CFRP) composite sheets. They told that doubling the amount of the vertical CFRP sheets from one to two layers increased the shear capacity but the additional shear capacity gain was not in proportion to the added amount of the CFRP. A while later Rami A. Hawileh joined with them and the research was carried out on the ANSYS program to confirm the results. Qudeer Hussain and Amorn Pimanmas [15] presents an experimental study on externally bonded sprayed fiber reinforced polymers (shortly as SFRP) RC deep beams to investigate the efficiency of SFRP in shear strengthening. indicated that SFRP was capable of enhancing the ultimate load and deflection of RC deep beams provided that an adequate anchoring system is installed. The performance of SFRP strengthening depends on several key variables such as SFRP material, thickness, strengthening configuration, the strength of concrete, type of anchoring system and length of the anchor bolt. Ashraf Ragab Mohamed et al. [16] used the finite element method is utilized to study the behavior of reinforced concrete deep beams with and without web openings. Furthermore, the effect of the reinforcement distribution on the beam overall capacity has been studied and compared to the Egyptian code guidelines. Results of the parametric analysis have shown that the effect of reinforcement distribution on the beam capacity was studied and the stress distribution in reinforcing steel has been monitored. A reduction, ranging from 0.3% to 12% in the beam capacity, was observed when the tension reinforcement distribution depth was increased from 0.1H to 0.4H.

Through this history of research, we will find that the following most of the researches that have been presented have studied the effect of openings and their locations and dimensions on the behavior of deep concrete beams with web openings. As well as the effect of continuity spans and strengthen the openings internally and externally using fibers and many other ideas. Through the paper of. Ashraf Ragab Mohamed et al. [16] and Based on other research we have done [17] a currency and it shows the effect of increasing the local stiffness of tie on the behavior of deep concrete beams we tried to clarify steps to implement an openings in deep concrete beams already exists with no effect on the safety of the beam and structure.

II. Verification of the Proposed Finite Element Model

The aim of simulating the finite element model is to make sure that the suggestion type of elements, properties of material, real constants, and criteria of convergence are Enough to make the behavior of the model like the real beam. To make the verification of the model, two beams with cross-section 150 x 700 mm and length of 1600 mm was made in the laboratory of reinforcement concrete at Assiut university. One of them had two rectangular openings with dim 150*150 mm and far from edges 275 mm from the bottom and 250 mm from the vertical sides. The beams were designed according to ACI code and that after making a comparison between the codes. The beams were designed to be simply supported throughout 1300 mm and loaded by two concentrated loads. The spacing between the load and support is equal to 350 mm {a/d = 0.54} where a/d ratio is shear span to beam depth ratio this number achieves the beam to be deep. The tie represents the longitudinal reinforcement of the beam chosen to be three bars with 18 mm. diameter. The minimum web reinforcement was token it consisted of stirrups with 10 mm. diameter and longitudinal bars with 10 mm. diameter with spacing 125 mm. in two directions. Fig. (1) and Fig (2), shows the geometry, reinforcement details, and loading of the analyzed beams. The steel had average yield stress of 490 MPa , and the concrete had an average compressive strength was 42 MPa and the strength was determined by testing concrete cubes of dimension 150 mm x 150 mm x 150 mm made in the laboratory. The maximum size of the coarse aggregate was 20 mm at the time the beam was formed.

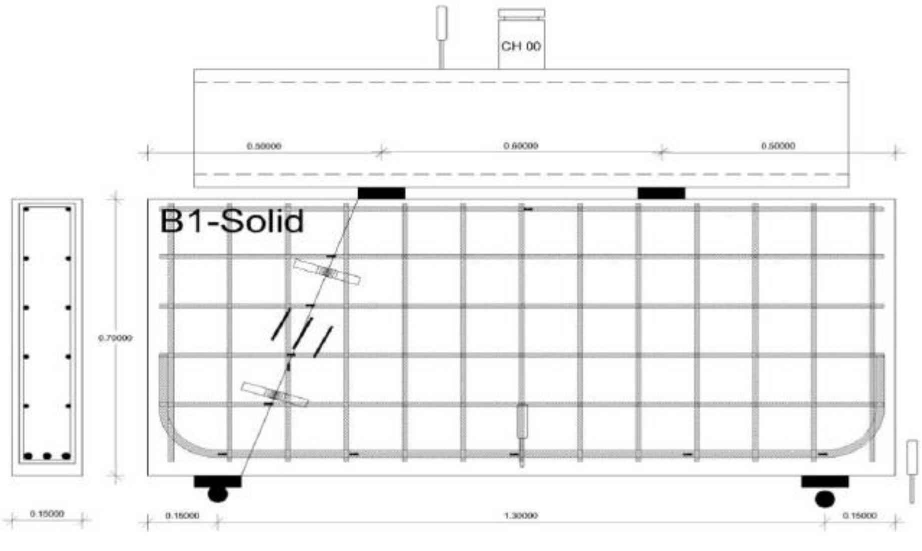

Figure (1) Geometry, Loading, and Reinforcement of Beam (B1) Tested in laboratory

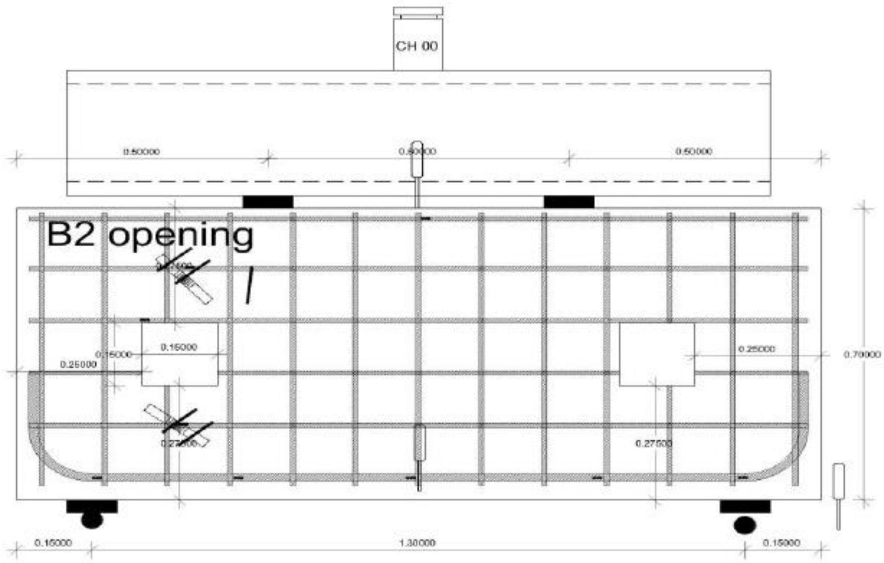

Figure (2) Geometry, Loading, and Reinforcement of Beam (B2) Tested in laboratory

The finite element model by the associated program was set up and the model was processed. The load with the med span deflection curve obtained from the finite element model with the experimental plots are presented and compared in Fig. (3).

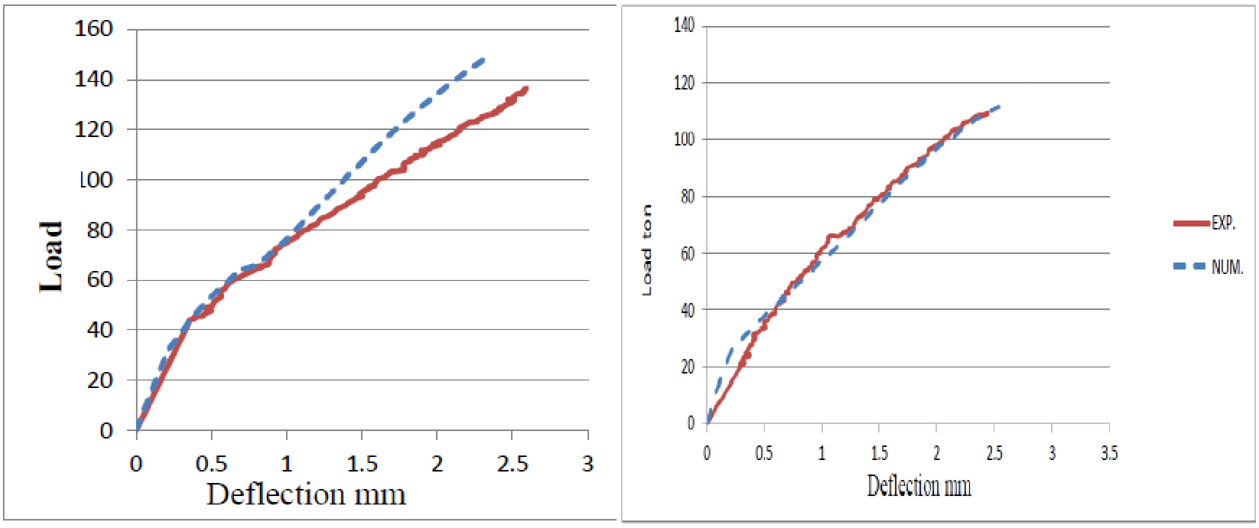

Fig. (3) Load deflection curve for numerical and excremental beam B1 solid beam and beam B2 opening beam

From the figures, we can note that the numerical model gives good agreement with the experimental beam. The effect of the openings is evident here, as both the maximum load and the stiffness decrease. Accordingly, the program was used to model different cases of beams under study.

III. PROGRAM OF ANALYZED BEAMS

A program consisting of eight bars has been developed and modeled by using a finite element method to study the effect of installing a jacket of steel sheets to support and strength the tension zone in the deep concrete beams. One of the beams was with a solid beam there are no openings. The remaining 7 beams have two rectangular openings with dim 150*150 mm and far from edges 275 mm from the bottom and 250 mm from the vertical sides as shown in fig (2). The composition of the steel jacket at the bottom was studied with different height and thickness in six beams. Table (1) & Fig (4) illustrate the different shapes of the beams under study. Where (As) equal summation area of main reinforcement and area of jacket cross-section, (I) moment of inertia for main reinforcement and jacket and type of beam.

Table (1) Details of the Analyzed Simply-Supported Beams

Beam no.	As mm2	I mm4	type	S jacket thickness mm	H jacket height mm
B1	762	*15451.16*	solid	-	-
B2	762	*15451.16*	opening	-	-
B3	*1813.02*	*1345770*	Strengthened	3	100
B4	*2163.02*	*1750582*	Strengthened	4	100
B5	*2513.02*	*2148748*	Strengthened	5	100
B6	*1888.02*	*2812500*	Strengthened	2.5	150

B7	*2180.52*	*3543750*	Strengthened	3.15	150
B8	*2563.02*	*4500000*	Strengthened	4	150

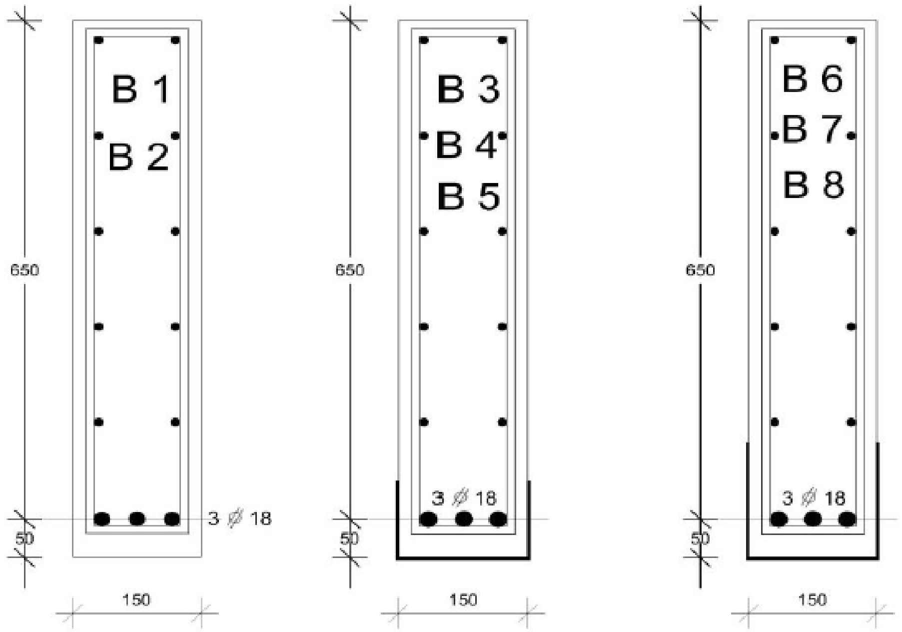

Fig. (4) The difference between studded cases

For beams B3, B4 and B5 had the same height of jacket but with different thicknesses, the same applies to beams B6, B7, and B8. B3and B6 had the same total area the same applies to beams B4, B7 and the same applies to beams B5, B6. To ensure the jacket can withstand tensile strength, the jacket should be closed on all sides, as shown in Fig. (5).

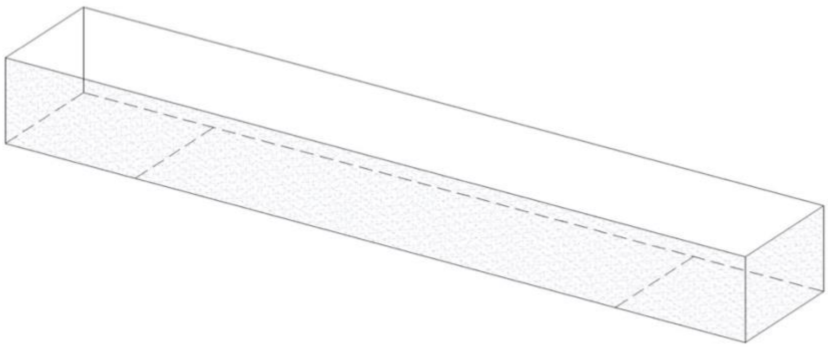

Fig. (5) The shape of the steel jacket

IV. Results and Discussion

The outcomes of the numerical study are presented to evaluate the influence of strength of the tension area for deep concrete beams with openings.

load-deflection curves

Fig. (6) shows the relation between load on the vertical axis and deflection at the bottom mid-span point at the horizontal axis. In general, we can note that adding the jacket to the beam with the opening worked to increase the stiffness and ultimate load of the beam. Increase the height of jacket branches it has had a greater impact on increasing the load capacity of a deep concrete beam with opening. The thickness of the steel jacket did not have a noticeable effect on the increasing stiffness of the beam.

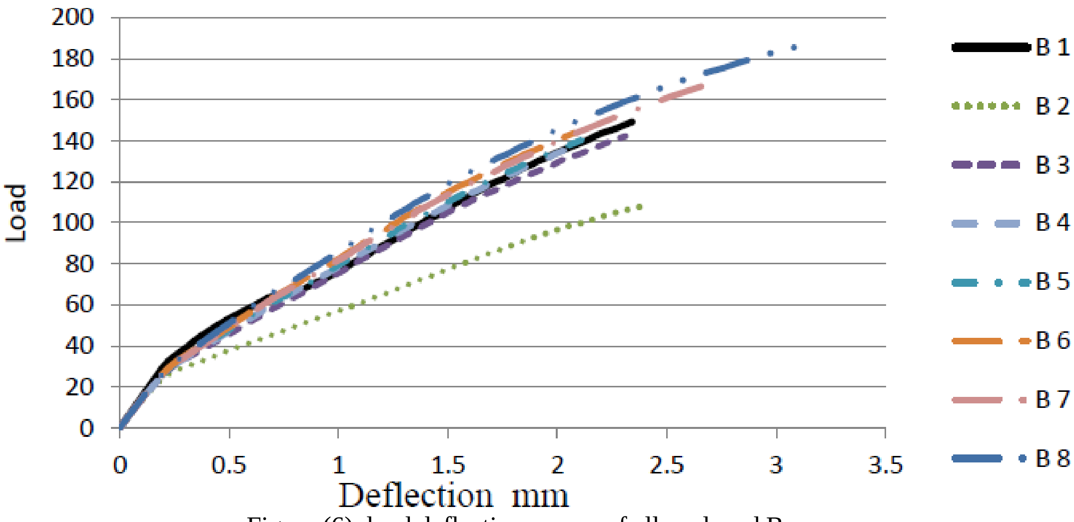

Figure (6) load deflection curves of all analyzed Beams

Crack patterns and stresses distribution

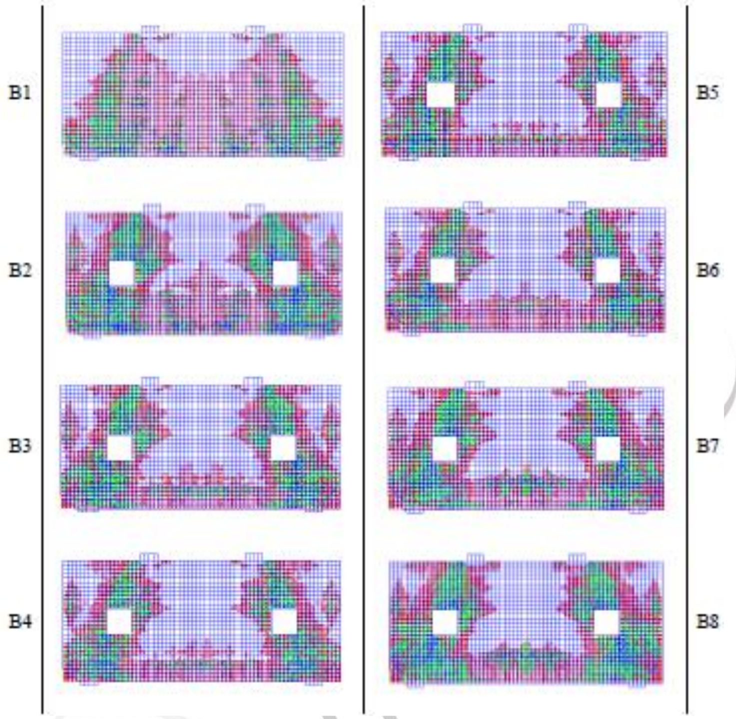

Figure (7) crack pattern for all analyzed Beams

Fig. (7) show the distribution of the crack in different cases of beams under study. The presence of an opening in the deep beams increased cracks in the area between the side of the beam and under the opening. The steel jacket at the tensioning zone at the bottom of the beam worked to reduce the cracking density at the bottom of the opening. Increasing the height of the jacket branch worked to increase the load of the beam, and this was accompanied by an increase in cracks on the sides of the deep concrete beams.

Steel jacket design proposal

Based on our understanding of the behavior of deep concrete beams, we find the following creating an opening in a deep concrete beam changes the shape of the proposed truss and follows a decrease in the height of the truss as shown in Fig (8). As a result of this deficiency, there is an increase in the force acting on the tie, which leads to the arrival of steel to the yielding point and there is lead to the collapse of the oblique side of the truss. After that, the load begins, taking a new path to reach the support, which is the path between the edge of the beam and the opening. As a result, there is no reinforcement at this zone, which serves the movement of the load, the collapse is achieved with an increase in the load. Thus, adding the steel jacket to the beam works to strengthen the tie and by reaching the Perfect Bond between the jacket and the beam, as well as taking the jacket closed box, so the jacket works to curry tension with the tie. By calculating the increase in tension force over the tie we can design the steel jacket as equation (1).

$$S = \frac{P * a\,(1/K\,fyj - 1/d\,fy)}{b + 2H} \quad mm \quad ....(1)$$

Were (P) shear load of beam, (a) distance between load and support, (K) distance between bottom edge of opening and the center of tie, (fyj) yielding stress for steel jacket, (d) depth of beam, (fy) yielding stress for steel bars, (b) breadth of beam and (H) height of jacket branch.

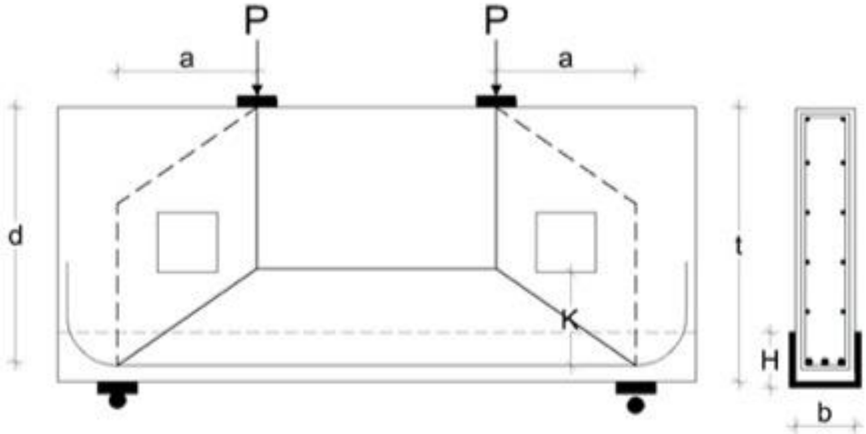

Figure (8) idolization truss for deep concrete beam with openings

Conclusions

Creating an opening in the deep concrete beams significantly reduces the load of the beam. According to the theoretical study, the installation of a steel jacket in the tensile area of the deep concrete beams is a very effective solution for strengthening the beams. Accordingly, if you want to create an opening in deep concrete beams, then you should design the steel jacket and then fabricate and install it, and you must verify the strength of the bond between the jacket and the beam by using epoxy and nails. When designing a steel jacket, the height of the branch should belong as much as possible, and the thickness of the plate used in making the jacket should not be less than 2 mm.

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