Numerical analysis of ultimate load and crack propagation in a concrete beam with longitudinal small hole

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Abstract. This analytical study aims to investigate the flexural behavior of simply supported RC beams having longitudinal hole with circle cross section under monotonic two point loads. The commercial FE program ABAQUS was used for simulating and implementing the specimens behavior that tested experimentally in previous researches. The overall specimens investigated were thirteen RC rectangular beam specimen, the first one was solid while the others with longitudinal circular hole. The specimens with holes divided into three groups, each one has a specified hole diameter 25 mm, 40 mm, and 50 mm. The distance from center of hole to the top section face was variable where the hole would be completely in the stress block, below it, or partially within it. The validity of the simulated model were verified by comparing the available load deflection data with the implemented one, where good agreement were noticed. The simulated models could introduce the ultimate load, first cracking load and its propagation in addition to the maximum attended deflection. It is concluded that the existence of a longitudinal hole with a percentage of diameter to beam depth ratio below 20% with different positions from top surface of the cross-section to the center of the hole values caused decreasing in ultimate load not exceeding 5% compared with the solid beam.

Keywords: Small longitudinal opening, deflection, first cracking load, depth of opening, diameter of opening.

1. Introduction
The need to exist or produce holes and openings in the structural elements has become a necessity in many nowadays structures. So, researchers have been attracted to investigate the behavior of such structural elements. Practically, the use of openings has many benefits such as satisfying requirements of passage of electrical and mechanical works, and also leads to reduce the storey height and the overall weight of the structure. The shape of the hollow that could be generated in the RC beams may be circular, diamond, triangular, trapezoidal, rectangular, or either irregular shapes. But the most commonly used are the rectangular and circular holes [1–3]. Therefore numerous researchers attempt to investigate the behavior of beams having holes or openings with different shapes, dimensions and positions either experimentally or numerically [4–7].

Jacob and Bincy (2018) studied experimentally the effect of different diameters of the circular hole (32, 40, and 50 mm) with different positions from bottom reinforcement (3 to 4 cm). The study noted
that the reduction of load capacity caused by the presence of the hole is slight and does not appreciable. So, the RC hollow beam can be used safely when the capacity required is relatively smaller [8]. Hassan and Salman (2018) [9] modeled the reinforced concrete hollow beam by ANSYS, where two values of the hole diameter (50 and 75 mm) and two central distance from the top face (160 and 180 mm) were adopted. The study involved a comparison between the behavior of normal concrete beam with those containing steel fiber. The maximum difference obtained of ultimate load between experimental and FE was about 18%. Also the study found that load-deflection curves obtained from the FE were stiffer compared with experimental results and that were due to neglecting concrete toughening mechanism.

Abtan and AbdulJabbar (2019) utilized solid and hollow beams with square longitudinal hole and investigate the effect of hole position in mid and bottom section [10]. Ismail El-kassas et al (2020) executed an investigation on deep beams with longitudinal openings. The study involved two shapes of holes (circular and square) with different size, and two positions of hole which is tension and compression zone. It was deduced that the existence of longitudinal hole in a deep beam reduced the beam load capacity, while the variation of hole shape has slight effect. But the reduction when the hole is in the compression zone is more than of beams with holes in the tension zone [11].

Othman et al (2020) showed close results between experimental and simulated model by ANSYS of hollow foamed concrete beams. It were deduced that the behavior of hollow beam with circular hole shape was better than the behavior with square hollow section [12]. The information about solid reinforced concrete beams and also beams having transverse openings are rather available from experimental or finite element investigation, while still the information is limited about the reinforced concrete beam with a longitudinal hole (hollow beam).

Recently, it has been recognized that the use of software based on the Finite Element Method (FEM) can deal with different engineering problems, and establish sensible and acceptable solutions of reinforced concrete (RC) nonlinear behavior. Hence, the FE software ABAQUS has been utilized to study the behavior of a RC solid beam and beams having a longitudinal hole with different diameter and position, which is subjected to two point load action.

2. Test specimens

To simulate a reinforced concrete beam with a longitudinal hole, two experimental studies performed by Murugesan and Narayanan (2017, 2018) [13][14] were chosen as a reference studies. In general, there are three possible positions of the longitudinal hole in the cross-section of the beam, below the stress block, within the stress block fully or partially. These cases arranged in three groups, each one has four hollow beams in addition to a solid one, as in Figure 1. All details of the tested beams subjected to two point load are stated in Table 1. The dimensions of each tested beam were 1700×150×250 mm. Where the ratio a/d (length of shear zone to the effective depth) is 2.69 as presented in Figure 2. The diameter of the circular longitudinal hole was taken equal to 25, 40, and 50 mm with different positions from top surface of the cross-section to the center of the hole (C'), which were 45, 55, 65, and 180 mm, as shown in Figure 2. The mix proportion adopted to produce M20 grade concrete by weight was 1:1.72:3.2:0.5 (cement, fine aggregate, coarse aggregate, water to cement ratio), where the initial materials used conformed to Indian Standards. Steel bars of Fe415 grade were used for reinforcing the beams. 12 mm rebars (three as tension and two as compression) reinforcement were used.
Table 1. Designations and details of the tested beams [13].

| No. | Designation | Diameter of hole mm | Distance from center of hole to the top |
|-----|-------------|---------------------|----------------------------------------|
| 1   | SF1 (solid) | 0                   | 0                                      |
| 2   | F1H25I      | 25                  | 45                                     |
| 3   | F1H25MI     | 25                  | 55                                     |
| 4   | F1H25MO     | 25                  | 65                                     |
| 5   | F1H25O      | 25                  | 180                                    |
| 6   | F1H40I      | 40                  | 45                                     |
| 7   | F1H40MI     | 40                  | 55                                     |
| 8   | F1H40MO     | 40                  | 65                                     |
| 9   | F1H40O      | 40                  | 180                                    |
| 10  | F1H50I      | 50                  | 45                                     |
| 11  | F1H50MI     | 50                  | 55                                     |
| 12  | F1H50MO     | 50                  | 65                                     |
| 13  | F1H50O      | 50                  | 180                                    |

Figure 1. Positions of the hole: (a) below the stress block, (b) within the stress block, (c) partially within the stress block [13].

Figure 2. Specimens details: (a) loading type, (b) diameters and positions of the holes [13].
3. Models simulation

On the basis of the main objectives of the present study, 3-dimensional Finite Element models of RC solid beam (without hole) and beams with a longitudinal hole have been sophisticated. The ABAQUS program [15] has been chosen for simulating and analyzing the considered RC beams, due to its capability and flexibility of dealing with structural elements. The symmetry condition has adopted and half of the beam in the longitudinal direction has depended which leads to reducing the number of elements and time-consuming for running.

The specimen named SF1 which is solid and doesn't have a hole is used as a reference to verify the modeling. The ratio of the shear zone to the effective depth of the cross-section (a_v/d) is taken 2.69 constant for all specimens (d=219 mm, a_v=589.11 mm).

3.1 Elements

Hexahedral 8-node elements (brick) with three degrees of freedom – which are translations in X, Y and Z directions - in each node are used for concrete modeling with reduced integration technique (C3D8R) to avoid the shear locking effect. While, linear truss elements with 2-nodes (T3D2)-each node has three degrees of freedom- are utilized to represent the reinforcements. A perfect bond between reinforcement and surrounding concrete is used to model the reinforcement-concrete bonding interaction properly. The effects typically associated with a reinforcement-concrete interface, including bond slip and dowel action, are implicitly defined in the reinforced concrete model by describing “tension stiffening” in order to approximately simulate load transfers through cracks through the rebar. [15].

3.2 Methodology of Analysis

The relation joint specimens are studied using Finite Element Analysis (FEA) in a nonlinear static analysis format, where, material and geometric nonlinearities are taken into account. In a nonlinear analysis, the total specified loads that acting on a finite element structure would be divided to a number of load increments. The structure is in estimated equilibrium at the end of each increments and the structure's stiffness matrix will be updated in order to take into account the nonlinear changes in the stiffness of the structure.

3.3 Concrete Damage Plasticity (CDP) Model

The concrete damage plasticity model (CDP) is utilized widely to represent the inelastic behavior of reinforced concrete structures, due to its ability to clarify and trace the failure mechanism. It is based on the incorporation proposed by Lubliner et al. [16] and Lee and Fenves [17]. The model assessed the isotropically damaged elasticity with isotropic tension and compression plasticity [15]. It supposes the essential mechanics of failure are tensile cracking mechanism and compressive crushing mechanism of the concrete material. The development of failure surface is guided by two hardening variables associated to failure mechanisms under two loading condition: tension and compression respectively.

3.4 Modeling of Materials

3.4.1 Modeling of Concrete Material

The compressive behavior of concrete under uniaxial compressive load is modeled by using a Hognestad type parabola [18] which can be noticed in Figure 3a. It is able to categorize the uniaxial stress-strain behavior of concrete into three major domains. First one is the linear-elastic stage that proceeds to reach the σ_{c0}-stress level, which is taken as σ_{c0} = 0.4 f_c. The second stage demonstrates the hardening part of the concrete uniaxial compressive stress-strain behavior that explains the rising branch reaching to the peak load at the corresponding strain level ε_0 = 2f_c/E_c. The post-peak softening behavior is characterized by the final part of the concrete uniaxial compressive stress-strain relation.

For modeling tensile behavior of concrete, tension stiffening sub-option in concrete should be specified. Either stress-strain or stress-displacement can be utilized the tension stiffening. According to Hibbit et al. [15], strain-stress tensile stiffening in concrete elements in regions where adequate reinforcing is not applied indicates excessive mesh sensitivity in findings. So, the tensile stiffening
function should be redefined when the element mesh size is modified. As a consequence, a stress-
displacement technique is advised. Figure 4a explains the bilinear tension softening model [19] which
is utilized to find the stress-displacement relation that used in the present study.

The uniaxial compressive and tensile conduct of concrete utilized in the CDP model for the present
study can be shown in Figures 3b and 4b respectively. The stiffness degradation in this model is isotropic
which is designated by the damage parameters, (dc) in the compression area and (dt) in the tension area,
see Figure 5. These variables change in limits (0 to 1) where zero mean undamaged material and 1 refers
to completely lost of the material strength. The following equations were used to calculate the damage
parameters [20]:

\[ d_c = 1 - \frac{\sigma_t}{\sigma_{tu}} \]  
\[ d_c = 1 - \frac{\sigma_c}{\sigma_{cu}} \]

Where: \( \sigma_c \): concrete stress in compression  
\( \sigma_{cu} \): ultimate concrete stress in compression  
\( \sigma_t \): concrete stress in tension  
\( \sigma_{tu} \): ultimate concrete stress in tension

The primary CDP parameters values especially dilation angle (\( \psi \)) and viscosity (\( \mu \)) were instituted
on previous recommendations [21–23] then calibrated with the experimental results. The parameters of
CDP adopted in the FE analysis model are listed in Table 2. Further information for these parameters is
explained in the ABAQUS user’s manual.

![Figure 3](image1.png)  
**Figure 3.** Concrete response to uniaxial compression loading: (a) Hognestad type parabola[18], (b) compressive stress-inelastic strain relation that used in the present study.

![Figure 4](image2.png)  
**Figure 4.** Concrete response to tensile loading: (a) Bilinear tension softening [19], (b) Stress-displacement relation that used in the present study.

\( G_f \): is fracture energy of the concrete.
Figure 5. Damage behavior of concrete, (a) In compression, (b) In tension.

Table 2. The parameters of CDP adopted in the model.

| Parameter         | Value       |
|-------------------|-------------|
| Dilatation angle  | 35          |
| Eccentricity      | 0.1         |
| $f_{0.2}/f_{c0}$  | 1.16        |
| $k$               | 0.66667     |
| $\mu$ (viscosity) | 0.00001     |

3.4.2 Modeling of Reinforcement. In order to define steel bars of Fe415 grade, elastic and plastic behavior parameters must be inputted. For elastic stage, Young modulus ($E$) and Poisson’s ratio ($\nu$) were specified based on the typical values. While, the typical values of yield and ultimate stresses and the corresponding plastic strains were used to define the steel bars plastic behavior. True stress and the logarithmic strain should be described according to Hibbit et al [24]:

$$\sigma_{\text{true}} = \sigma_{\text{nominal}}(1 + \epsilon_{\text{nominal}})$$

$$\epsilon_{\text{in}}^{\text{pl}} = \ln(1 + \epsilon_{\text{nominal}}) - \frac{\sigma_{\text{true}}}{E}$$

Table 3 describes the steel bars properties that used in ABAQUS.

Table 3. Material properties for steel reinforced bars.

| Parameter | Value       |
|-----------|-------------|
| E (GPa)   | 200         |
| $\nu$     | 0.3         |
| Yielding  | 422.902     |
| Ultimate  | 527.314     |
| $\sigma_{\text{true}}$ (MPa) | 0.06478 |
| $\epsilon_{\text{in}}$ | 0.00001 |

3.5 Mesh Size

Different sizes of mesh were examined to specify optimal mesh density. Based on the ultimate load and cracking load of the tested beams, a 15 mm mesh size was adopted. According to Mohammed H et al [25] and many other researcher, generally FE analysis affected by the mesh size to some extent. That appears within the results of a case study done, revealed that 25 mm to 15 mm mesh size has a very slight difference on ultimate load and maximum deflection and no effect on the load-deflection curve (that can be attributed to the full interaction between concrete and reinforcement assumed in FE model). On the other hand, fine mesh gives a clear cracking appearance, as will presented later.

Relevant boundary conditions are carried out in the simulation sample, taking into account the symmetry where half of the beam was considered for the beam analysis. Figure 6 shows mesh, boundary conditions, and loading. The simulations of the present model can be adopted in validating and
developing the experimental work, where the present study demonstrates the investigation of the concrete beam response having a longitudinal hole with different diameters and also a different depth to the hole center (C’) under two-point loading.

4. Results and discussion

The results of FE simulation in ABAQUS program of a solid and hollow RC beams explained above are specified and discussed in this section.

4.1 Load-Deflection Behaviors

The load-deflection diagrams generally indicate the reasonable interpretation of the overall behavior of the beams, so they were used to verify the numerical simulation of the tested beams. The solid specimen (SF1) and three beams with longitudinal hole symbolized as (F1H25I, F1H40I, F1H50I) experimentally tested by Murugesan and Narayanan (2018) [14], were simulated numerically and introduced in the present work as shown in Figures 7-10. These figures present rather more stiff behavior at the primary linear stage by FE analysis, that's may attribute to experimental conditions and any assumptions involved in simulating numerical model such that boundary conditions, type of interaction assumed between concrete and reinforcement, and any other perfect conditions assumed in the numerical model. Although it can be an indication of the overall behavior of such type of concrete beam with a longitudinal hole.

Firstly, at the elastic stage, the behavior is linear up to the initial cracking load. Then, new cracks appeared and continued up to the first yield point, which are flexural cracks. As loading was continued, plastic deformation increased up to failure condition, where the deflection increased without additional load capacity. The flexural behavior of the same specimens with a different hole distance from the top face of the beam (C’) was investigated in the present study as shown in Figures 11-13. It can be observed that there are slight differences and insignificant effects of (C’) on the overall behavior of the beams with the longitudinal hole. That’s can be attributed to the small hole diameter where the percentage of the maximum diameter of the holes adopted in the study to the depth of the beam does not exceed 20% and can be considered a small opening according to Hafiz et al and Mansur [26,27].
Figure 7. Load-Deflection curves of SF1 specimen.

Figure 8. Load-Deflection curves of F1H25I specimen.

Figure 9. Load-Deflection curves of F1H40I specimen.

Figure 10. Load-Deflection curves of F1H50I specimen.

Figure 11. Load-Deflection curves of specimens F1H25 (I, MI, MO, O).

Figure 12. Load-Deflection curves of specimens F1H40 (I, MI, MO, O).

Figure 13. Load-Deflection curves of specimens F1H50 (I, MI, MO, O).
4.2 Cracking Load and Ultimate Strength

The thirteen specimens subjected to two-point monotonic loading revealed a flexural failure when analyzed by finite elements and that's agreed with experimental results by Murugesan and Narayanan [13]. The first cracking load appeared in the region of maximum bending moment. Table 4 shows the amounts of the loads had caused the first crack predicted by finite elements and also listed the results observed experimentally and theoretically by Murugesan and Narayanan [13]. The maximum observed variation was not exceeding absolutely 13% than both the theoretical and experimental values. So, the results of the simulated model could be considered with some confidence. The models show the gradual propagation of cracks from bottom to top face as the load increases until failure happened with clear appearance especially with the rather fine mesh size, see Figure 16. Table 4 and Figure 14 show the difference in predicting the first cracking load resulted theoretically, experimentally, and numerically.

Tracing the crack patterns is significant to satisfy premature prediction of a serious situation and for fulfilled early treatment [28]. Figure 16 shows the cracking patterns of four specimens predicted by FE at the ultimate state of each one, where the photos on the right gave an outer look of the crack whereas the left photos show an inside look of the crack passing through the hole.

Generally, for each specimen, the theoretical values of the first cracking load are rather smaller than the other two values. So it can be considered conservative. While, the experimental and numerical first cracking load are converged obviously for specimens with a longitudinal hole and the difference of them is below 6%. As shown in Figure 16 the cracks started their propagation from the bottom flexural region toward the top. Then the cracking region increased and the cracks propagated around the existing hole. According to the present study, the existence of a small hole had no clear effect on the magnitude of the first cracking load or acceleration of its occurrence. It could say the longitudinal hole with a ratio of hole diameter to the depth of the beam section below 20% could be utilized without additional requirements.

The ultimate load (Pu) values also present the same scenario of the first cracking load, where the theoretical values are also conservative, and the experimental and numerical values of (Pu) are so converged and the differences between them do not exceed 4%, see Table 5 and Figure 15. The existence of a longitudinal hole with a percentage of diameter to beam depth ratio below 20% (small opening) with different (C') values caused decreasing in ultimate load not exceeding 5% compared with the solid beam. From these tables and figures, it can be observed that the first cracking load is about 20% of the ultimate load. So, the first cracking load and ultimate load of a concrete beam with a longitudinal small hole can be predicted well by FE analysis. Obtaining numerical results close to practical results help in understanding the behavior of beams without the need for laboratory tests. This program can be developed to clarify the behavior of other beams with a ratio of the diameter of hole to the depth of the beam section of more than 20%.
Table 4. First cracking loads.

| Sample   | T. Fcr (kN) | FE. Fcr (kN) | E. Fcr (kN) | FE. Fcr /T. Fcr | FE. Fcr / E. Fcr |
|----------|-------------|--------------|-------------|-----------------|-----------------|
| SF1      | 23.316      | 25.47        | 28          | 1.092           | 0.910           |
| F1H25I   | 21.207      | 23.83        | 24          | 1.124           | 0.993           |
| F1H40I   | 20.912      | 23.63        | 24          | 1.130           | 0.985           |
| F1H50I   | 20.613      | 23.01        | 22          | 1.116           | 1.046           |
| F1H25MI  | 21.597      | 23.81        | 24          | 1.102           | 0.992           |
| F1H40MI  | 21.391      | 23.41        | 24          | 1.094           | 0.975           |
| F1H50MI  | 21.184      | 22.97        | 22          | 1.084           | 1.044           |
| F1H25MO  | 21.993      | 24.59        | 26          | 1.118           | 0.946           |
| F1H40MO  | 21.871      | 24.21        | 24          | 1.107           | 1.009           |
| F1H50MO  | 21.742      | 22.93        | 22          | 1.055           | 1.042           |
| F1H25O   | 22.591      | 24.86        | 26          | 1.100           | 0.956           |
| F1H40O   | 22.177      | 24.75        | 26          | 1.116           | 0.952           |
| F1H50O   | 21.779      | 23.98        | 24          | 1.101           | 0.999           |

* T. Fcr: First cracking load theoretically, FE. Fcr: First cracking load by Finite element, E. Fcr: First cracking load experimentally.

Figure 14. The difference in predicting the first cracking load.
Table 5. Ultimate loads.

| Sample   | T. $P_u$ (kN) [13] | FE. $P_u$ (kN) | E. $P_u$ (kN) [13] | FE. $P_u$ / T. $P_u$ | FE. $P_u$ / E. $P_u$ |
|----------|---------------------|----------------|---------------------|-----------------------|-----------------------|
| SF1      | 93.812              | 119.74         | 120                 | 1.276                 | 0.998                 |
| F1H25I   | 92.862              | 117.29         | 118                 | 1.263                 | 0.994                 |
| F1H40I   | 92.080              | 117.84         | 114                 | 1.280                 | 1.034                 |
| F1H50I   | 91.159              | 116.49         | 112                 | 1.278                 | 1.040                 |
| F1H25MI  | 93.497              | 116.61         | 120                 | 1.247                 | 0.972                 |
| F1H40MI  | 93.144              | 116.48         | 116                 | 1.251                 | 1.004                 |
| F1H50MI  | 92.464              | 117.09         | 114                 | 1.266                 | 1.027                 |
| F1H25MO  | 93.54               | 118.26         | 120                 | 1.264                 | 0.986                 |
| F1H40MO  | 93.444              | 119.03         | 116                 | 1.274                 | 1.026                 |
| F1H50MO  | 93.233              | 117.54         | 114                 | 1.261                 | 1.031                 |
| F1H25O   | 93.73               | 115.84         | 120                 | 1.236                 | 0.965                 |
| F1H40O   | 93.73               | 117.35         | 116                 | 1.252                 | 1.012                 |
| F1H50O   | 93.73               | 116.10         | 116                 | 1.239                 | 1.001                 |

Figure 15. The difference of predicting the ultimate load.
4.3 Maximum deflection

Table 6 and Figure 17 expose the final deflection of the RC beams with and without longitudinal hole analyzed in the present study. The first four samples show a comparing between the deflection recorded experimentally by Murugesan A and Narayanan[14] and ones that achieved numerically in the present study, where the maximum difference does not exceed 13% for the specimen F1H40I and less than 5% for the other three specimens. The final deflection of the latest nine specimens with longitudinal hole have different diameters and different depth of hole (C') were analyzed in the present study and introduced here.

Figure 16. Crack patterns of four specimens.
Table 6. Deflection differences.

| Sample | Exp. Def. (mm) | FE. Def. (mm) | FE. Def./ Exp. Def. | Diff. (Exp. & FE. Def.) % |
|--------|----------------|---------------|---------------------|--------------------------|
| SF1    | 11.9**         | 12.23         | 1.028               | 2.77                     |
| F1H25I | 11.8**         | 12.30         | 1.042               | 4.24                     |
| F1H40I | 12.3**         | 13.87         | 1.128               | 12.76                    |
| F1H50I | 11.3**         | 10.82         | 0.958               | -4.25                    |
| F1H25MI| N/A            | 11.23         | -                   | -                        |
| F1H40MI| N/A            | 11.09         | -                   | -                        |
| F1H50MI| N/A            | 12.08         | -                   | -                        |
| F1H25MO| N/A            | 11.09         | -                   | -                        |
| F1H40MO| N/A            | 12.10         | -                   | -                        |
| F1H50MO| N/A            | 13.92         | -                   | -                        |
| F1H25O | N/A            | 9.06          | -                   | -                        |
| F1H40O | N/A            | 13.02         | -                   | -                        |
| F1H50O | N/A            | 10.36         | -                   | -                        |

* Exp. Def.: Ultimate experimental deflection, FE. Def.: Ultimate deflection by finite element, Diff. (Exp. & FE. Def.) %: Percentage of deflection difference obtained experimentally and numerically. ** from the reference [14].

5. Conclusions

On the basis of the present study involved FE analysis of 13 RC beams (with and without longitudinal small hole) having different diameters and different depths of hole center from the top beam face (C'), the following conclusions can be depicted:

1. The numerical simulation demonstrated by using the program ABAQUS for a solid RC beam and twelve RC beams with longitudinal small hole (involving different diameters and different
distance \( C' \), can give an indication of the overall behavior of such type of concrete beam with a longitudinal hole.

2. The maximum diameter of holes adopted in the present study to the depth of the beam does not exceed 20%, so it could be considered a small opening.

3. There is a slight effect of the distance from the top face of the beam to the center of the hole for the same specimen on the load-deflection behavior.

4. The experimental and numerical first cracking load and also the ultimate load parameter are convergent clearly for specimens with a longitudinal hole, where the difference are below 6% and 4% respectively. So, the first cracking load and ultimate load of a RC beam with a longitudinal small hole can be predicted well by FE analysis.

5. The existence of a longitudinal hole with a percentage of diameter to beam depth ratio below 20% with different \( (C') \) values caused decreasing in ultimate load not exceeding 5% compared with the solid beam.

6. It can be observed that the first cracking load of the RC beam (with and without longitudinal hole) is about 20% of the ultimate load recorded.

7. Future study may include FE analysis of RC beams with a longitudinal hole where the ratio of hole diameter to the depth of the beam more than 20% and also may take the effect of hole section shape into consideration.

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