World Academy of Science, Engineering and Technology
International Journal of Civil and Environmental Engineering
Vol:12, No:11, 2018

Investigation on Behavior of Fixed-Ended Reinforced Concrete Deep Beams

Y. Heyrani Birak, R. Hizaji, J. Shahkarami

***Abstract*—**Reinforced Concrete (RC) deep beams are special structural elements because of their geometry and behavior under loads. For example, assumption of strain- stress distribution is not linear in the cross section. These types of beams may have simple supports or fixed supports. A lot of research works have been conducted on simply supported deep beams, but little study has been done in the fixed-end RC deep beams behavior. Recently, using of fixed-ended deep beams has been widely increased in structures. In this study, the behavior of fixed-ended deep beams is investigated, and the important parameters in capacity of this type of beams are mentioned.

***Keywords*—**Deep beam, capacity, reinforced concrete, fixed-ended.

I. Introduction

GENERALLY reinforced concert beams are classified as ordinary and deep beams according to their span/depth ratios. The span/depth ratio of beams is very important. According to the ACI 318-14 [1], the beams with span to depth ratio less than 4 are categorized as deep beams. However, the behavior of beams is also influenced by the other factors such as concrete strength, reinforcement characteristics, support conditions, and the location of load that is applied. For the design of simply supported RC deep beams, the ACI 318 code has recommended strut-and-tie method (STM), but currently, there are no design documents written specifically for the RC deep beams with fixed-end supports.

It is considered that the fixed-ended or partially fixed-ended conditions in the RC deep beams are more likely to occur in actual structures than simply supported end conditions. For example, in buildings, the coupling beams in shear walls are effectively fixed-ended, and the fixity will be provided by the transverse walls as shown in Fig. 1. Other examples of fixed or partially fixed-end conditions are deep beams supported on heavy columns, and continuous deep beams supported with columns as illustrated in Fig. 2.

In the past, considerable research works have been done on simply supported concrete deep beams, but fixed-ended supported conditions have scarcely been investigated [2]. This is maybe occurred because of complexity in the structural behavior of RC fixed-ended deep beams.

Regarding to the tendency for the application of deep beams, possibility of using fixed-ended deep beams are increased in some structures. Therefore, it seems necessary to investigate the aforementioned structural element in more details.

In this paper, the behavior of fixed-ended deep beams that are important in the capacity is illustrated.

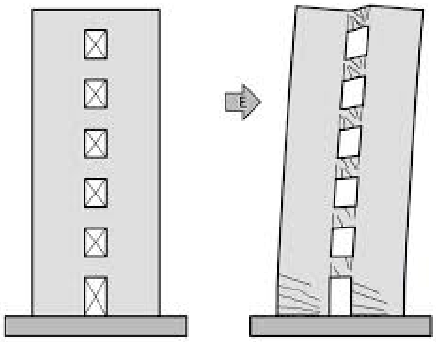

Fig. 1 Beams supported on concrete shear walls

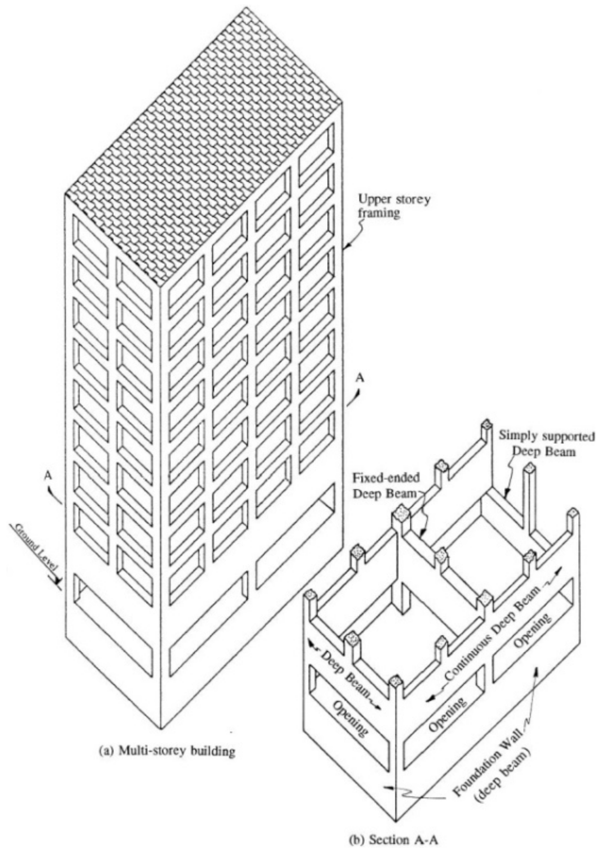

Fig. 2 Continuous deep beams supported on concrete columns

Rouhollah Hizaji is the PhD candidate of Structural engineering in Tarbiat Modares University (e-mail: rouhollah.hizaji@modares.ac.ir).

II. Category of Deep Beams

RC deep beams are classified in four categories according to their boundary conditions; simply supported, continued, cantilever, and fixed-ended deep beams. Also, it should be mentioned that each category of deep beams should be designed by a different method. These categories are described as follows:

A. Simply Supported Deep Beams

This type of deep beams often is supported on two columns like the deep beams of bridge that are located on the columns with neoprene [3]. This type of deep beams often has a shear behavior in structural elements. Fig. 3 shows the schematic of RC simply supported deep beam.

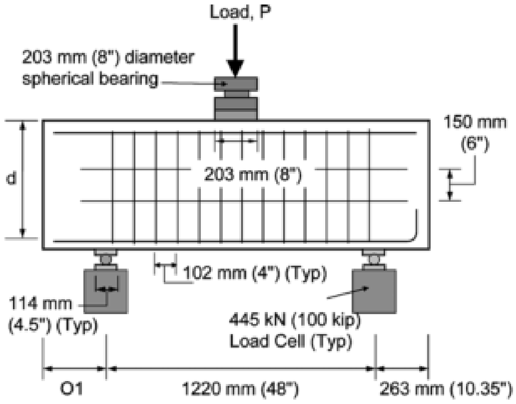

Fig. 3 Schematic of simply supported deep beam

In this beam, when the load is applied on the beam from above, the bottom of beam tolerates tension stress, so some steel bars are need for controlling tension stress.

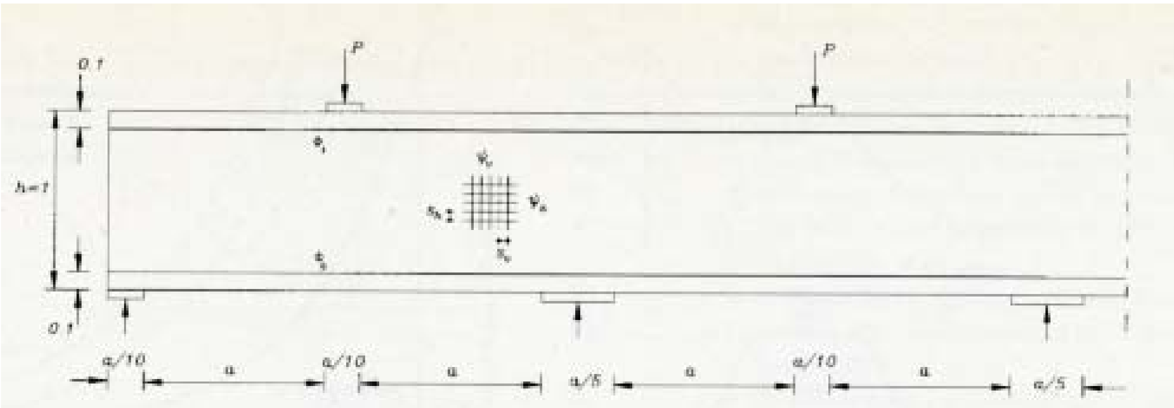

Fig. 4 Schematic of continuous deep beam

B. Deep Beams with Continuous Span

This type of deep beams located between some columns has more than one span and the first and end span have a simple support, but other spans have fixed or partially fixed supported [4]. Fig. 4 shows the schematic of RC continues deep beam.

C. Cantilever Deep Beams

Cantilever deep beams are spatial deep beams that are supported on one side of beam. This type of beams often has flexural and shear behavior, so steel bars are needed in the top and bottom of beam. Fig. 5 shows the schematic of RC cantilever deep beam.

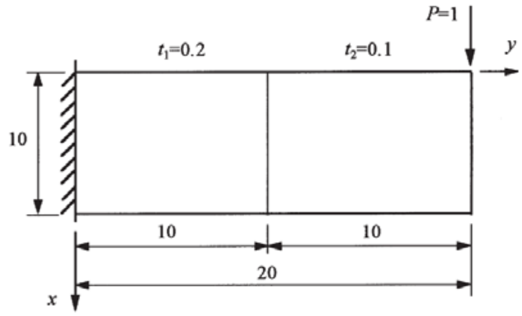

Fig. 5 Schematic of cantilever deep beam

D. Fixed-Ended Deep Beams

This type of beam has a behavior similar to the continued deep beams. These beams are supported by heavy columns or walls. The structural behavior of fixed-ended deep beams is flexural plus shear action, and the strip bars have significant effects in the capacity of these beams. Fig. 6 shows the schematic of RC fixed-ended deep beam.

III. Behavior of Deep Beams

The behavior of deep beams is quite different from the ordinary beams because the distribution of stress on section does not remain linear when the height of beam increased in constant span. This change in the distribution of stress on the section has been shown in Fig. 7.

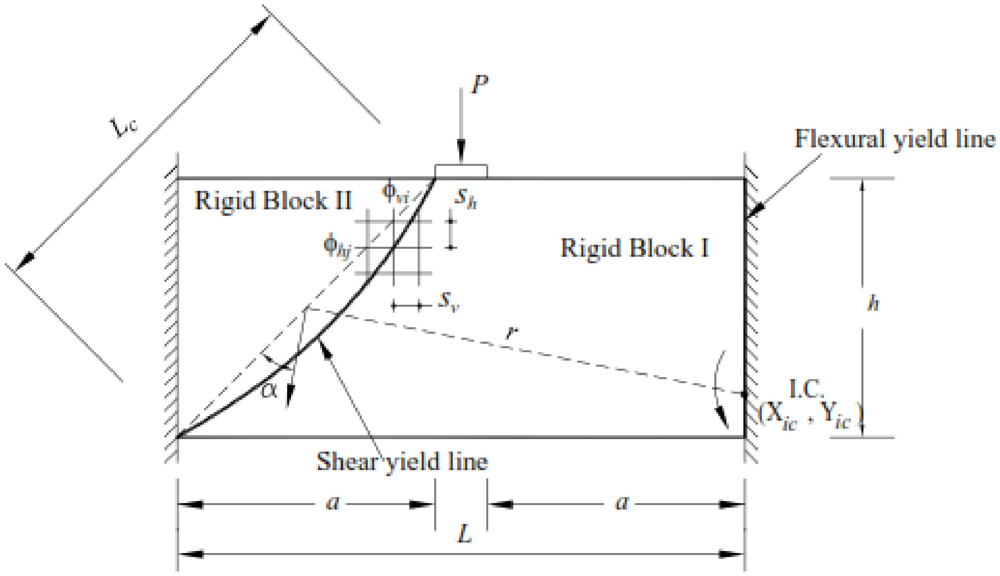

Fig. 6 Schematic of fixed-ended deep beam

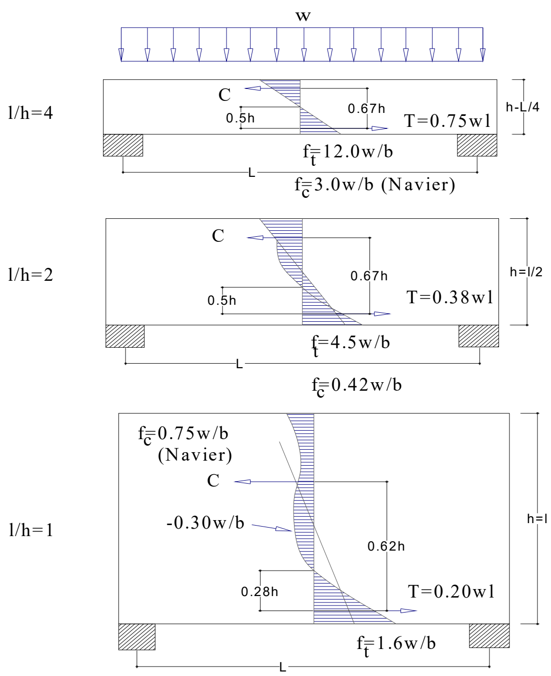

Fig. 7 Distribution of stress on the section of beam with increasing height

The contour of stress in deep beams will be also changed according to different type of loading because the behavior of deep beams for loading from top and bottom is different. Fig. 8 shows the contour of stress in the face of deep beams according to their loading. In this contour, filled lines are used for the tension stress, and dash lines are for the compression stress.

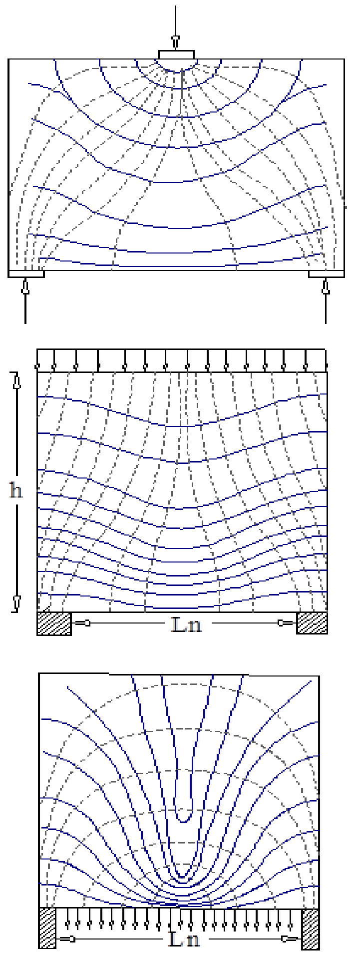

Fig. 8 Contour of stress on the face of deep beam

IV. Modes of Failure in Fixed-Ended Deep Beams

Three different modes of failure were identified for RC fixed-ended deep beams in the literature [5]. The parameters which are more important in failure modes are: a) the amount of top and bottom reinforcement; b) the concrete strength; c) the shear span to depth ratio; d) the amount of web reinforcement; e) the overall geometry and the position of loading. Thus, the failure modes are described in the following [5]:

A. Flexure plus Shear Failure Mode

This type of failure occurs in the beam with minimum amount of top reinforcement about 0.002bd where b and d are the beam thickness and the effective depth, respectively. The failure occurs when the major diagonal and flexural cracks are formed together with crashing concrete at the ends of major diagonal cracks. Fig.9 shows this type of failure.

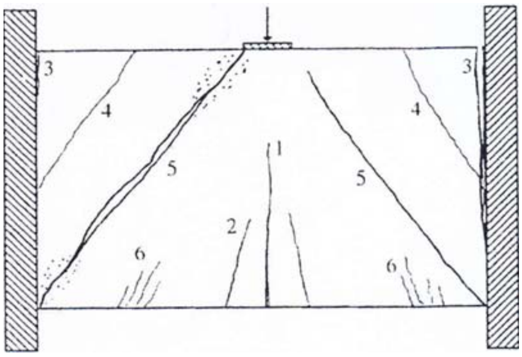

Fig. 9 Schematic shape of flexure plus shear failure mode

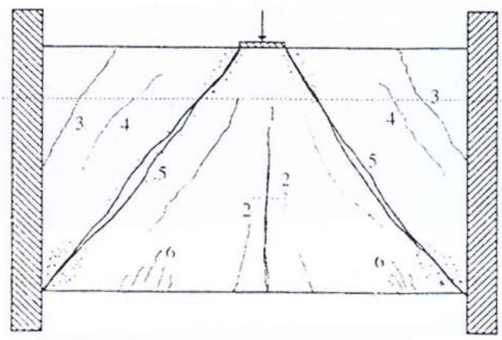

Fig. 10 Schematic shape of shear failure mode

A. Shear Failure Mode

The shear failure mode occurs in the absence of flexural cracks at the fixed-ended supports. In this mechanism, after the formation of initial flexural cracks at the mid span of beam, the diagonal cracks appeared and caused the excessive spalling and crashing of the concrete at the edges of the loading patch and the lower corner of beam. Fig. 10 shows the shear failure of fixed-ended deep beams.

B. Bearing Failure Mode

When the area of loading is not enough to distribute the applied load, reinforcement concrete deep beams are vulnerable to bearing failure under the applied load. This failure is basically a local failure and it is preventable with suitable detailing around the loading area, so the load can be distributed into the body of beam without overstressing locally. The bearing failure mode is presented in Fig. 11.

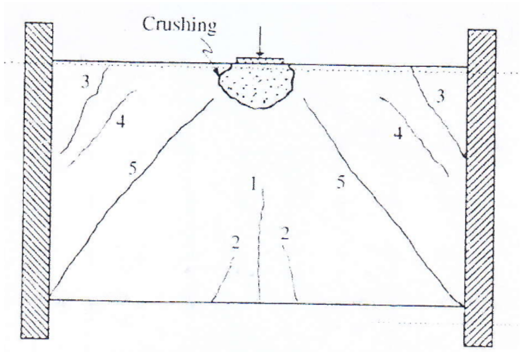

Fig. 11 Schematic shape of bearing failure mode

It should be mentioned that the failure modes in fixed ended deep beams are little different from the simply supported deep beams. Because simply supported deep beams have also buckling failure modes in addition to these failures.

V. Designing of Deep Beams

One of practical methods for designing the deep beams is STM that is acceptable by most of international codes like ACI-318, AASHTO-LRFD, and CSA A23.3-94. STM is a simplified analytical method that the comparison force is tolerated by diagonal concrete strut and tension stress is tolerated by bottom reinforcements as shown in Fig. 12.

For the fixed-ended deep beams, the international codes do not suggest any analytical STM method, but Arabzadeh [6] achieved to develop analytical STM method for fixed-ended deep beams. In this method, unlike the simplified supported deep beams, the strip is considered in the capacity of fixed-ended deep beams, if they are steeper than 60 degrees. Fig. 13 shows the schematic of STM method for fixed-ended deep beams.

Considering the effect of strips in the capacity of this beams are caused, the fixed-ended deep beams sustain loads for 6 times in comparison with simply supported deep beams [5].

VI. Conclusion

Based on the above study and discussions, the following conclusions are drawn:

1) The distribution of stress on the section does not remain linear in deep beams.
2) The capacity of fixed-ended RC deep beams may reach until 6 times more than simply supported deep beams. This is because of considering strips in the capacity of fixed-ended-deep beams.
3) Unlike the simply supported deep beams, Fixed-ended deep beams do not have buckling failure mode.

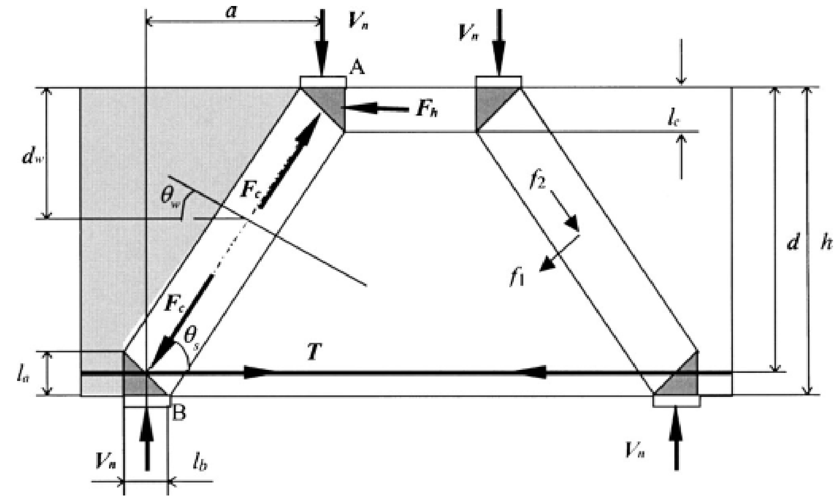

Fig. 12 Schematic shape of STM method

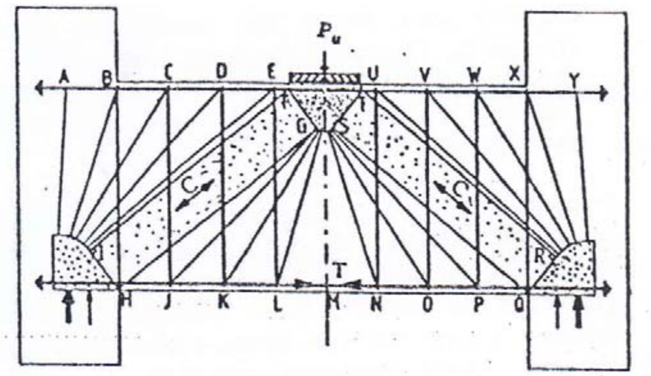

Fig. 13 Schematic shape of STM method for fiexed-ended deep beams

REFERENCES

[1] American Concrete Society "Building code requirements for structural concrete (ACI 318-14)"), Materials and Structures, 2014.

[2] N.K. Subedi, A. Arabzadeh "Reinforced concrete deep beams with fixed boundary conditions," developments in structural engineering preceding of the forth rail bridge conference, Edinburgh (B. H. V. Topping, ed.), Vol. 2, 1990, pp 833-845.

[3] M.D. Brown, C.L. Sankovich, O. Bayrak, and J.O. Jirsa, "Behavior and Efficiency of bottle-shaped struts," ACI Structural Journal, V. 103, No. 3, May-June 2006, p.p. 348-355.

[4] N. Zhang, Kang-Hai Tan "Effects of support settlement on continuous deep beams and STM modeling," Engineering Structures, V. 32, 2010, p.p. 361-372.

[5] N.K. Subedi, A. Arabzadeh, "Some experimental results for reinforced concrete deep beams with fixed-ended supports," Structural Engineering Review, Vol. 6, No. 2, 1994, pp 105-128.

[6] A. Arabzadeh, "Truss Analogy for the Analysis of Reinforced Concrete Fixed-ended Deep Beams," The Second International Conference in Civil Engineering on Computer Applications, Research and Practice. 6-8 April, 1996.