Al-Azhar University Civil Engineering Research Magazine (CERM)
Vol. (43) No. (1) January 2021

Behavior of Simply Supported Deep Beams Using Different Concrete Grades

Prof. Ayman Hussein Khalil[1], Dr. Ezz El-din Mostafa[2], and Noha Ahmed Metwally Ahmed[3]

1 Professor of Reinforced Concrete Structures, 2 Assistant Professor of Reinforced Concrete Structures, and 3 senior structural Engineer

Structural Department, Ain Shams University, Cairo, Egypt

ملخص البحث:

تم فى هذا البحث عرض وتحليل النتائج لدراسة سلوك الكمرات الخرسانية المسلحة العميقة بسيطة الارتكاز بإستخدام خرسانة مختلفة الإجهاد ذات حمل مركز فى منتصف البحر وذلك بعمل تجربة معملية لمجموعة كمرات مختلفة الإجهاد .المتغيرات التى تم دراستها هى إجهاد الخرسانة مع تثبيت التسليح العلوي والسفلي والجانبي والكانات .

ABSTRACT:

This paper presents the behavior of simply supported deep beam using different concrete grade with concentrated load at the middle of span. An experimental program is carried out for five simply supported deep beams with 1100 mm effective span, 1000 mm height and 200 mm width. The parameters considered are different compressive strength (25 MPa and 50 MPa) with minimum and horizontal reinforcement.

Introduction

A- Deep beam is a beam having large height/width ratio and shear span depth ratio. Because the geometry of deep beams, their behavior is different from slender beam.

B- The strain or stress distribution across the depth is no linear line, and the variation is mainly dependent on the aspect ratio of the beam.

C- Deep beams have many useful applications for both residential and commercial building structures such as transfer girders, transfer caps of high-rise buildings and as part of lateral load resisting system (Outriggers)…etc.

Literature review

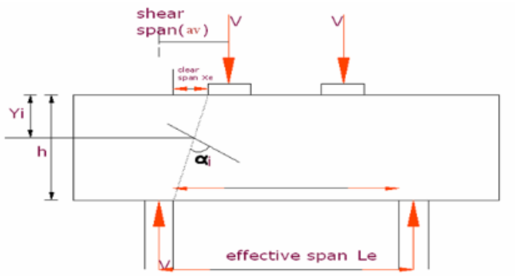

Figure 1 - Geometry of Simple Deep Beam

According to (ECP 203-2018). Deep beams are characterized as beams whose effective span to depth ratios conforming to: $L/d \leq 4$ Where: d = the effective depth of the section and L = the effective span of the beam. According to (ACI Committee 318-19) [2] Deep beams are members that are loaded on one face and supported on the opposite face such that strut-like compression elements can develop between the loads and supports and that satisfy A or B either of

A. Clear span doesn't exceed four times the overall member depth (h).

B. Concentrated loads exist within a distance (2h) from the face of the support.

In this paper, five concrete deep beams subjected to vertical concentrated load at mid span has been considered.

Laboratory testing

1.1 Sample configuration

All five tested deep beams share same dimensions; specimens with an effective span of 1100 mm, width of 200 mm and a height of 1000 mm as shown in Figure 2. Specimens also share same top, bottom reinforcement, stirrups and side bars as shown in Figure 3.

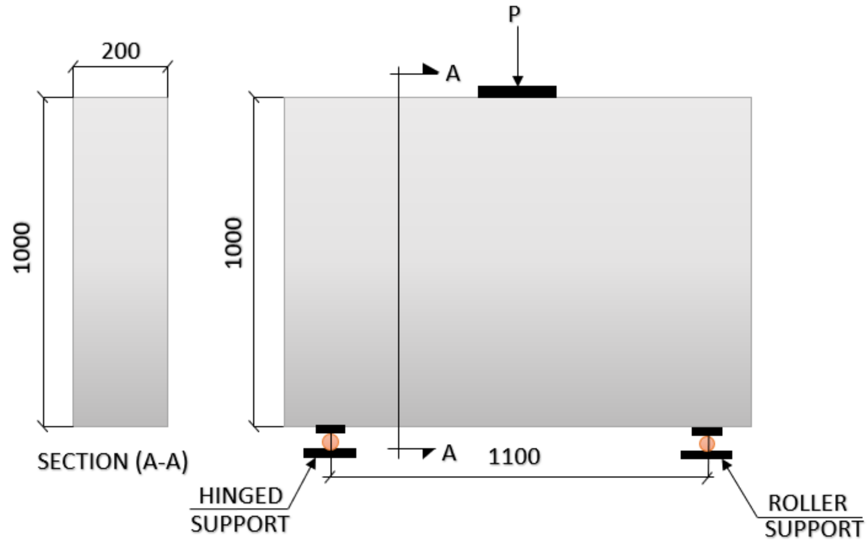

Figure 2 - Specimen dimensions

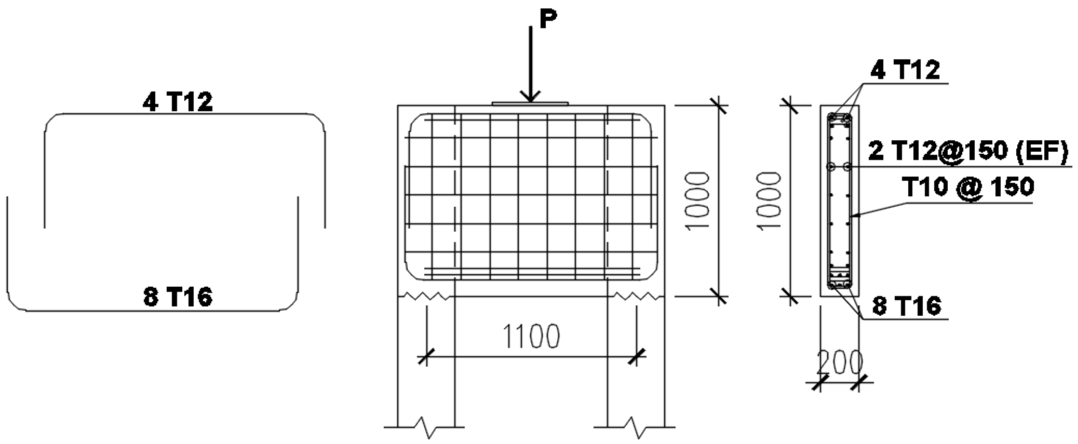

Figure 3 - Reinforcement details of tested specimens

3.2 Samples parameters

Different parameters and combinations had been used to configure the five specimens to cover some of the studied variables; parameters can be summarized as below:

- Different compressive strength (Fcu 25 Mpa and Fcu 50 Mpa).
- Constant amount of reinforcement (top, bottom, stirrups and side bars).

Each specimen has a unique identification name indicating what parameters values are used in it. The description of each beam is summarized as follows:

Table 1- Properties of beam specimens and concrete strength

Specimen	Beam Dimension b(mm)xh(mm)	Effective Span (mm)	Layers	Layer height (mm)	Compressive strength (Fcu) Mpa
B1	200x1000	1100	1	1000	25
B2	200x1000	1100	1	1000	50
B3	200x1000	1100	1	330	25
			2	330	25
			3	340	50
B4	200x1000	1100	1	330	50
			2	330	25
			3	340	50
B5	200x1000	1100	1	200	50
			2	200	25
			3	200	25
			4	200	25
			5	200	50

Table 2- Specimen's matrix

Sample number	1	2	3	4	5
Sample name	B1	B2	B3	B4	B5
Top RFT	4T12	4T12	4T12	4T12	4T12
Bottom. RFT	8T16	8T16	8T16	8T16	8T16
Vertical stirrups	T10@150	T10@150	T10@150	T10@150	T10@150
Middle Horizontal side bars	2T12@150(EF)	2T12@150(EF)	2T12@150(EF)	2T12@150(EF)	2T12@150(EF)

3.3 Material Properties:

a) Concrete with Fcu 25 Mpa: Concrete mix had were designed to obtain an average cube compressive strength of 25 MPa.

Table 3- Concrete mix design by Weight (KG/m3)

Component	Weight "KG"
10 mm coarse aggregates	1200
Fine aggregates "sand"	800
Cement	300
Water	150

b) Concrete with Fcu 50 Mpa: Concrete mix had been designed to obtain an average cube compressive strength of 50 MPa.

Table 4- Concrete mix design by Weight (KG/m3)

Component	Weight "KG"
10 mm coarse aggregates	1180
Fine aggregates "sand"	620
Cement	500
Water	190
S.F	75
HRWR	14

c) reinforcement: High strength steel with grade of 400/600 with elastic Modulus E = 200000 MPa. Three diameters were used; 10 mm, 12 mm and 16mm

Figure 4 - Reinforcement Details

Figure 5 - Preparation of formwork

Figure 6 - Removing of formwork After 10 Days from casting

3.5 Test setup and Loading program

The tested deep beams were simply supported vertically using steel plates rested above rigid steel columns which are fixed in place and capable of carrying vertical loads at the support were represented by steel plates. Figure 10 shows specimen testing setup components and Loading setup for tested specimens.

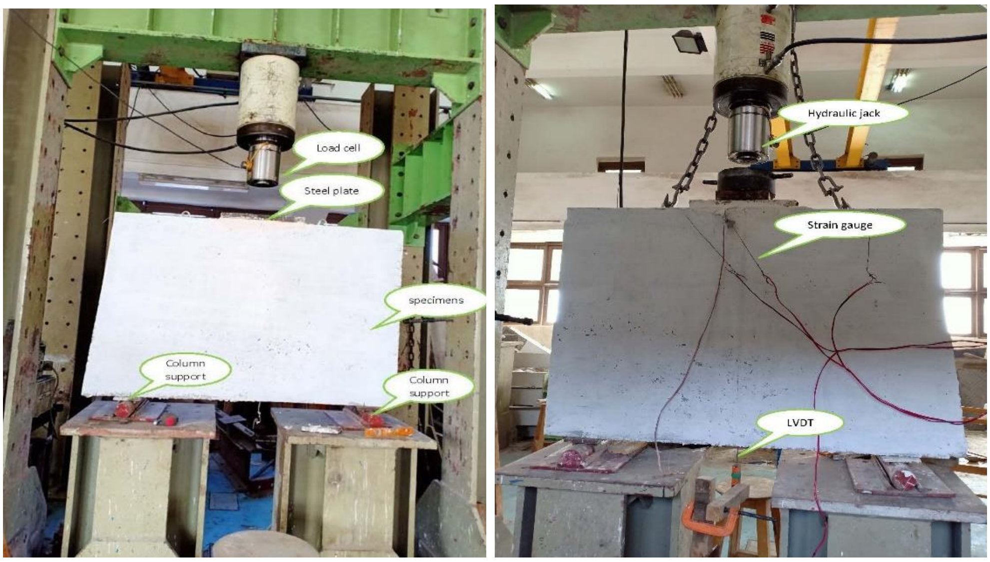

Figure 7 – Test setup for tested specimens

Data acquisition device was used to monitor the data while testing. All instruments (LVDTs, strain gauges and load cell) were connected to an electronic data acquisition system to monitor and recorded the data while testing.

Analysis and discussion of experimental results

4.1 Crack Pattern and Failure Mode

The observed behavior under the applied concentrated vertical load for the tested deep beams indicated that the first crack was a vertical flexural crack initiated at the middle bottom of the beam web. As the load was increased, the width of this crack increased and additional flexure cracks initiated with different angle, then the widths of these cracks become stretched and extended along the depth of the beam. Prior to flexural failure, as shown in the figure 8.

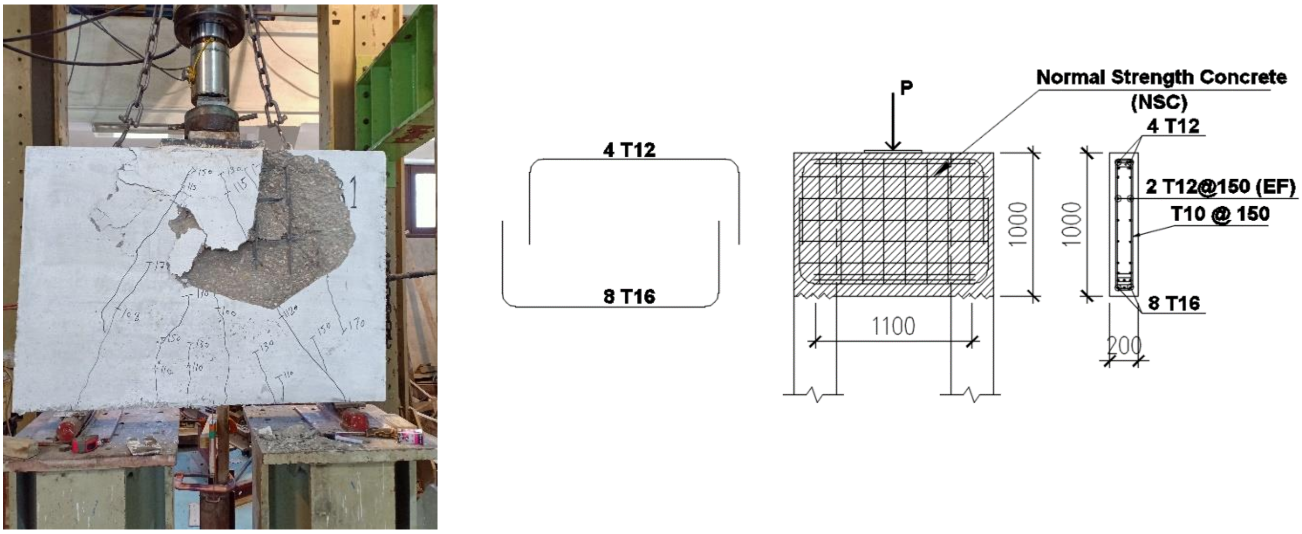

Figure 8 - Flexural crack pattern and failure mode for specimen (B1)

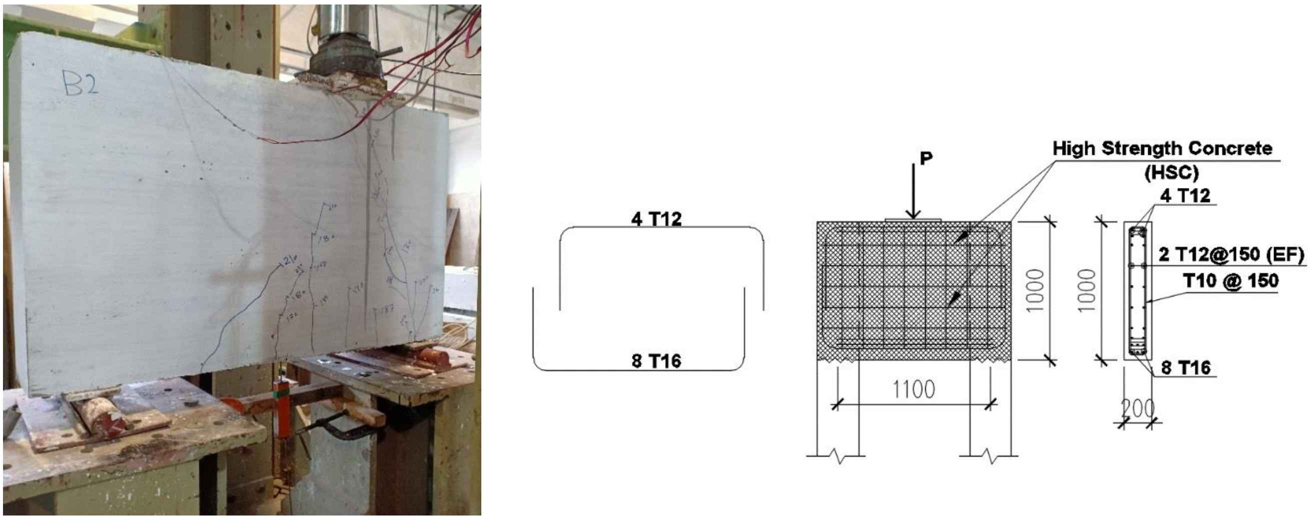

Figure 9 - Crack pattern and failure mode for specimen (B2)

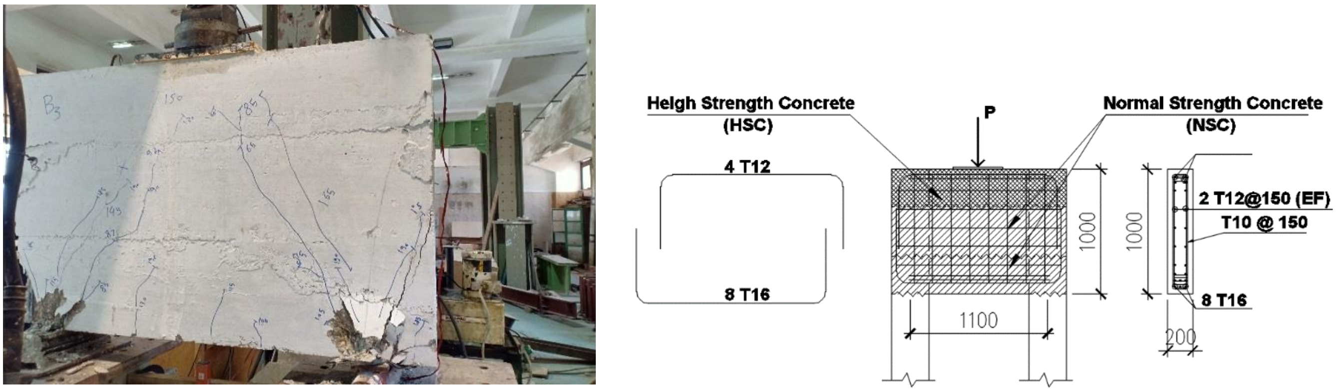

Figure 10 - Crack pattern and failure mode for specimen (B3)

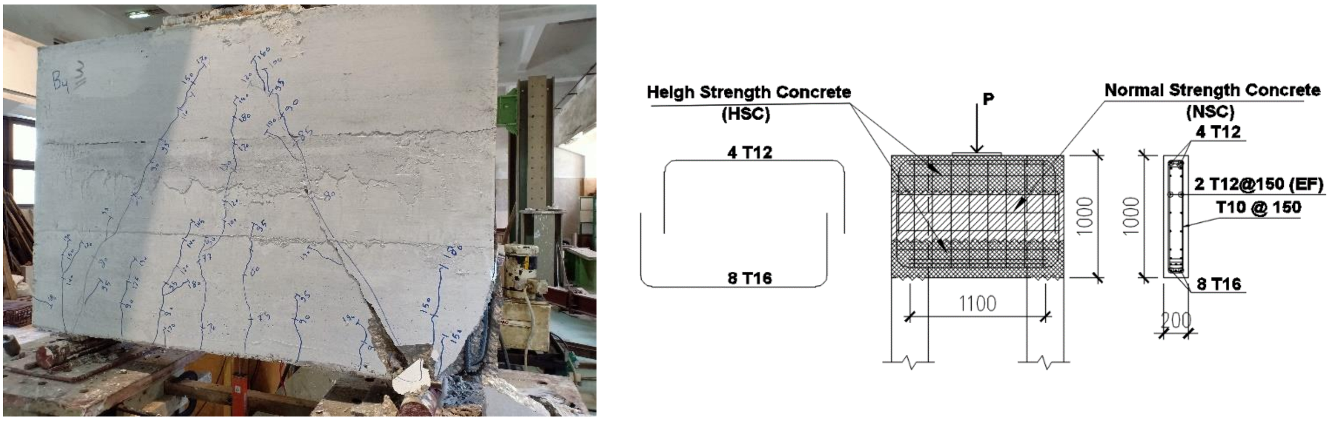

Figure 11 - Crack pattern and failure mode for specimen (B4)

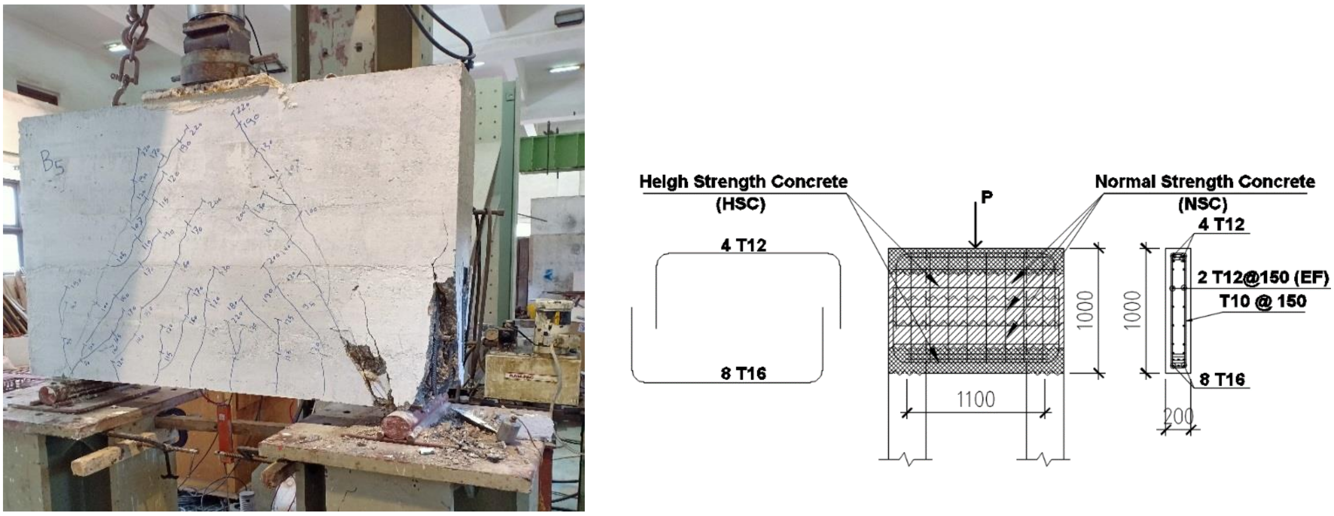

Figure 12 - Crack pattern and failure mode for specimen (B5)

4.2Experimental Failure Load

The summary of the experimental test results is shown in Table 5.

Table 5 - Experimental deep beams failure loads

Sample	Layers	Layer height (mm)	Compressive strength (fcu) Mpa	Failure load (ton)
B1	1	1000	25	180
B2	1	1000	50	220 (Max load cell)
B3	1	340	50	200
	2	330	25	
	3	330	25	
B4	1	340	50	190
	2	330	25	
	3	330	50	
B5	1	200	50	220 (max load cell)
	2	200	25	
	3	200	25	
	4	200	25	
	5	200	50	

4.3 Deformations of tested specimens

The load-vertical deflection behavior of deep beams B1 – B2 – B3 – B4 and B5 is shown in figure 13. String potentiometers placed along the web bottom face of the deep beams. The deflection behavior at the selected locations indicates that the maximum deflection occurred at the mid span of the deep beams due to load increasing. The maximum vertical deflection was for beam (B1) at mid span of the beam was 3.2 mm and the minimum deflection was for beam(B2) at mid-span was 1.6 mm at the maximum load cell as shown in figure 13.

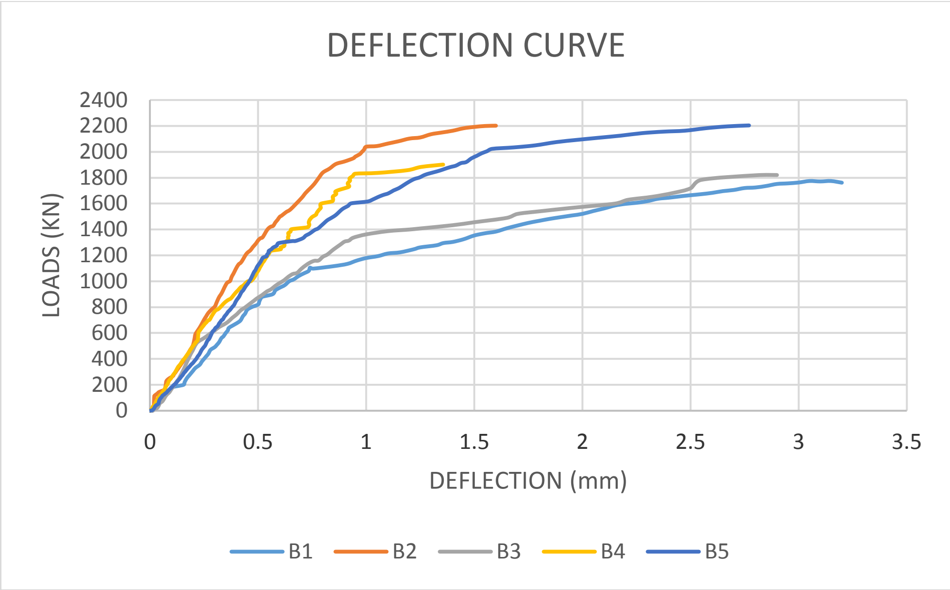

Figure 13 - Load-vertical deflection for all tested specimens at mid span

4.4 Cracking Loads and Failure Loads

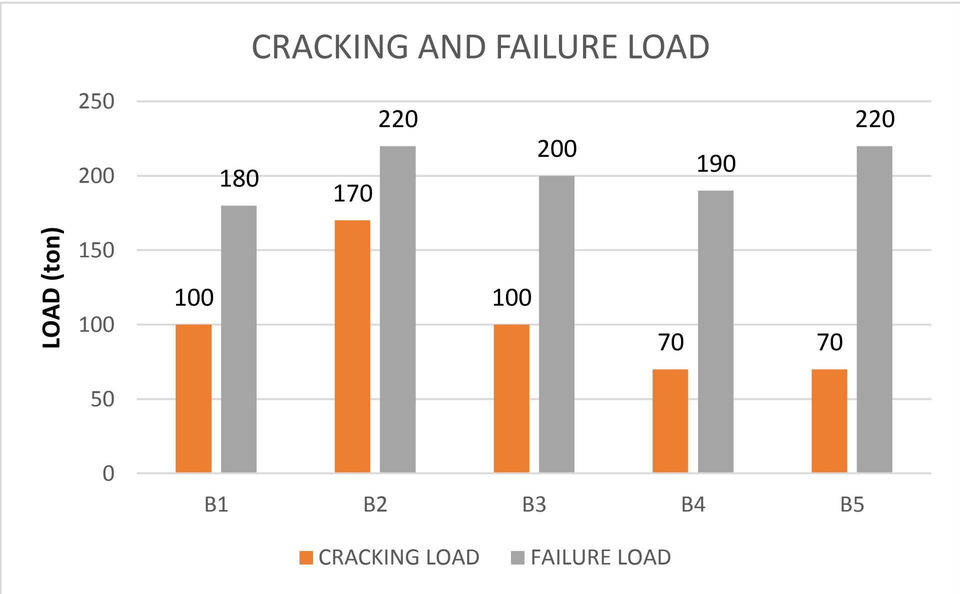

Figure 14 summary of the experimental test results

4.5 Strain of steel bars of tested specimens

The strain of steel bars for all tested specimens was recorded with load increment and up-till specimens' failure. Figure 15 show load versus steel bars strains at mid-span (ε_1) for all tested deep beams. These figures are used to determine yielding loads of beams when yielding strain of steel bars is reached. The yield strains of the bottom steel bars, based on laboratory tests, are measured for all tested beams. Yielding of bottom steel bars was initiated at mid span for all deep beams as shown by the schematic view in figure 15.

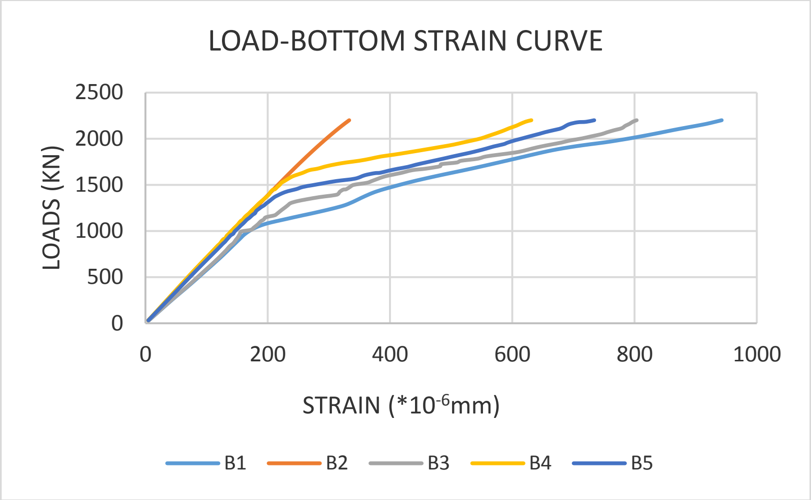

Figure 15 - Load versus steel strain for all tested specimens

Conclusion:

From the experimental studies in the present paper, the following conclusion are drawn:

1- Failure of deep beam was mainly due to diagonal cracking and it was along the lines joining the loading points and supports.

2- Changing compressive strength of concrete from 25 Mpa to 50 Mpa has a high effect on the failure load for deep beams.

3- Behavior of simply supported deep beams using different grades of compressive strength gives results worse than the behavior of simply supported deep beams using one grade of compressive strength.

4- Increasing compressive strength under load zone and tie zoneat gives result very close to result from fully high compressive strength beam.

6. References

[1] Egyptian Standard “Egyptian Code of Practice for Design of Reinforced Concrete Structures (ECP 203)”, published in 2018.

[2] BS8110, “Structural Use of Concrete: Code of Practice for Design and Construction,” Part 1, British Standards Institution, London, UK, 1997.

[3] American Concrete Institute “Building Code Requirements for Structural Concrete (ACI 318-18)”, published in September 2018.

[4] Ciria Guide: "the design of deep beams in reinforced concrete", Jan 1977.

[5] K. H. Tan, Member, ASCE, K. Tong, and C. Y. Tang, Affiliate, ASCE Journal Of Structural Engineering / September 2001 / 1083 Vol. 127, No. 9.

[6] T. H. K i m, J.H. Cheon and H.M. Shin 1. Construction Technology R&D Center, Samsung C&T Corporation, 1321-20 Seocho2-dong, Seocho-gu, Seoul 137-956, Korea 2 Department of Civil and Environmental Engineering, Sungkyunkwan University, 300 Cheoncheon-dong, Jangan-gu, Suwon-si, Gyeonggi-do 440-746, Korea. (Accepted June 28, 2011)

[7] Guo-Lin Wang, Shao-Ping Meng. Modified strut-and-tie model for pre-stressed concrete deep beams. Engineering Structures, 2008, 30, 3489-3496.

[8] Kong, F.K, Robins, P,J "web reinforcement effects on light weight concrete deep beams" ACI Journal proceedings, No.7, Jully 1971

[9] Ramarkrishnan, V. and Anan Thanaryana, Y,"Ultimate strength of deep beams in shear" ACI Journal proceedings, Feb 1968.