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EFFECT OF WEB REINFORCEMENT ON SELF-COMPACTING REINFORCED CONCRETE CONTINUOUS DEEP BEAMS

Dr. Adnan Falih Ali [1], *Dr. Abdul_Qader Nihad Noori [2]

1) Prof., Civil Engineering Department, Baghdad University, Baghdad, Iraq.
2) Lecturer, Civil Engineering Department, Mustansiriyah University, Baghdad, Iraq.

Abstract: The main purpose of this experimental study is to investigate the behavior and strength of self-compacting reinforced concrete continuous deep beams with and without web reinforcement. The program included cast and test of five beam specimens, in which the vertical and horizontal shear reinforcement were varied. All specimens had the same length, depths and main flexural reinforcement ratio and they were subjected to concentrated vertical loads only. It was found that the addition of vertical shear reinforcement with minimum ratio (ρ_v=0.25%) increases the both of cracking and ultimate loads by about 10%, When vertical shear reinforcement is increased by about 80% (from 0.25% to 0.45%) a noticeable increases in the ultimate load capacity is observed (the enhancement reached to 18.6%).
When providing horizontal web reinforcement of (ρ_h=0.343%) in addition to the provided vertical shear reinforcement (ρ_v=0.25%), the cracking and ultimate loads increased by about (17.5% and 25%) respectively, while the previous ratios of the cracking and ultimate loads increased to (20% and 33%) respectively when vertical shear reinforcement increased to (ρ_v=0.45%).

Keywords: *Continuous deep beam (CDB), Self-compacting concrete (SCC), Fresh properties, Hardened properties, Strength, Slump flow test.*

تأثير حديد تسليح الوترة على العتبات الخرسانية المسلحة المستمرة العميقة ذاتية الرص

الخلاصة: الهدف الرئيسي لهذا البحث العملي هو لتحري سلوك ومقاومة الخرسانة المسلحة ذاتية الرص للعتبات المستمرة العميقة ذات الوترة المسلحة و الغير مسلحة، يتضمن البرنامج العملي صب وفحص خمسة نماذج يكون فيها حديد تسليح القص العمودي والافقي متغيرا. تمتلك جميع النماذج المفحوصة نفس الطول والعمق و نسبة حديد التسليح الرئيسي (المقاوم للانثناء) وتم فحصها تحت تأثير حمل عمودي مركز. وجد ان اضافة حديد تسليح القص العمودي بنسبة (ρ_v=0.25%) يؤدي الى زيادة كل من حمل التشقق والحمل الاقصى بنسبة تصل الى حوالي (10%)، وعند زيادة نسبة تسليح حديد القص العمودي بمقدار 80% (من 0.25% الى 0.45%) لوحظت زيادة محسوسة بالحمل الاقصى تصل الى حوالي (18.6%). عند اضافة تسليح القص الافقي بنسبة (ρ_h=0.343%) بالإضافة الى وجود تسليح القص العمودي بنسبة (ρv=0.25%) يزداد كل من حمل التشقق والحمل الاقصى بنسبة تصل الى (17.5%و 25%) على التوالي، تزداد هذه النسب لتصل الى (20 %و 33 %) على التوالي عند ازدياد نسبة تسليح القص العمودي الى (ρ_v=0.45%).

1. Introduction

The continuous deep beams are common structural elements that occur as transfer girders in high-rise building, pile caps and foundation walls and many other uses "Fig. 1". Predominantly receiving many small loads and work on transfer them to a few number of reaction points [1].

* phd.abdulqadernihad1974@gmail.com

According to ACI 318M-11 Code [2], deep beams can be defined as:
Structural Members loaded on one face and supported on the opposite face so that compression struts can develop between the loads and the supports. Deep beams must have either:

a) The ratio of clear spans to overall member depth (l_n/h) equal to or less than four. or
b) Regions with concentrated loads within twice the member depth from the face of the support.

In mathematical forms ($a/h \geq 2$) for simple span deep beams and ($a/h \geq 2.5$) for continuous deep beams [2]**,** where (a/h)= shear span to overall depth ratio.

Continuous deep beams act differently from both simply supported deep beams and continuous slender beams. By ignoring these differences through design, one gives up potential available strength and may get significant unpredicted cracking. Continuous deep beams show a distinct 'tied arch' or 'truss' behavior not exist in continuous slender beams. This leads us to an important conclusion that traditional reinforcement detailing rules, based on shallow beams or simply span deep beams are not necessarily suitable for continuous deep beams [3,4].

Because of deep beams heavy reinforcement, the difficult of filling areas between congested reinforcement is serious, the conventional concrete does not flow well when it travels to the web and does not completely fill the bottom part. This results in many problems in concrete such as, voids, segregation, weak bond with reinforcement bars and holes in its surface Therefore, self-compacting concrete (SCC) is the suitable choice to be used for those members [5,6].

2. Experimental Program

The experimental program includes testing of five samples of (two-span) reinforced concrete deep beams designed as continuous deep beam constructed using self-compacted concrete (SCC). All beams had the same dimensions and the same flexural reinforcement.

Each beam had an overall length of 2300 mm, a width of 150 mm and a height of 500 mm as shown in "Fig. 2" and they were designed to fail in shear. The parameters that were considered in this study are: amount of vertical reinforcement (ρ_v) presence or absence of horizontal reinforcement (ρ_h). These parameters are chosen according to their importance in determination of SCC continuous deep beams behavior and to fill the shortage in knowledge of behavior of such type of continuous deep beams that constructed using normal strength of SCC.

The experimental work include five beams according to the web reinforcement type (CDB_A, CDB_B, CDB_C, CDB_D and CDB_E), the details of reinforcement for each beam are shown in "Table 1". The (A) symbol is refers to the tested specimen without vertical or horizontal web reinforcement as the shear reinforcement (ρ_v=0.0%) and (ρ_h=0.0%), these specimen considered as reference beams.

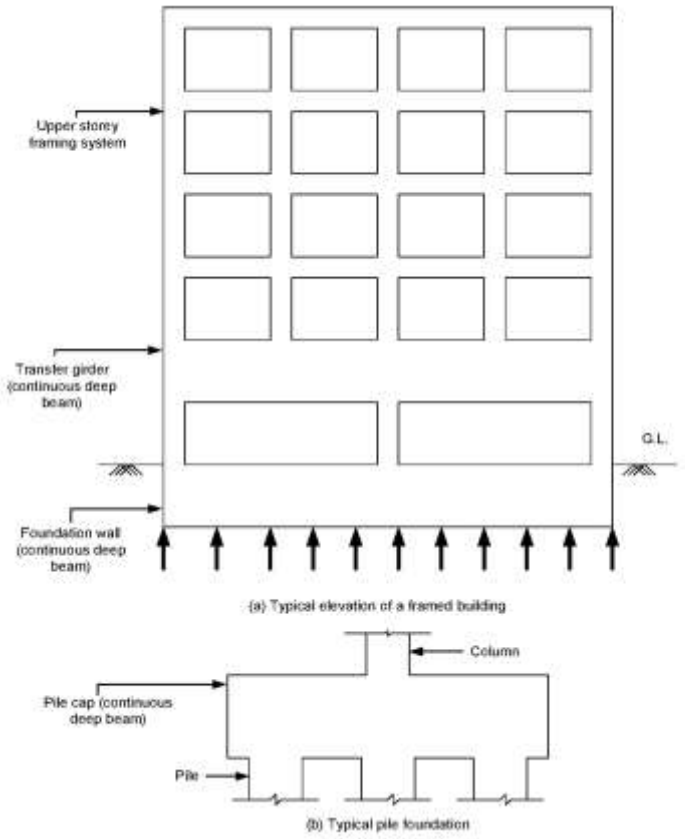

Figure 1. Examples of continuous deep beams [3].

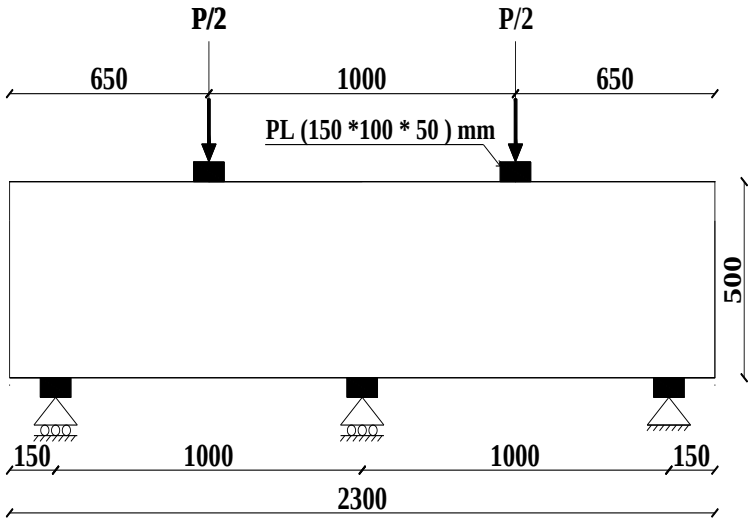

Figure 2. Geometrical Dimensions of the Tested Deep Beams, (dimensions in mm).

The (B) symbol refers to the tested specimen having a minimum vertical shear reinforcement ratio (ρ_{vmin}=0.0025) according to ACI318M-2011[2] provisions, where the horizontal web reinforcement ratio equal to zero (ρ_h=0.0).

The (C) symbol refers to tested specimen with maximum vertical shear reinforcement ratio (ρ_{vmax}=0.0045), where the horizontal web reinforcement ratio equals to zero (ρ_h=0.0).

The (D) symbol refers to the tested specimen with minimum vertical shear reinforcement ratio (ρ_{vmin}=0.0025) according to ACI318M-2011[2] provisions and horizontal web reinforcement ratio (ρ_h=0.00343).

Finally, the (E) symbol refers to tested specimen with maximum vertical shear reinforcement ratio (ρ_{vmax}=0.0045) and horizontal web reinforcement ratio (ρ_h =0.00343).The magnitude of horizontal web reinforcement ratio (ρ_h) was chosen to be between the minimum and maximum reinforcement ratios.

Table 1. Details of tested beams and research parameters

Beam designation	a/h	Vertical shear reinforcement	ρ_v %	Horizontal shear reinforcement	ρ_h %
CDB_A	1	0	0	0	0
CDB_B	1	Ø6 mm @ 150mm c/c	0.25	0	0
CDB_C	1	Ø8 mm @ 150mm c/c	0.45	0	0
CDB_D	1	Ø6 mm @ 150mm c/c	0.25	Ø6 mm @ 110mm c/c	0.343
CDB_E	1	Ø8 mm @ 150mm c/c	0.45	Ø6 mm @ 110mm c/c	0.343

The main longitudinal reinforcement at top and bottom was adequate and were kept constant for all tested continuous deep beams to prevent flexural failure. The magnitude of flexural reinforcement (top and bottom) for all the tested beams was the same (4Ø16mm) with flexural reinforcement ratio equal to ($\rho_v = 0.0213$). The vertical shear reinforcement ratio (ρ_v) implemented in (ρ_{vmax}) maximum ratio and (ρ_{vmin}) minimum ratio. For (ρ_{vmax}) maximum 8 mm steel bars were used (8 mm @150 mm c/c) to provide vertical shear reinforcement ratio equals to (0.0045). This percentage of vertical shear reinforcement is larger by about (1.8) times than the minor proportion of vertical shear reinforcement mentioned in ACI318M-11[2].

To provide minimum vertical shear reinforcement ratio (ρ_{vmin} = 0.0025) a steel bars with diameter of (6mm @150 mm c/c) are used. For other horizontal shear reinforcement ratio (ρ_h) 6mm diameter steel bars (Ø6 mm @ 110mm c/c) were used to provide (ρ_h = 0.00343), this ratio is larger by about (1.3) times than the minimum shear horizontal reinforcement ratio mentioned in ACI318M-11[2] and equal to (ρ_{hmin} = 0.0025). All longitudinal bottom steel reinforcement covers full length of the beams and through the depth to provide sufficient anchorage lengths. The vertical web reinforcement was of closed stirrups and the horizontal web reinforcement as longitudinal bars in both sides of the beam. Horizontal stirrups were anchored at each end with standard hooks. All specimens having two spans were tested to failure using a universal testing machine with a capacity of 3000 kN under two-point symmetrical top loads at mid-span of each span length. All tested beams were loaded up to failure. Each

span has 1000 mm overall clear length (L) which results in a ratio of (L/h=2) that is less than 4.0 as recommended by the ACI318M-11[2] provisions for deep beam requirements.

3. Material Properties

3.1. *Cement*

Ordinary Portland cement produced at Northern Cement Factory (Tasluja) was used throughout this investigation, with the requirements of the Iraqi Standard Specification I.Q.S. No.5, 1984 [7].

3.2. *Fine Aggregate*

Natural sand brought from AL-Ukhaider region was used in concrete mixes for this investigation. The fine aggregate had (4.75mm) maximum size with rounded partial shape and smooth texture with fineness modulus of (2.43). The obtained results indicate that, the fine aggregate grading is within the Iraqi Specification No. 45/1984 [8] as shown in "Fig. 3".

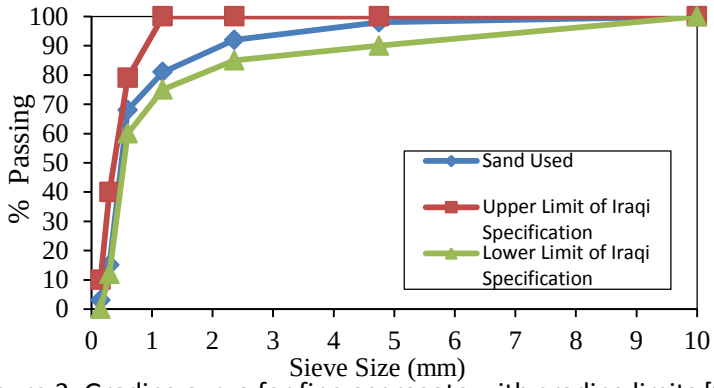

Figure 3. Grading curve for fine aggregate with grading limits [8].

3.3. *Coarse Aggregate*

Crushed gravel of maximum size 10 mm brought from Al-Niba'ee region was used. "Fig. 4" shows the grading of this aggregate, which conforms to the Iraqi Specification No.45/1984 [8].

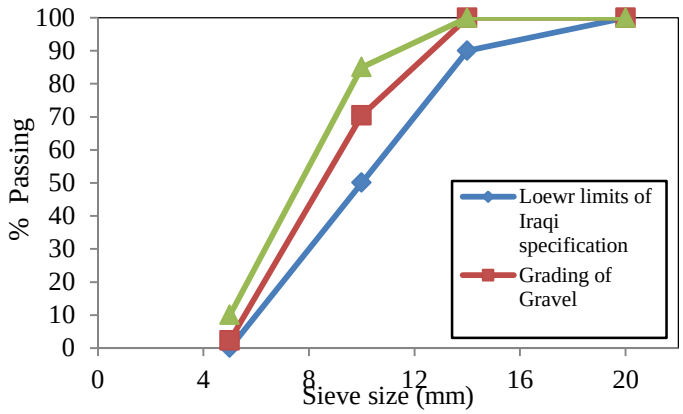

Figure 4. Grading curve for coarse aggregate [8].

3.4. *Water*

Ordinary tap water was used for both mixing and curing of all concrete specimens used in this investigation. It was free from injurious substances like oil and organic materials.

3.5. *Superplasticizer*

In this work, the superplasticizer used is known commercially as "GLENIUM-51". It is a new generation of modified polycarboxylic ether. It is compatible with all Portland cements that meet recognized international standards.

Superplasticized concrete exhibits a large increase in slump without segregation. However, this provides enough period after mixing for casting and finishing the concrete surface.

3.6. *Limestone Powder (LSP)*

This material is locally named “Al-Gubra”. It is a white grinding material from lime-stones excavated from Al-Mosul province in the north of Iraq, Particle size of the limestone powder is less than 0.125 mm, it is confirm to EFNARC 2002 [9].

3.7. *Steel Reinforcing Bars*

All reinforcement bars were deformed bars; three types of deformed steel bars according to nominal diameter have been used in this study.

Steel bars of nominal diameter of (16) mm were used as longitudinal reinforcement in the tension zone at top and bottom of the beams. Steel bars of nominal diameter of (6) mm were used as vertical shear reinforcement (minimum ratio) and as horizontal web reinforcement.

Finally, steel bars of nominal diameter of (8) mm were used as vertical shear reinforcement (maximum ratio). According to ASTM A615/A615M-05a [10] and ASTM A496-02 [11], tensile tests were carried out for the steel reinforcement using three 450 mm long specimens for each nominal diameter.

Tensile tests of steel reinforcement are carried out at the laboratory of Materials at the College of Engineering in Mustansiriyah University to determine the average yield stress and the ultimate stress.

The test results are listed in “Table 2”. "Fig. 4-a" to "Fig. 4-e" shows the details of reinforcement for each beam.

Table 2. Properties of reinforcing steel bars

Nominal bar diameter (mm)	Measured bar diameter (mm)	Bar area (mm^2)	Yield stress (MPa)	Ultimate stress (MPa)
16	16.1	201	495	*720*
8	8.02	50.8	431	*695*
6	*6.08*	*28.3*	*510*	*812*

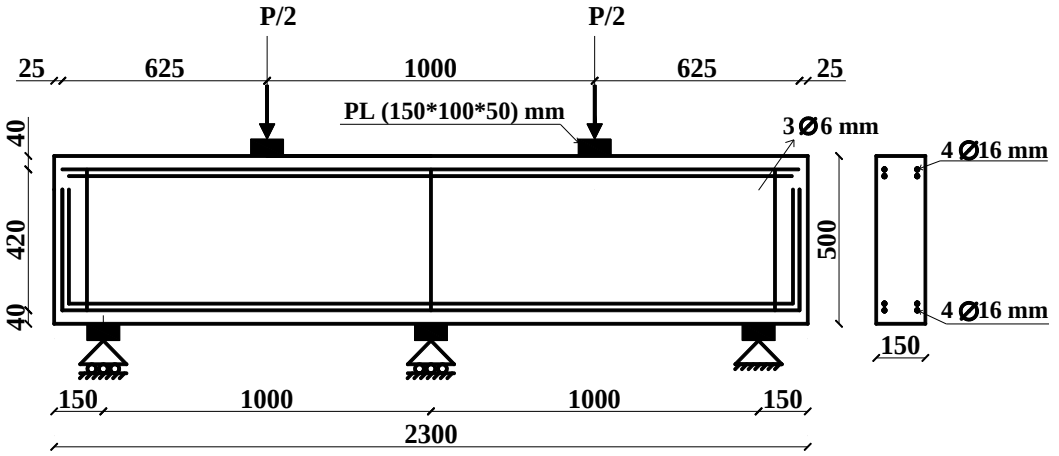

Figure (4-a). Details of beam CDB_A, (dimensions in mm).

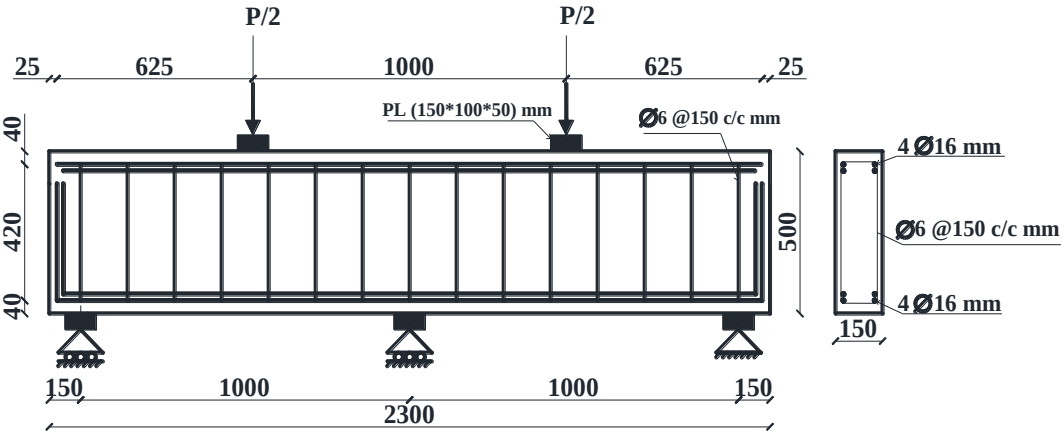

Figure (4-b). Details of beam CDB_B, (dimensions in mm).

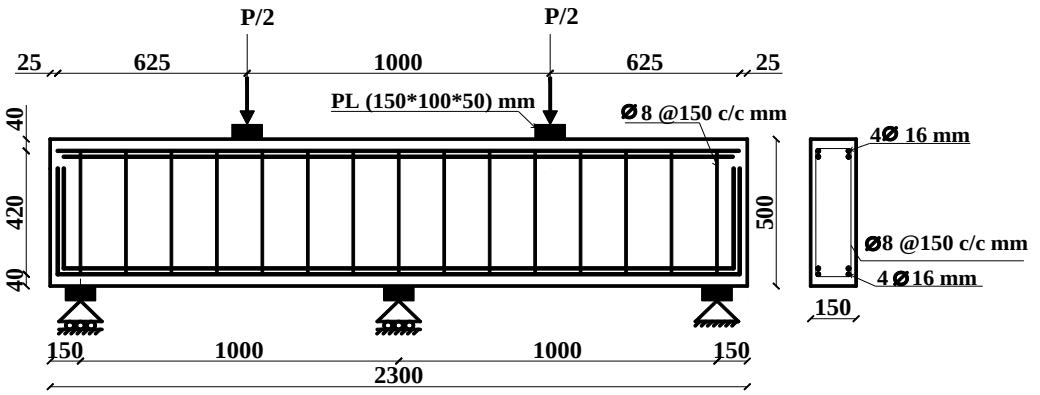

Figure (4-c). Details of beam CDB_C, (dimensions in mm).

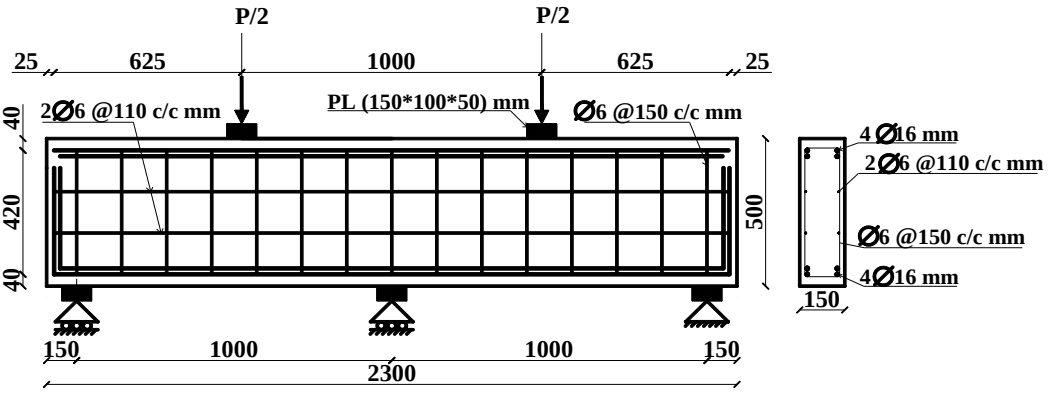

Figure (4-d). Details of beam CDB_D, (dimensions in mm).

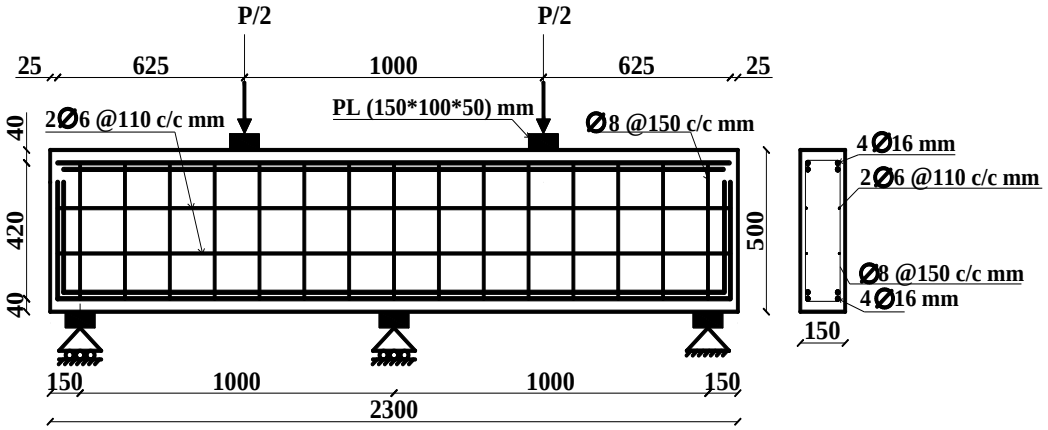

Figure (4-e). Details of beam CDB_E, (dimensions in mm).

4. Concrete Mix Proportions

To achieve SCC fresh properties of the mix was designed according to EFNARC 2002[9].

Regrettably, the fresh properties of SCC are most important than the compressive strength in all mix design methods.

In this study, many trial mixes were carried on to obtain the proper design for compressive strength and to achieve the fresh properties of SCC requests commonly.

In the present work, the cement content was 400 kg/m^3, fine aggregate content was 785 kg/m^3, course aggregate content was 770 kg/m^3, limestone powder contents was 50 kg/m^3, water content was 165 lit/m^3 and the superplasticizer content was 7.5 lit/m^3, these values satisfy all the values recommended by EFNARC's mix design method.

5. Tests on Fresh Concrete Testing Procedure

In this work, consideration of concrete mix as a self-compacting concrete (SCC) is verified by three standard tests: Slump flow,T_{50} slump flow and L-box, "Table 3" shows the results of properties of fresh SCC, as shown in "Fig. 5" and "Fig. 6".

Table .(3) Tests results of properties of fresh SCC

Mix name	*Slump flow, (mm)*	T_{50} *(sec)*	L – box,(H_2/H_1)
NSCC	753	2.5	1
Limits of EFNARC	650-800	2-5	0.8-1
Limits of ACI-237[14]	450-760	2-5	0.8-1

Figure 5. Flowing of concrete in horizontal section in L-box test of SCC.

Figure 6. Spreading concrete in Slump Flow test of SCC.

6. Testing Procedure

Initially, all specimens were painted with white for all sides to observe the formation of first crack, crack patterns and the development of these cracks. Thereafter, the beams were labeled then for accuracy; signs were placed to indicate the supports points, loading points, dial gauges and concrete strain gauges locations. Then the specimens were lifted and placed onto supports to carry out load tests.

All CDB's specimens have two spans and tested up to failure by applying two symmetrical concentrated loads vertically at the top side of each span. the rigid frame helps to divided the single load created by the testing machine into two equal concentrated loads, as shown in "Fig.7". Testing starts by applying the load monotonically in increments of about (10 kN) per stage until failure. Five steel plates each of dimensions of (150x100x50) mm were used as bearing plates located under load and over supports to prevent premature failure or local failure of concrete.

At each loading stage, the strains in steel reinforcement and at concrete surface were recorded and automatically saved by data logger. The crack patterns, deflection and the corresponding loads were marked at each load stage.

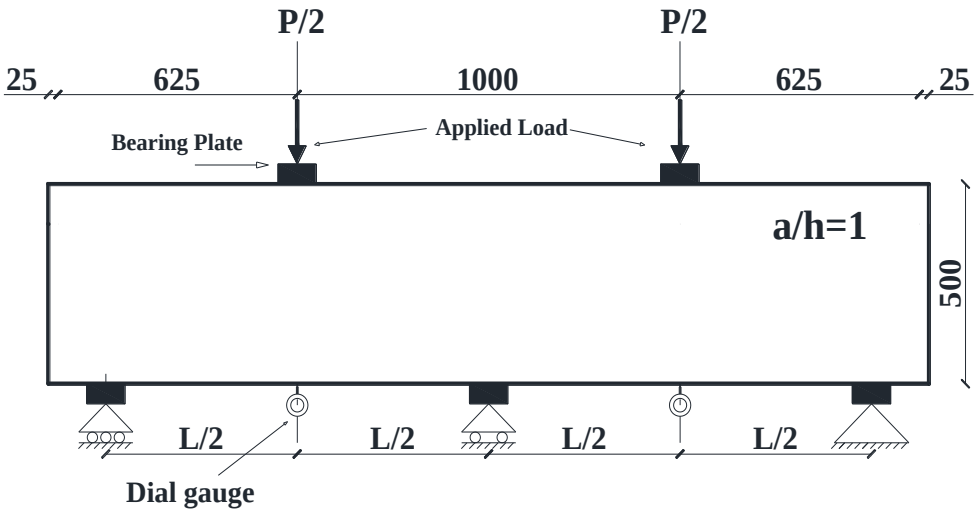

Figure 7. Setup of continuous deep beam (CDB), (dimensions in mm)

7. Mechanical Properties of Hardened SCC

The hardened mechanical properties of SCC that were studied in the present work are; concrete compressive strength (f′c), splitting tensile strength (ft), modulus of rupture (fr) and modulus of elasticity (Ec). "Table 4**"** illustrates the test results of the hardened SCC, with the note that each value presented in this table denotes the average value of three specimens.

Table 4. Tests results of mechanical properties for hardened SCC

Beam designation	f'_c *(MPa)*	f_t *(MPa)*	f_r *(MPa)*	*Ec (MPa)*
CDB_A	33.81	3.18	4.45	24973.96
CDB_B	34.52	3.27	4.79	25598.66
CDB_C	36.05	3.41	5.39	26168.40
CDB_D	35.12	3.38	5.28	25103.41
CDB_E	36.41	3.42	5.68	26705.14

9. Test Results of SCC Continuous Deep Beams

Among all of the tested specimens, it was noted that in general, the first crack was at mid-span developed suddenly in the flexural sagging region just about (20 to 23) % of the ultimate load, after that, the first diagonal cracks starts suddenly at mid-depth of the concrete strut within the interior shear span between the applied load and the middle support. As observed, the first flexural crack over the middle support occurred at about 80% of the ultimate load. As the load increases, more flexural and diagonal cracks start

to develop and a major diagonal crack extended to join the edges of the applied load and the middle support plates.

As the load was increased further, the cracks became wider associated with a large increase of deflection. When the load levels became close to failure loads, the two spans showed nearly the same crack patterns. Finally, at failure, an end block formed because of the significant diagonal crack connecting the edges of the load and the inner support plates, rotated about the end support leaving the rest of the beam fixed over the other two supports. The shear cracking loads at various stages of loadings are shown in "Table 5**"** and in "Fig. 8" to "Fig. 12".

Table 5. Summary of test results for the tested beams.

Beam designation	f'c MPa	a/h	a/d	ρ_v%	ρ_h%	P_{cr} (kN)	P_{ult} (kN)	Type of Failure
CDB_A	33.81	1	1.25	0.0	0.0	200	873	D.S*
CDB_B	34.52	1	1.25	0.25	0.0	205	958	D.S
CDB_C	36.05	1	1.25	0.45	0.0	220	1035	D.S
CDB_D	35.12	1	1.25	0.25	0.343	235	1093	D.S
CDB_E	36.41	1	1.25	0.45	0.343	240	1165	D.S

* D.S = Diagonal Splitting.

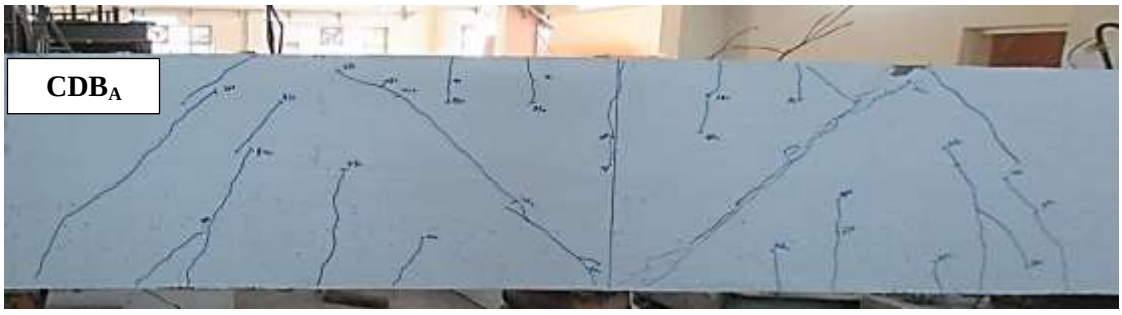

Figure 8. Crack pattern for beam CDB_A after testing.

Figure 9. Crack pattern for beam CDB_B after testing.

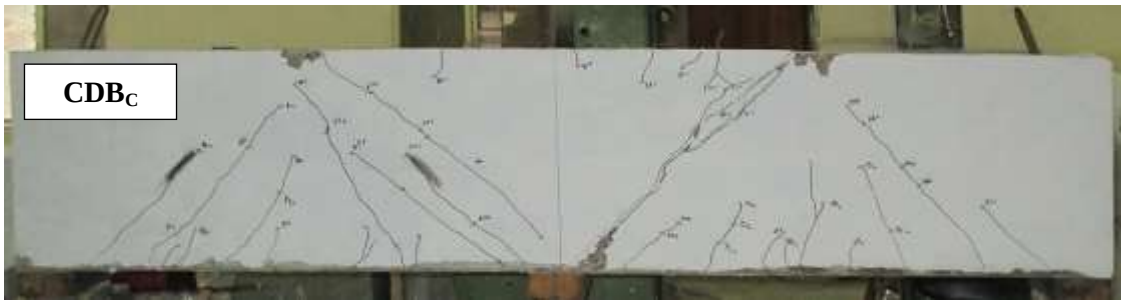

Figure 10. Crack pattern for beam CDB_C after testing.

Figure 11. Crack pattern for beam CDB_D after testing.

Figure 12. Crack pattern for beam CDB_E after testing.

10. Effect of Web Reinforcement

10.1. *Effect of Vertical Web Reinforcement*

It is of a common knowledge that shear capacity of a deep beam is a function and increases with the presence of shear reinforcement because of increasing the ability of the reinforced deep beam to resist cracking.

The enhancement in shear strength depends on some factors, those are: the area of web reinforcement, spacing between steel bars and reinforcement type (horizontal and/or vertical). Test results indicated that vertical web reinforcement has a significant influence in transferring shear forces in reinforced SCC continuous deep beams more than horizontal web reinforcement.

A SCC continuous deep beam with 0.25% of (ρ_v) results in an increase in the value of (P_{cr}) by 2.5% while the increase in (P_{ult}) was 9.74 %. Increasing the magnitude of (ρv) by 80% (from 0.25% to 0.45%) that is (ρ_{vmin} and ρ_{vmax}) results in a noticeable increase in the shear capacity of (enhancement reached to18.56%).

10.2. *The Combined Effect of Both Horizontal and Vertical Shear Reinforcement*

The combined effect of both horizontal and vertical shear reinforcement were studied to evaluate the contribution of horizontal reinforcement to the serviceability (cracking load) and strength (ultimate load). If the beam is supplied with minimum vertical reinforcement only (ρ_v=0.25% and ρ_h=0.0) the beam shows an enhancement (as compared to the case of no web reinforcement) in serviceability (P_{cr}) by about 2.5%. At the same time, the enhancement in the ultimate load (P_{ult}) reached to 9.7%.

If the beam is supplied with a horizontal web reinforcement of (ρ_h=0.343) in addition to the provided minimum vertical reinforcement (ρ_{vmin}=0.25%), then extra enhancement in both cracking and ultimate loads took place; that is, the enhancement in cracking load (P_{cr}) is about 17.5% while the ultimate load (Pult) is enhanced by 25.2%. In the other hand, providing a deep beam with the maximum web reinforcement (ρ_{vmax}=0.45%), the cracking load (Pcr) seems to increase by 20% while the ultimate load (P_{ult}) is enhanced by 33.45%. "Table 6", and "Fig.13 and Fig.14" shows the effect web shear reinforcement ratio on cracking and ultimate failure loads.

Table .(6) Effect of web shear reinforcement ratio on cracking and ultimate failure loads

Beam designation	*a/h*	*ρ_v%*	*ρ_h%*	*P_{cr} (KN)*	*P_{ult} (KN)*	*% of increase in P_{cr} comparing with reference beam*	*% of increase in P_{ult} comparing with reference beam*
CDB_A		0.00	0.00	200	873	*Reference*	*Reference*
CDB_B	1.00	0.25	0.00	205	958	2.5	9.74
CDB_C		0.45	0.00	220	1035	10	18.56
			Effect of Adding Horizontal Web Reinforcement				
CDB_A		0.00	0.00	200	873	*Reference*	*Reference*
CDB_D	1.00	0.25	0.0343	235	1093	17.5	25.20
CDB_E		0.45	0.0343	240	1165	20.0	33.45

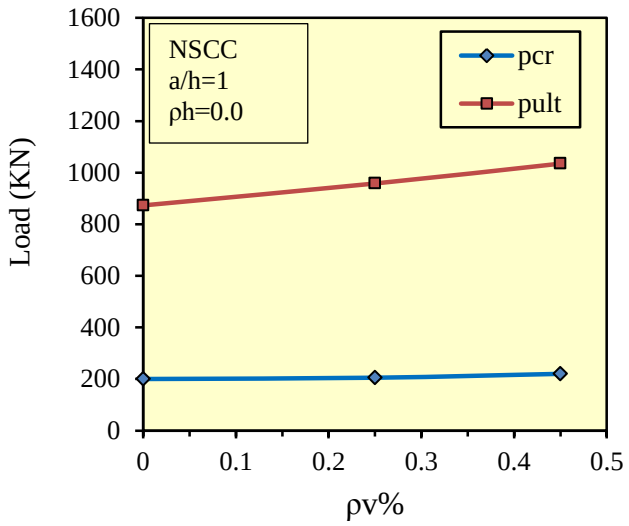

Figure 13. Effect of vertical shear reinforcement on cracking load (P_{cr}) and ultimate failure load (P_{ult}).

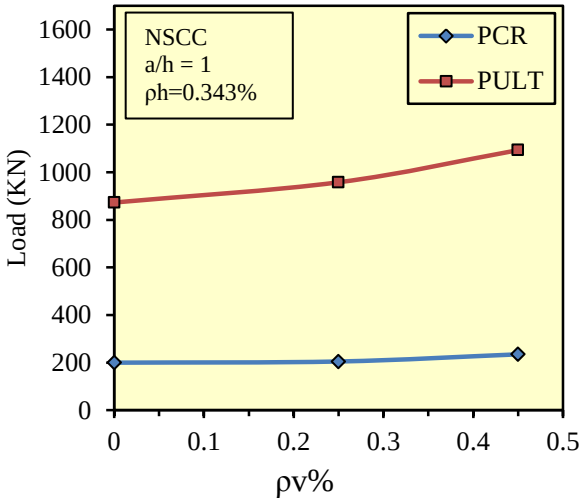

Figure (14-a). The effect of adding web reinforcement ratio on both ultimate and cracking loads in groups (A, B and D).

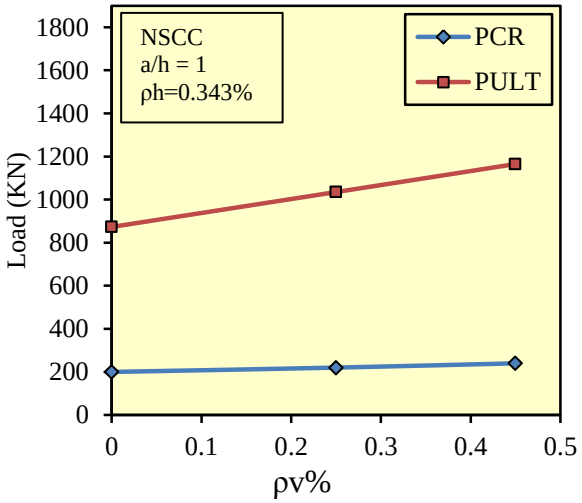

Figure (14-b). The effect of adding web reinforcement ratio on both ultimate and cracking loads in groups (A, C and E).

Figure 14-a and b. The effect of vertical shear reinforcement on both cracking loads (Pcr) and ultimate (P_{ult}) when (ρh=0.343%).

Where:-
Group A: ρv=ρh=0.0.
Group B: ρv=0.25%,ρh=0.0.
Group C: ρv=0.45%, ρh=0.0.
Group D: ρv=0.25% ρh=0.343%.
Group E: ρv=0.45%, ρh=0.343%.

11. Load- deflection Relation

The mid-span deflections curves for all the tested beams of each beam as a function of the total applied loads are shown in "Fig. 15**"**, they are essential for describing the behavior of a beam at various stages of loading. Those mid-span deflection curves are those recorded at the failed span. At low load level and prior to first crack formation (up to first crack load), the load-deflection relations seem to be linear with semi constant slope. After cracking, the load- deflection response takes a nonlinear form with a variable slope where the deflection increases at an increasing rate as the applied load increases.

From "Fig. 15"**,** it is observed that the increase in web reinforcement ratio (ρv) leads to improvement in the ultimate load and hence increasing the deflection for all cases. Increasing the shear reinforcement improves the shear capacity because of the contribution of this reinforcement with concrete in resisting the diagonal tension stresses which often govern the failure where the reinforcement carries a portion of these stresses. Therefore, increasing the reinforcement area within the shear span leads to delay failure by splitting until it reaches the maximum tension capacity at further loads. It can be noticed also that presence horizontal web reinforcement decreases the

deflection values at each load stage for the same level of load and that's because of the effect of confinement.

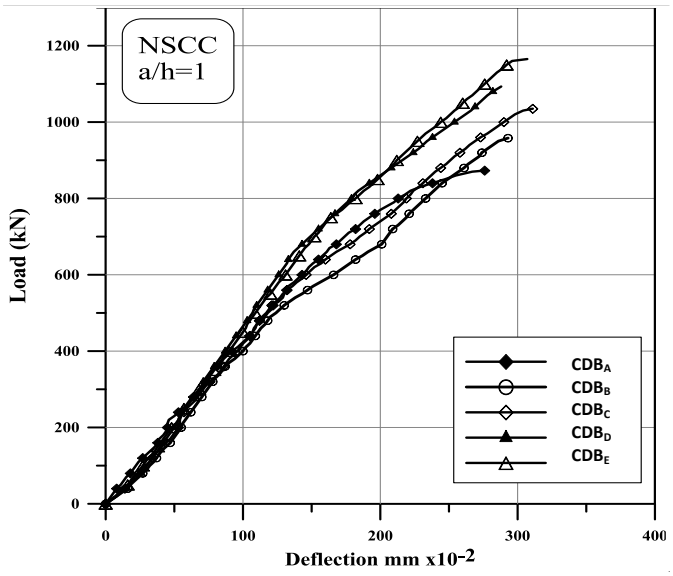

Figure 15. The load and mid-span deflection relationship for the tested beams.

12. Concrete Surface Strains

Concrete strains were measured at critical locations on the tested beams. Two Electrical resistance strain gauges (Type: TML/ PL-60-11-3L) made in Japan, were placed on the front face of the specimen to measure the compressive concrete surface strains, were located at the center of inclined strut track and parallel to the direction of concrete strut, as shown in "Fig. 16".

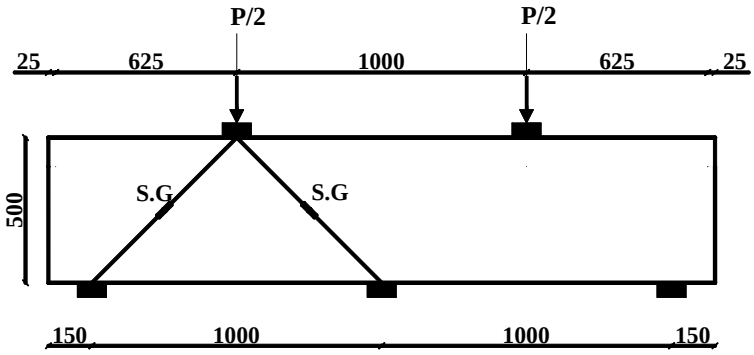

Figure 16. Location of Concrete Strain Gauges on the tested Continuous deep beams, (dimensions are in mm).

At early stages of loading, the developed concrete surface strains were very small. Further by increasing the applied load a sudden change in the average strain values will occur as shown in "Fig. 17", at this stage of loading, the formation of first shear crack took place. After that, concrete cracking became visible and strains increased at an increasing rate with respect to the applied load.

After cracking, the load- compressive strain takes a nonlinear form. "Table 7" shows the results of the estimated from experimental strain diagram first shear cracking load and the visually observed shear cracking load, from "Table 7" the results are relatively close and the difference in the results may be explained on the basis that the concrete strain gauges can predict the formation of crack in a manner greatly more accurate than visual inspection.

Table 7. Values of experimental shear cracking loads and shear cracking loads obtained from strain diagram

Beam designation	P_{cr} (kN) experimental	P_{ult} (kN)	(P_{cr}/P_{ult}) %	P_{cr} (kN) Estimated from Strain diagram	(P_{cr}/P_{ult}) %
CDB_A	200	873	23	200	23
CDB_B	205	958	21	200	21
CDB_C	220	1035	21	210	20
CDB_D	235	1093	22	230	21
CDB_E	240	1165	21	250	21

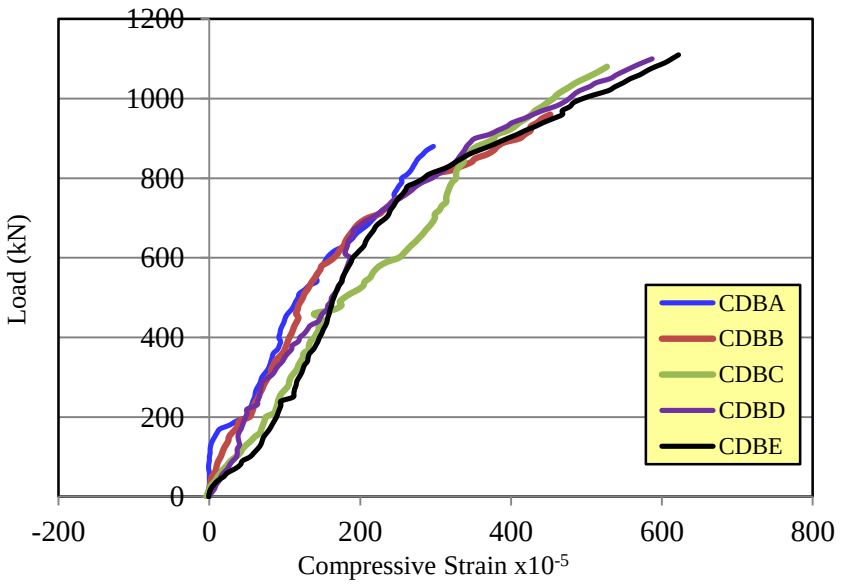

Figure 17. The concrete surface compressive strain for the tested beams.

13. Conclusions

From the experimental studies in the present work, the following conclusions are drawn:

1- All tested SCC continuous deep beams were failed by shear. The shear failure took place by diagonal splitting mode for all tested beams.
2- The presence of web reinforcement with (ρ_v=0.25%) enhances the behavior of SCC continuous deep beams by increasing both the cracking and ultimate loads by about 10%.

3- The ultimate and cracking loads (P_{ult} & P_{cr}) seem to be improved by increasing the magnitude of vertical web reinforcement ratio (ρ_v) from (0.25%) to (0.45%), the enhancement exceeds 18%.
4- It can be noticed that, for a certain load level, the values of mid-span deflection in beams supplied with both horizontal and vertical web reinforcement are smaller than those in beams having vertical stirrups only .
5- The concrete surface compressive strain will be increased when the horizontal web reinforcement exist.

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