# Effecting Shear Span Ratio on High Strength Fiber Reinforced Concrete Deep Beams with Circle Openings

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*Abstract*-**Through this paper the effecting a/d on high strength fiber reinforced concrete deep beams with circle openings without stirrups have been studied to report behavior of deep beam by chang shear span ratio a/d for high strength deep beam with circle opening (12.6 cm) diameter at the center of shear span in term of crack pattern and load-deflection curve and stress-strain curve, this paper aim to investigate which specimen has better a/d, this study done by tested four specimens; first specimen is control deep beam without opening and steel fiber while the other are with steel fiber ratio (1%) and circle opening has diameter (12.6 cm) at the center of shear span and reinforced by (2Ø12mm) at the top and (3Ø16mm) at the bottom and two stirrups at the supports to prevent local failure, specimens with circle opening have various a/d (0.75,1,1.5) and total lengths (1025,1200,1550)mm, all specimens are simply supported with two points applied load, finally, the results present the perfect shear span ratio (a/d) with steel fiber (1%) is (0.75), The strength of specimens with circle opening decrease with increase shear span ratio (a/d) where strength rising into (5.48 %) at (a/d = 0.75) over than strength at (a/d = 1).**

## I. INTRODUCTION

Deep beam is an element that has a deeper depth as compare to it overall length (ln≲4h)**[1]** and has a geometry make it stress and strain distribution don't follow a linear distribution and it analysis become nonlinear like two dimension, sometime the depth of beam is increase to meet some of architecture requirement and because the increasing of depth more the limit of ordinary beam the geometry is change and principle stress is change due to geometry change and the compressive stress transfer directly to the support making a compression path and make the shear strength is control rather than flexure failure and the plane section don't remain plane after applied the load to induce the nonlinearity of distribution of stress and strain through the overall depth and the equations that is used to calculate the shear strength be don't apply in this state the two dimension elasticity analysis used to predicted the shear strength like finite element and strut and tie method.

Sometimes in the tall building the passageway of services maybe intersect with deep beams that used in building so that an opening with different shapes and size and locations are required to pass the services, like ducts and electrical and mechanical services, through the deep beams so that strength of deep beams is decreasing and the cracks will appear around the opening and behavior of deep beam with openings become different from the solid beam.

## II. LITERATURE REVIEW

Kute and Naik (2013) **[2]** , reported **Span-to-depth ratio effect on shear strength of steel fiber-reinforced high-strength concrete deep beams using ANN model ,** in this paper the artificial neural network (ANN8) to assess the shear strength of RC high strength steel fiber deep beam by taking consideration the (L/D)on shear strength , this done by using model of three layered that is contain 8 node each node represent one factors effecting on deep beam like ;depth (d) and width and steel fiber fraction and a/d and (L/D)..etc then the data that's obtain has been verification with data obtain from equations of previous studies the important conclusions in this paper were ; by increasing the (vf) of steel fiber (0,0.25,0.5,…..,2)% for different ratio of (L/D) by increasing the SF ratio the shear strength to the contrary of (L/D) that decrease the strength and a decreasing in strength at Vf =0.5% for rising the value of (L/D) while the decreasing about induced at Vf =2% the decreasing is 6% , by increasing the longitudinal reinforcement to 1.5% the shear strength has been increased to 140% at SF Vf=0.5% and the decreasing occur at Ast =2% even increasing ht (SF Vf), and the shear strength increasing about 91% at (L/D=1.75) and Ast=1.5%, and the peak increasing can obtain at a/d =1.5 for different ratio of (L/D) and small effect obtain when using (SF Vf=2% at a/d=1.5%) the increasing in strength was 2% , and after verification between (ANN8,ANN7(without (L/D) effect), equations proposed from previous research ) the good agreement notice between data obtain from ANN7 and equations of previous studies while data of ANN8 give high of shear strength.

Mohamed (2013)**[3]** , **Effect of Web Openings Size on Steel Fiber Reinforced Concrete Deep Beams ,** study the behavior of deep beam with steel fiber by presence of web opening with different sizes, in this study an analytical results have been obtained by analyze sixteen model by using ADINA program the models different between each other by size of opening and steel fiber fraction and shear span ratio and these results have been compared with previous experimental results withstand of load deflection curve to show ; the deflection increase in the models with opening , the models with shear span to depth (a/h =0.5) has higher ultimate load than models with shear span to depth (a/h=0.7) in case of with or without steel fiber , the models with steel fiber 1% and without opening have least deflection and large ultimate load as compared with other models , the ultimate load increased in model that have steel fiber as compared with model without steel fiber because the steel fiber increase the stiffness of beam.

Karunakaran et al (2017) **[4]**, study the **Experimental Study on Behavior of Steel Fiber Reinforced Concrete,** in this thesis they study the effect of steel fiber on compressive strength and tensile strength and flexure strength of concrete by varied the ratio of steel fiber in concrete (0,0.25,0.5,0.75,1,1.5,2)% versus the compressive and tensile and flexure strength finally, they arrived to the results , by increasing the steel fiber percentage this lead to increase in compressive and tensile and flexure strength.

Sethuraman at el (2017) **[5]** , carry out **Numerical Analysis of High Strength Concrete Beams using ABAQUS ,** the goal of this study is simulate the high strength concrete in ABAQUA and make a comparison between the analytical result and experimental results that have been did recently , a six specimens have been tested under static load while another six beam tested under cyclic load then the same specimens analyzed by using ABAQUS finally the results show the failure mode and deflection in ABAQUS and experimental works are matched closely.

## III. EXPERIMENTAL WORK

All materials have been tested in collage of engineering in Basrah University Laboratory and testing of material was according to American Society for testing and materials (ASTM) and Iraqi specifications.

- **Cement** that has been used in this study is (ALDOUH) cement that meeting the Iraqi specifications (5:1984)**[6].**
- **Fine aggregate** that is used in this study is natural sand from Al-Zubair area, test made to show the meeting of sand properties to Iraqi specification (45:1984) **[7].**
- **Coarse aggregate** that is used in this study is natural gravel from sanam mountain, test made to show the meeting of sand properties to Iraqi specification (45:1984) **[8].**
- **Steel reinforcement** is Ukrainian reinforcement factory, the sizes of bars used in this study is (ø 12mm) for top reinforcement for deep beam specimens an (ø 16mm) for flexural bottom bars and (ø 10mm) as shear reinforcement stirrups, the quantity and spread of steel were according deep beam design by strut and tie method.

A tensile test has been made for steel bar to know the properties of steel the test was according to (ASTM A615/A615M-04b) **[7]**

- In this study a **Hyperplast** PC200 from (DCP company) that's know sometimes (Flocrete PC200).**[9]**
- **Water** is clear and potable that used in concrete mix

The steel fiber that have been added according to ASTM A820 **[10]**

### *A: Concrete Mix Design*

Mix design is according to British method (DOE)[11] and the quantity of material is according to table (1)

### *B: Specimens Details*

The details of specimens, which will be casted are, are tabulated in table (2) and explain in fig.(1)

**Photo (1):** Specimens Casting and Vibration

**Photo (2):** Specimens Curing

**Table (1):** Mix design quantity

| Type | Cement content (1) | Fine aggregate (1.33) | Coarse aggreg-ate (2.167) | Water (0.28) | Superplasticiz-er (2%) | Steel fiber |
|---|---|---|---|---|---|---|
| Weight (kg) per 1m3 | 502 | 669 | 1087 | 140.6 | 10 | 0 |
| SF0.5 | 500 | 665 | 1084 | 140 | 10 | 39.28 |
| SF0.75 | 498.64 | 663.2 | 1080.55 | 139.62 | 9.97 | 58.92 |
| SF1 | 497.38 | 661.52 | 1077.82 | 139.27 | 9.95 | 78.56 |

**Table (2):** Specimens Details

| No | Beam Description | Symb-ol | Openi-ng | Steel Fiber | a/d | Total length | Reinforcement |
|---|---|---|---|---|---|---|---|
| 1 | Control beam | D-CO-SO-SF0 | without | without | 1 | 1200 mm | 2ø12 mm top<br>3ø16 mm bottom |
| 2 | With steel fiber and circle opening | D-CP2-SF1 | Circle<br>12.6 cm<br>diameter | 1 % | 1 | 1200 mm | 2ø12 mm top<br>3ø16 mm bottom |
| 3 | With steel fiber and circle opening | D-CO2-SF1%-a/d=1.5 | Circle<br>12.6 cm<br>diameter | 1 % | 1.5 | 1550mm | 2ø12 mm top<br>3ø16 mm bottom |
| 4 | With steel fiber and circle opening | D-CO2-SF1%-a/d=0.75 | Circle<br>12.6 cm<br>diameter | 1 % | 0.75 | 1025 mm | 2ø12 mm top<br>3ø16 mm bottom |

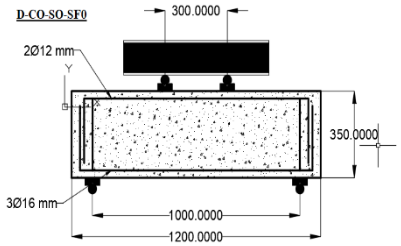
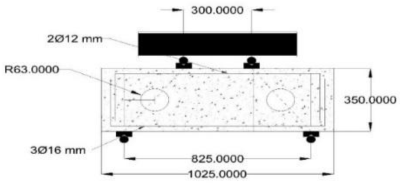
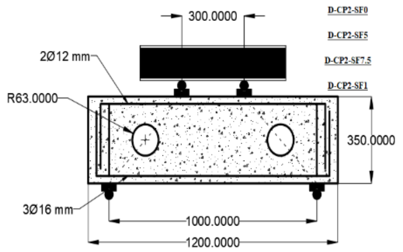
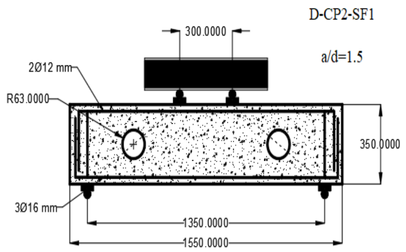



**Fig. (1):** Specimens Detail




*C: Concrete Casting*

After mixing, the concrete casting in mold then concrete has been compacted by using poker vibration to extract the air content from concrete and spread concrete regularly through reinforcement, the using trowel to level specimens surface, a sign identification put for each specimen, a three cubic and 1 cylinder used for each specimen casting for the test in order to specify concrete characteristics as shown in Photo.(1

*D: Concrete Curing*

After concrete casted, the specimens covered by wet damp burlap sacks in laboratory at 25 ℃ and humidity 90% for 28 days as shown in Photo (2)

*E: Testing*

*E-1: Compressive Strength*

The cubes of concrete with dimensions (15x15x15)cm according to (BS 1881 : Part 116 : 1983) **[12]** have been casted, then after 24 hour ago cubes putted in water reservoir for curing, after 7 days a part of this cubs test then after 28 day from curing a remaining parts of cubs testing as shown in Photo (3) to know the compression strength of concrete, the test is done by using digital compression machine shown in fig. (2), test in Basra laboratory and result record in table (3):

**Table (3):** Compression Strength 28 Days

| NO. | Cube Name | 28 Days Compression Strength (MPa) | Average Strength (MPa) |
|---|---|---|---|
| 1 | AG1-SF0 | 52.631 | 52.574 |
| 2 | BG1-SF0 | 53.111 | |
| 3 | CG1-SF0 | 51.981 | |
| 4 | AG2-SF10 | 59.143 | 59.535 |
| 5 | BG2-SF10 | 62.131 | |
| 6 | CG2-SF10 | 58.233 | |
| 7 | AG3-SF10 | 60.611 | 60.759 |
| 8 | BG3-SF10 | 60.03 | |
| 9 | CG3-SF10 | 61.636 | |

**Photo (3):** Compressive and Split Tensile Machine

*E-2: Split Tensile Strength*

Three cylinders have been tested as shown in Photo (3) according to (C496/C496M) **[13]** and tabulated in table (4) and shown in fig. (2):

**Table (4):** Split tensile strength

| NO. | Cylinder Name | Split Tensile Strength (MPa) |
|---|---|---|
| 1 | G1-SF0 | 4.31 |
| 2 | G2-SF10 | 6.76 |
| 3 | G3-SF10 | 6.88 |

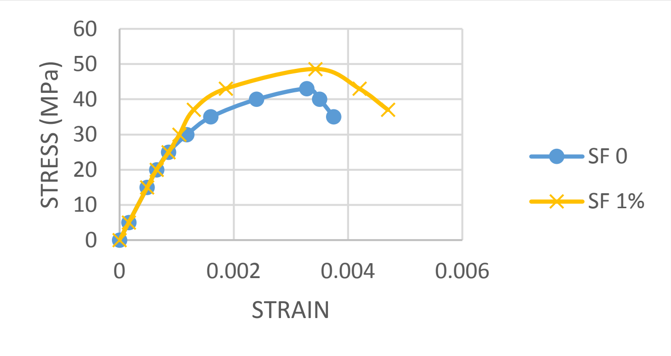



**Fig. (2):** Stress-Strain curves

**Photo (4):** Cylinder for uniaxial compression test

**Photo (5):** Universal Machine Test and Extensometer

*E-3: Uniaxial Compressive Strength*

A three concrete cylinders with various steel fiber ratio have been tested in order to study behavior of concrete under compression stress and find modulus of elasticity a data recorded and curve constructed in fig. (2), the test done in Basra University at college of engineering by using (H-2911 instrument) the test is according to (ASTM C-469) **[14]** as shown in Photo (4)

## IV. SPECIMENS RESULT

A 2000 KN universal testing machine which located in Basra university laboratory as shown in Photo (5), used in this test for all specimen groups, in this machine we use (H-beam) shaft to distributed concentrated load (P) into two load (P/2) that's applied on specimen by distance (30 cm) between two loads, the support of specimen is done by using (H-section) beam fix on rail at the center of machine, thick plate with widith (7cm) is fix above H-beam to support the specimen at the (10 cm) from edges of specimen at the each side.

At the first (before loading applied) an initial reading of strain is take it at the zero load by using extensometer as show in Photo (5) then the dial gauge is put on zero reading.

*A: Ultimate Load*

The ultimate loads have been recorded for each specimen and tabulated in table (5) which represented effecting of a/d on deep beam with opening

**Table (5):** Ultimate load of specimens

| **NO.** | **Specimens Name** | **Steel Fiber Ratio** | **a/d** | **Ultimate Load (KN)** | **Pu/Pcn %** |
|---|---|---|---|---|---|
| **1** | D-CO-SO-SF0 | 0 | 1 | 320 | - |
| **2** | D-CP2-SF10 | 1% | 1 | 305 | 95.31 |
| **3** | D-CO2-SF10-a/d=0.75 | 1% | 0.75 | 335 | 104.69 |
| **4** | D-CO2-SF10-a/d=1.5 | 1% | 1.5 | 230 | 71.88 |

From observation the results; the specimen (D-CO2-SF10-a/d=0.75),that has circle opening size (12.6 cm dia.) and steel fiber (1%) with shear span ratio (a/d) equal to (0.75), has ultimate load (335 KN) which is greater than ultimate load of specimen (D-CP2-SF10) and the deflection for (D-CO2-SF10-a/d=0.75) is (3.6mm) which is less than deflection of specimen (D-CP2-SF10) is (3.65 mm), while the specimen (D-CO2-SF10-a/d=1.5), that has circle opening size (12.6 cm dia.) and steel fiber (1%) with shear span ratio (a/d) equal to (1.5), has ultimate load is (230 KN) which is less than ultimate load for specimen (D-CP2-SF10) while the deflection of specimen (D-CO2-SF10-a/d=1.5) is (3.67 mm) which is greater than deflection for specimen (D-CP2-SF10), so that best shear span ratio (a/d) in this study is (0.75) which has biggest value of ultimate load the reasons that make deep beam with (a/d) equal to (0.75) has greater ultimate load because the struts of compression path is convergence to verticality that mean become more steeper so that the load is closely transfer to supports and the compression path has importance of transfer the load also when shear span is less the strut will be smaller and width of compression path become wider so that the maximum compression stress transfer directly.

Also the Arch action become significant at smaller shear span ratio, in contrast of long shear span because the deep beam convergence to behavior of ordinary beam.

*B: Load-Deflection Curve*

After specimen placed inside the universal, the load applying, at the beginning the load apply and the deflection record for known step of load even appear first crack the load recorded at this stage represent by (First crack load) in this stage the beam transfer from elastic behavior into plastic behavior, the records of (load-Deflection readings) for plastic stage and the crack width is measure for crack.

The cracks formation at the bottom side of opening between support and opening then cracks development and new cracks appears at final noise of crashing hear and drop in load indicate the beam is failure

The fig. (3) Represented load-deflection curves for all tested specimens

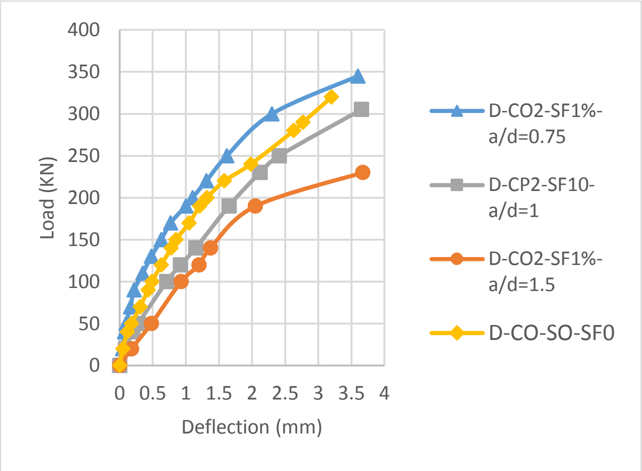



**Fig. (3):** Load-Deflection Curves for Specimens

Fig. (3) show that specimen with steel fiber content 1% but with (a/d=0.75) has steeper curve than the other specimen which have bigger a/d, also the hardening region is biggest due to steel fiber effect, this specimen stiffer than control because of effecting of small a/d and steel fiber is more effect than effecting of small opening size.

The results show the specimens with (a/d=1.5) have larger deflection than other specimens at the same time it have less shear strength because of the shear resist is changing from the arch action at specimens with less a/d ratio to beam action at specimens with higher a/d ratio so that the steel fiber play main role to improve ductility of deep beam with higher a/d, that's noticeably in large deflection in specimen with higher a/d , then the shear strength improvement all that is identical with conclusion of Narayanan, R. and Darwish, I.Y.S..

*C: Crack Width*

For all specimens, after applied load and first crack is formation, loading stop then crack width is taken by micro crack reader then the crack width and first crack load is recorded then the propagation of first crack is highlight by special pen to study cracks propagation,

**Table (6)**: First crack of specimens

| NO. | Specimens Name | First Cracking Load (KN) | Ultimate load (KN) | Pfc/Pu % |
|---|---|---|---|---|
| **1** | D-CO-SO-SF0 | 170 | 320 | 53.13 |
| | D-CP2-SF10 | 190 | 305 | 62.3 |
| **2** | D-CO2-SF10-a/d=0.75 | 215 | 335 | 64.18 |
| **3** | D-CO2-SF10-a/d=1.5 | 142 | 230 | 61.74 |

Then the load is release and monitoring the specimen for the new crack same procedures that followed in first crack used with new cracks this procedure is follow for all specimens, first crack tabulated in table (6)

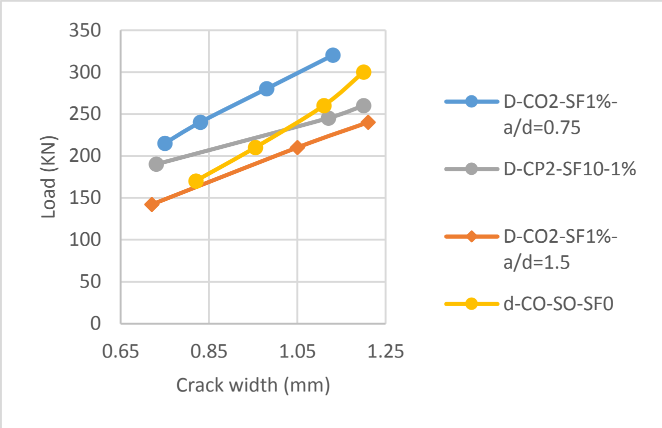



**Fig. (4): Cracks Width for Specimens**

For specimens, with circle openings and different shear span ratio (a/d), the first crack is formation when the applied load reach to (61%-64%) from the ultimate load as shown in fig. (4) and the position of crack occur at tangential of circumference opening corner below neutral axis at limit of compression path, the initial crack is very shallow and has narrow width the initial crack formation when stress reach to level in compression path in some region that has small area so that the intensity of compressive stress more than strength so that the crack start propagate and when load increments increase the tensile stress corresponding to compressive stress at perpendicular direction make crack width become wider and the main factor that contribute with shear strength is aggregate interlock when the shear reinforcement absence.

When increased load some of cracks are completely formation, the first crack or other cracks which formation beside the first crack in regions inside compression path along length and wide are different in each loading stage and propagate toward the supports and point of where load applied the reasons about formation cracks are when the load reach to level in compression path has small area stress intensity become more than compression strength in addition to maximum tensile stress at crack tip is redistribution every load stage to reach to stable state even failure occur by diagonal crack as shown in photo (6).

D-CP2-SF1

D-CO2-SF1%-a/d=1.5

D-CO2-SF1%-a/d=0.75

Photo (6) : Crack pattern of specimens

## V. ABAQUS

A process of simulating and meshing experimental specimens viewing, analysis of specimens doing by using Abaqus 6.13 and results get like; cracks propagation and plastic strain and deflection stress distribution then a comparison has been done between deflections at failure in case of experimental and numerical to make verification by load-displacement between them.

Every modeling that creating in Abaqus must be passing cross sequence step like; create part, define material property and assigned, assembly, step, interaction, boundary condition, meshing, and run job.

### *A: Concrete Properties*

**Table (7):** Property of Concrete

| | Property | Value |
|---|---|---|
| General | Density | 2.4 g/mm3 |
| | Modulus of Elasticity | Depend on UCT according to ASTM C-469 |
| | Poisson's ratio | 0.2 |
| Concrete Damage Plasticity | | |
| Plasticity | Dilation Angle | 30 |
| | Eccentricity | 0.1 |
| | Fb0/Fc0 | 1.16 |
| | K | 0.667 |
| | Viscosity Parameter | 0 |
| **Compressive Behavior** | | |
| Depend on uniaxial compression test | | |
| **Tension Behavior** | | |
| Depend on uniaxial tension test | | |

### *B: Steel Properties*

**Table (8):** Steel properties

| | **Property** | **Value** |
|---|---|---|
| General | Density | 7.856 g/mm3 |
| Mechanical | Modulus Of Elasticity | 200000 N/mm2 |
| | Poisson's ratio | 0.3 |
| Plastic | Yield Stress Vs Plastic Strain | Depend on Tensile test for Reinforcement |

### *C: Elements*

**Table (9):** Elements

| **No.** | **Part Name** | **Element Type** | **Type Description** | **Element Size** |
|---|---|---|---|---|
| 1 | Concrete | C3D20R | Continuum brick element 3d with 20 nodes reduced integration (quadratic) | 50 |
| 2 | Plate | C3D8R | Continuum brick element 3d with 8 nodes reduced integration (linear) | 25 |
| 3 | Stirrup | T3D2 | Truss element 3d with 2 node | 50 |
| 4 | Bar12 | T3D2 | Truss element 3d with 2 node | 50 |
| 5 | Bar16 | T3D2 | Truss element 3d with 2 node | 50 |

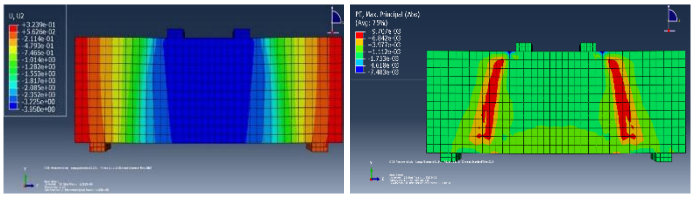
### *D: Results*

Any Specimen that have been cast in laboratory modeled individual in Abaqus by follow steps which are mentioned above, each specimen has it material properties and geometry and boundary conditions.

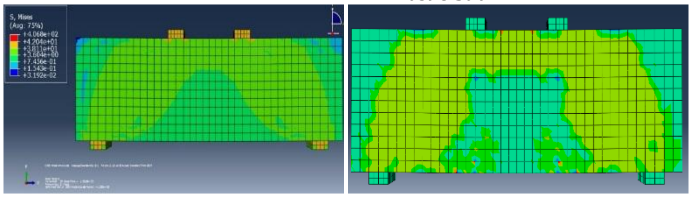
The results, that will present, represent by; Deflection contour values, plastic strain, stress distributions and cracks pattern.

Then a comparison has been made between an experimental and analytical load-deflection curve

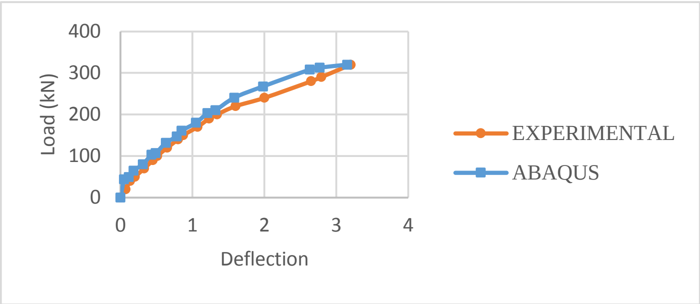
The fig. (5), (6), (7), (8) represented all outfield data of abaqus for each specimen castes, also include a comparison between abaqus and experimental load deflection curves Table (10).



Deflection Plastic Strain

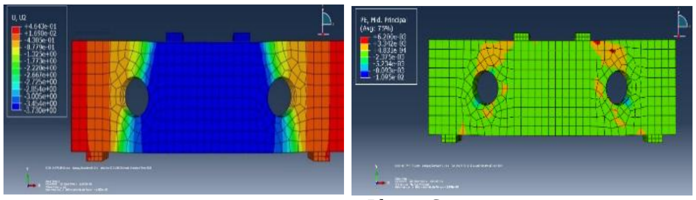


Stress Crack Distribution

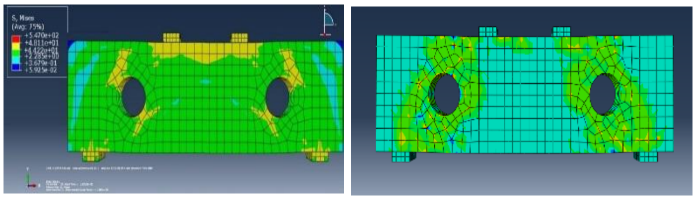



Load Deflection Curves for Experimental

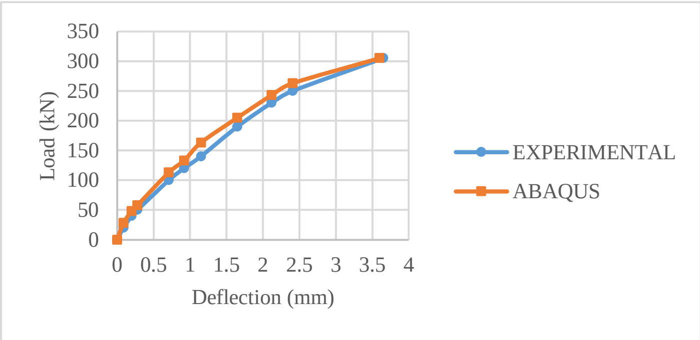
**Figure (5):** Data of Specimen D-CO-SO-SF0 Data



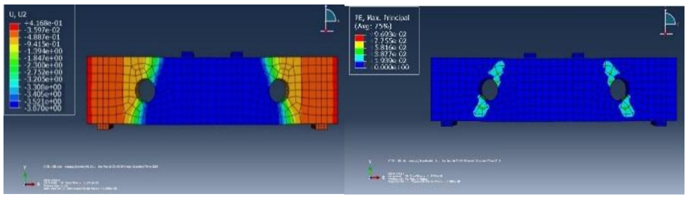
Deflection Plastic Strain



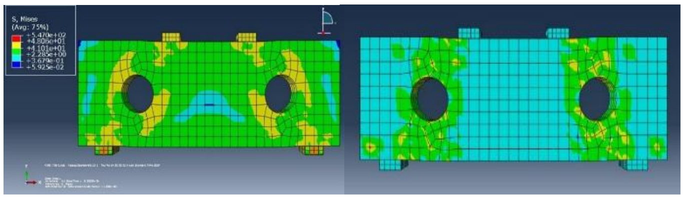
Stress



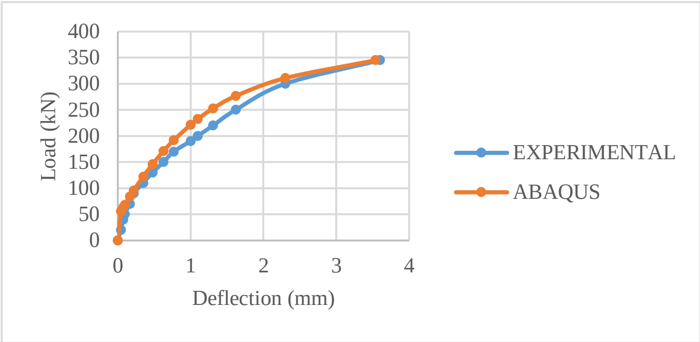

Load Deflection Curves for Experimental and Abaqus`
**Figure (6):** Data of Specimen D-CP2-SF10



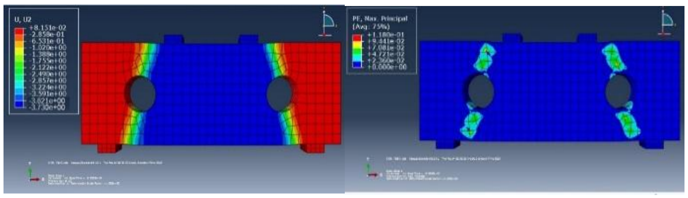
Deflection Plastic Strain



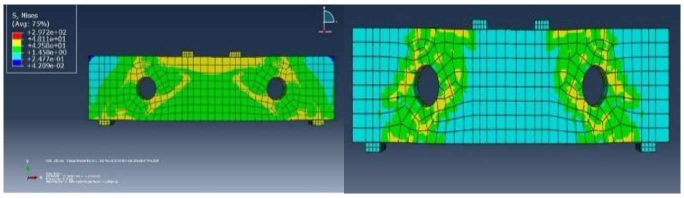
Stress Crack Distribution



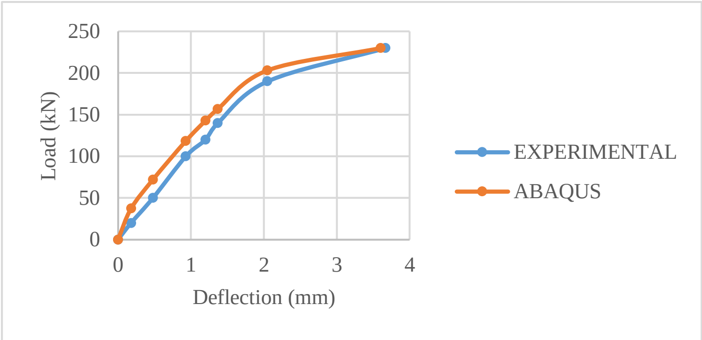

Load Deflection Curves for Experimental and Abaqus`
**Figure (7):** Data of Specimen D-CO2-SF1%-a/d=0.75



Deflection Plastic Strain



Stress Crack Distribution




Load Deflection Curves for Experimental and Abaqus`
**Figure (8):** Data of Specimen D-CO2-SF1%-a/d=1.5

**Table (10):** Comparison between Experimental and Numerical Displacement at Failure

| NO. | Deep Beam | Experimental Displacement (U2) mm | Numerical Displacement (U2) mm | U2Num/U2Exp. % |
|---|---|---|---|---|
| 1 | D-CO-SO-SF0 | 3.2 | 3.15 | 98.44 |
| 2 | D-CP2-SF10 | 3.65 | 3.6 | 98.63 |
| 3 | D-CO2-SF1% a/d=0.75 | 3.6 | 3.54 | 98.33 |
| 4 | D-CO2-SF1%-a/d=1.5 | 3.67 | 3.602 | 98.15 |

After presented the comparison between experimental and numerical displacement at failure and data obtained from Abaqus we notice following:

**1.** The results that are obtained from Abaqus have good agreement to experimental result with Average percentage of agreement about 98% so that it possible to depend on Abaqus to predict the ultimate load for deep beam.

**3.** In Abacus the stress transmitting from point of apply load to point of supporting in compression path and create strut like the strut in reality.

**4.** The cracks distributions and propagation which are formation in compression path are approximately agreement with real specimen.

**5.** Load-Deflection curves that obtained from Abaqus have very good agreement with Load-Deflection curves of experimental with little conservation stiffer than experimental because of:

5.1-In Abaqus the interaction between steel and concrete is fully bond so the modal become stiff than experimental.

5.2-Abaqus doesn't take consideration the air content inside concrete that influence on concrete strength.

5.3- the climate of curing is influence on experimental result so that it differ than Abaqus

6. The stresses in Abaqus doesn't exceed the (fc') of concrete for plain concrete and with steel fiber .

### 6.1: Conclusions

**1**. By using deep beams with circle opening size (12.6 cm dia.) and steel fiber (1%) and different shear span ratio, the results show that the ultimate load increase with decrease (a/d), and shear span ratio (a/d = 0.75) rising ultimate load by (104.69%) and it better ratio between other shear span ratio.

**2**. For the deep beam with circle opening (12.6 cm dia.) and steel fiber (1%) and with different shear span ratio (a/d), the first cracking load is about (61%-64%) from the ultimate load.

**3**. Crack width in specimen with higher (a/d) is wider than other specimen with lower (a/d).

**4**. The results that obtained from Abaqus have good agreement to experimental result the Average percentage of agreement about 98% so that it possible to depend on Abaqus to predict the ultimate load

**5**. The cracks distributions and propagation is approximately agreement with real specimen.

**6**. Load-Deflection curves that obtained from Abaqus have very good agreement with Load-Deflection curves of experimental with little conservation.

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