Experimental Investigation of Effect of Steel Fiber on Concrete Construction Joints of Prism

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Abstract. Joints in construction are finishing casting points in the placing of a concrete process, and these are needed in various constructions because it is impossible to install concrete in an individual connected procedure. The quantity of mixture that can be installed at a whole time is administered by the batching and mixing ability and by the strength of the formwork. A qualified joint in construction must afford sufficient continuity in shear and flexural completed the interface. In this investigation, the influence of position and character of joints in construction on the achievement of concrete components is laboratory examined with the impact of steel fiber. Prism with dimensions of (100*100*400mm) was used. The factors examined are the position of the joints in construction (at mid-span or at the third point of the prism), construction joints type (horizontal, inclined, and vertical joints).

1. Introduction
In concrete constructions, Joints are essential for a difference of purposes. Not entirely concrete in an assigned construction can be incessantly installed, so there is joints construction that provides for employment to be continued subsequent a while and considering concrete encounters changes in volume, it can be beneficial to implement joints and consequently substitute stresses in compressive or tensile. It is essential later to accommodate numerous varieties of joints in most concrete structures which should function sufficiently for designed purposes \cite{1, 2}.

To better experience the mechanism of bonding at the interface connecting new and early concrete outsides, it is fundamental to estimate the strength of bond at the layer interfacial and to examine influencing parameters of its characteristics. Numerous investigations have concentrated on the mechanism of the bond within renovation concrete and substrate concrete. In this utilization, the features of the interfacial bond essentially rely on the adhesion connecting the replacement concrete at the interface and the concrete substrate, the repair concrete, cohesion in the substrate concrete, friction, aggregate interlock, and different time-dependent constituents which in turn, rely on other variables \cite{3-6}. Normal concrete has moderate strength in tensile and efficiently cracks following tensile stress. This deficiency is defeated by installing, steel fiber in the mixture. The steel fibers employed are small discrete dimensions of steel possessing a various aspect ratio, with each of individual cross-sections and such is adequately small sufficient to be separated randomly in an unhardened mixture of concrete utilizing conventional mixing schemes. Fibers significantly overcome the concrete brittleness and advance its design characteristics such as toughness, flexural, impact resistance, tensile, fatigue, load-bearing capacity after cracking, etc \cite{7-12}.

2. Literature Review
Camille A et al. (2014) \cite{1} studied the concrete compressive strength and the modulus of rupture for beams of plain concrete with a vertical construction joint placed at their center. Zena W (2011) \cite{2} presented the consequence of position and variety of construction joints on the production of structural elements of reinforced concrete. Hussain A et al. (2017) \cite{3} have investigated the influence
of development joints on the achievement of reinforced concrete beams. Cheng Z et al. (2013) [4] studied the construction joints with three joint types, including arc joints, trapezoid joints, and flat joints. Ju’lio E et al. (2005) [13] presented a pull-off test to study the strength of the bond within a couple of concrete layers, using various procedures for improving the hardness of the substrate exterior. Pedro M et al. (2006) [14] investigate individuals with the substrate outside provided with various roughening procedures with tests of shear of slant and pull-off. Eduardo N et al. (2006) [15] estimate the strength of bond within a couple of layers of concrete of varying generations, mixtures, and strengths. Al-Sulayvani B J, and Al-Feel J R (2008) [16] study the shear transfer of uncracked fibrous concrete using the push-off and modified push-off type. Beushausen H and Alexander MG (2008) [5] introduced a couple of different experimental techniques for the shear strength of the interface evaluation. Husain M et al. (2009) [17] have investigated eight tests in which in-plane shear forces are applied across the joint between two different concretes forming a composite action. Shin and Z Wan (2010) [18] fabricated overlaid specimens to measure shear bond strength. Riyadh J (2010) [19] a push-off tests were conducted to quantify the shear strength capacity at the interface within old and new concretes. Pedro M et al. (2011) [20] examination managed to estimate the impact of differential shrinkage and stiffness on the strength of bond about new-to-old concrete interfaces. Hakim S (2015) [21] A mathematical equations assumed to find out the horizontal shear strength. The deviation recorded is about 4% which is an acceptable one. Vandhiyan R and Kathiravan M (2017) [22] have investigated the old and new concrete layers bond strength, using different tests for adding epoxy-based bonding agent.

3. Details Description of the Experimental Work

The objective of the current investigation is to explain the impact of the types and locations of the joints of construction on the structural performance of concrete prism and find the effect of steel fiber on construction joints. Mixes were divided into three different types with different steel fiber content (normal concrete, normal concrete of 1.0% steel fiber and normal concrete of 2% steel fiber). Different properties tests were performed including (compressive strength, tensile splitting, and flexural strength). All work were investigated over a period of 28 days. Table 1 presents the features of various characters of mixes employed in the existing investigation work. Further details on specimen, fabrication, casting and testing will be given in subsequent sections. Plywood molds were prefabricated to cast the specimens. It consists of (100*100*400mm) size prisms as shown in Figure 1 separated by thin plywood sheets for the concrete casted at different time, while for the prism casted at the same time the mold full with concrete without separation. For the different layer, one layer was cast first, while the other cast later after 28 days. Table 2 shows construction joint locations and types.

| Concrete type                  | Cement kg/m3 | Sand kg/m3 | aggregate kg/m3 | w/c   | Steel fiber (%) |
|--------------------------------|--------------|------------|-----------------|-------|-----------------|
| Normal Concrete                | 420          | 650        | 1000            | 0.45  | --              |
| Normal Concrete with 1.0% fiber| 420          | 650        | 1000            | 0.45  | 1.0             |
| Normal Concrete with 2.0% fiber| 420          | 650        | 1000            | 0.45  | 2.0             |

4. Factors of the Test Program

The factors influencing the joints in the construction of concrete fundamental components are investigated experimentally. These factors incorporate the position and type of engineering joint.

4.1 Location of Construction Joint

Couple separate positions are recognized: in the center of the mold and at the third point. The motivation for preferring the couple positions is to examine the performance of the concrete prism during the planning joint is at highest moment and zero shear and the position of small moment and shear.

4.2 Classes of joints in construction

Three varieties of joints in construction were examined in this research:

a.1. Construction joint (Vertical)
This kind of joint composition is performed by utilizing a stop-wood board installed vertically following forming the initial section of the prism. The concrete then has to be spread out to extend from the former concrete to the late one.

a.2. Construction joint (Horizontal)

This kind of joint is produced through casting the prism at different depth. The concrete then has to be spread out to continue from the early concrete to the late one.

a.3. Construction joints (Inclined)

In this kind of joints, the stop-wood is formed so that the direction of the joints of construction be able to manage. One inclination was employed, 45° with the vertical axes. The motivation for adopting this inclination is to examine the influence of such inclination on the function of the prism.

![Figure 1. Experimental test type.](image)

| Series | Specimen No. | Location of Construction joints | Type of construction joint |
|--------|--------------|---------------------------------|-----------------------------|
| 1      | S1           | --                             | --                          |
|        | S2           | Middle                         | Horizontal                   |
|        | S3           | First Quarter                  | Horizontal                   |
|        | S4           | Fourth                         | Horizontal                   |
|        | S5           | Middle                         | Vertical                     |
|        | S6           | Third                          | Vertical                     |
|        | S7           | Middle                         | Inclined 45°                 |
|        | S8           | Two third                      | Inclined 45°                 |
|        | S1F1         | --                             | --                          |
|        | S2F1         | Middle                         | Horizontal                   |
|        | S3F1         | First Quarter                  | Horizontal                   |
|        | S4F1         | Fourth                         | Horizontal                   |
| 2      | S5F1         | Middle                         | Vertical                     |
|        | S6F1         | Third                          | Vertical                     |
|        | S7F1         | Middle                         | Inclined 45°                 |
|        | S8F1         | Two third                      | Inclined 45°                 |
|        | S1F2         | --                             | --                          |
|        | S2F2         | Middle                         | Horizontal                   |
|        | S3F2         | First Quarter                  | Horizontal                   |
|        | S4F2         | Fourth                         | Horizontal                   |
| 3      | S5F2         | Middle                         | Vertical                     |
|        | S6F2         | Third                          | Vertical                     |
|        | S7F2         | Middle                         | Inclined 45°                 |
|        | S8F2         | Two third                      | Inclined 45°                 |

5. Mixing procedure of Specimens

In the case of a non-fibrous normal concrete mixture, the dry materials initially mixed including cement, sand, and gravel for a certain period and then added the water to obtain a homogeneous mixture. For the mixture containing fiber, the fiber is added finally by hand to distribute evenly. High tensile strength steel fiber manufactured by (Hebei Yusen Metal Wire Mesh Company, China), were used with round straight having (13mm) length and (0.25mm) diameter. Earlier to molding, all parts of molds were well scrub completely, compressed properly and their inside surfaces were delicately greased to avoid and prevent the adhesion of hardened concrete to the inner molds surface. After
finishing the casting process, the homogeneous mixture is distributed to the molds where it is filled with three layers and shaken using shakers to remove the air from the concrete to obtain a homogeneous casting. The surface of the molds shall be modified and covered with special concrete sheets to prevent the water evaporation from the concrete for a whole day and then taken out of the template and placed in water containers for 28 days after which they are taken out in preparation for the examination day. Figure 2 shows the mixing and curing of samples.

![Figure 2. Mixing and curing of samples.](image)

6. Concrete hardened properties

Several kinds of examinations for hardened concrete were constructed which are cylinders examined in compression according to [B.S-1881; part 116] and with [ASTM C39-2005] and cylinders examined in implied tension [ASTM specification C496-04] and prisms for flexure [ASTM C 348-02] specification. The results were analyzed and discussed in tables and figures forms of mechanical properties of all mixtures for different mixes specimens. For each of these properties, the average value of three specimens was obtained. Table 3 and Figures 3, 4 and 5 show the concrete hardening properties for different concrete strength.

1. When concrete changed from normal concrete to steel fiber concrete with percentage of (1.0 and 2.0%) the compressive strength, splitting and flexural tensile strength increased by (0, 10.34 and 17.24%), (0, 12, 18.42%) and (0, 20, 26.67%) respectively.

![Table 3. Strength and Mechanical Properties of Hardened Concrete.](image)

| Concrete type                  | f’c Cylinder (MPa) | Splitting tensile strength (MPa) | Flexural tensile strength (MPa) | % Compressive strength of cylinder | % Splitting tensile strength | % Flexural tensile strength |
|-------------------------------|--------------------|----------------------------------|--------------------------------|-----------------------------------|----------------------------|-----------------------------|
| Normal concrete               | 29                 | 3.80                             | 4.5                            | 0.00                              | 0.00                       | 0.00                        |
| Fiber-Normal concrete (1%)    | 32                 | 4.26                             | 5.4                            | 10.34                             | 12.00                      | 20.00                       |
| Fiber-Normal concrete (2%)    | 34                 | 4.50                             | 5.7                            | 17.24                             | 18.42                      | 26.67                       |

![Figure 3. Average compressive strength and fiber effect in increasing percentage.](image)
7. Results of all series
For the different layers, one layer was cast first, while the other cast later after 28 days. The concrete used was produced using three types of mixes. The experimental program includes testing of prism specimens under flexure listed in Table 4 and Figure 6.

Table 4. Flexural stress in all series.

| Series | Specimens No. | Construction joints | Locations | Type of construction joint | Load (kN) | Flexural stress (Mpa) | (%) Decreasing or Increasing percentage |
|--------|---------------|---------------------|-----------|---------------------------|-----------|----------------------|----------------------------------------|
| Series 1 | S4 | Middle | Horizontal | 15 | 4.5 | 0.00 |
| | S5 | Middle | Vertical | 13 | 3.9 | -13.33 |
| | S6 | Middle | Vertical | 13 | 3.9 | -13.33 |
| | S7 | Middle | Inclined 45° | 13 | 3.9 | -13.33 |
| | S8 | Two third | Inclined 45° | 12 | 3.6 | -20.00 |
| | S9 | -- | monolithic | 15 | 4.5 | 0.00 |
| | S10 | Middle | Horizontal | 14 | 4.2 | -6.67 |
| | S11 | First Quarter | Horizontal | 13 | 3.9 | -13.33 |
| Series 2 | S4F1 | Fourth Quarter | Horizontal | 15 | 4.5 | 0.00 |
| | S5F1 | Middle | Vertical | 14 | 4.2 | -6.67 |
| | S6F1 | Third | Vertical | 14 | 4.2 | -6.67 |
| | S7F1 | Middle | Inclined 45° | 14 | 4.2 | -6.67 |
| | S8F1 | Two third | Inclined 45° | 13 | 3.9 | -13.33 |
| | S9F1 | -- | monolithic | 15 | 4.5 | 0.00 |
| | S10F1 | Middle | Horizontal | 16 | 4.8 | 6.67 |
| | S11F1 | First Quarter | Horizontal | 15 | 4.5 | 0.00 |
| Series 3 | S4F2 | Fourth Quarter | Horizontal | 17 | 5.1 | 13.33 |
| | S5F2 | Middle | Vertical | 15 | 4.5 | 0.00 |
| | S6F2 | Third | Vertical | 16 | 4.8 | 6.67 |
| | S7F2 | Middle | Inclined 45° | 16 | 4.8 | 6.67 |
| | S8F2 | Two third | Inclined 45° | 15 | 4.5 | 0.00 |
7.1 Series 1 results and discussion (Normal Concrete)
When prism changed from monolithic to (middle-horizontal), (first quarter-horizontal), (fourth quarter-horizontal), (middle-vertical), (third-vertical), (middle-inclined 45°) and (two third-inclined 45°) normal concrete layer there was a decreasing in flexural stress of about (13.3, 20.0, 0, 13.33, 13.33, 13.33, 20.0%) as shown in Figure 7.

7.2 Series 2 results and discussion (1.0% steel fiber)
When prism changed from monolithic to (middle-horizontal), (first quarter-horizontal), (fourth quarter-horizontal), (middle-vertical), (third-vertical), (middle-inclined 45°) and (two third-inclined 45°) with (1.0% steel fiber concrete) layer there were a decreasing in flexural stress of about (6.67, 13.33, 0, 6.67, 6.67, 6.67 and 13.33%) as shown in Figure 8.

7.3 Series 3 results and discussion (2.0% steel fiber)
When prism changed from monolithic to (middle-horizontal), (first quarter-horizontal), (fourth quarter-horizontal), (middle-vertical), (third-vertical), (middle-inclined 45°) and (two third-inclined 45°) with (2.0% steel fiber concrete) layer there were an increasing in flexural stress of about (6.67, 0, 13.33, 0, 6.67, 6.67 and 0%) as shown in Figure 9.
For construction joint at (middle-horizontal) there was a decreasing in flexural stress of about (13.33%) for (normal concrete), and (6.67%) for (1.0% fiber concrete) and increasing in flexural stress of about (6.67%) for (2.0% fiber concrete) as shown in Table 5 and Figure 10.

Table 5. Flexural stress and percentage decreasing or increasing in flexural stress for middle and horizontal construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (%) Decreasing or Increasing percentage |
|---------------|------------------------------|----------------------------|----------------------------------------|
| S1            | --                           | Monolithic                 | 0                                      |
| S2            | Middle                       | Horizontal                 | -13.33                                 |
| S2F1          | Middle                       | Horizontal                 | -6.67                                  |
| S2F2          | Middle                       | Horizontal                 | 6.67                                   |

For construction joint at (first quarter-horizontal) there was a decreasing in flexural stress of about (20.0%) for (normal concrete), and (13.33%) for (1.0% fiber concrete) and no decreasing in flexural stress for (2.0% fiber concrete layer) as shown in Table 6 and Figure 11.

Table 6. Flexural stress and percentage decreasing or increasing in flexural stress for first quarter and horizontal construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (%) Decreasing or Increasing percentage |
|---------------|------------------------------|----------------------------|----------------------------------------|
| S1            | --                           | Monolithic                 | 0                                      |
| S3            | First Quarter                | Horizontal                 | -20.00                                 |
| S3F1          | First Quarter                | Horizontal                 | -13.33                                 |
| S3F2          | First Quarter                | Horizontal                 | 0.00                                   |
Figure 11. Flexural stress for first quarter and horizontal construction joint.

- For construction joint at (fourth quarter-horizontal) there was no decreasing in flexural stress for (normal concrete) and (1.0% fiber concrete) but for (2.0% fiber concrete) there was an increase in flexural stress of about (13.33%) as shown in Table 7 and Figure 12.

Table 7. Flexural stress and percentage decreasing or increasing in flexural stress for fourth quarter and horizontal construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (%) Decreasing or Increasing percentage |
|----------------|-------------------------------|----------------------------|----------------------------------------|
| S1             | --                            | Monolithic                 | 0                                      |
| S4             | Fourth Quarter                | Horizontal                 | 0.00                                   |
| S4F1           | Fourth Quarter                | Horizontal                 | 0.00                                   |
| S4F2           | Fourth Quarter                | Horizontal                 | 13.33                                  |

Figure 12. Flexural stress for fourth quarter and horizontal construction joint.

- For construction joint at (middle-vertical) there was a decreasing in flexural stress of about (13.33 and 6.67%) for (normal concrete), (1.0% fiber concrete), but no changes in (2.0% fiber concrete) as shown in Table 8 and Figure 13.

Table 8. Flexural stress and percentage decreasing or increasing in flexural stress for middle vertical construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (%) Decreasing or Increasing percentage |
|----------------|-------------------------------|----------------------------|----------------------------------------|
| S1             | --                            | Monolithic                 | 0                                      |
| S5             | Middle                        | Vertical                   | -13.33                                 |
| S5F1           | Middle                        | Vertical                   | -6.67                                  |
| S5F2           | Middle                        | Vertical                   | 0.00                                   |
Figure 13. Flexural stress for middle vertical construction joint.

- For construction joint at (third-vertical) there was a decreasing in flexural stress of about (13.33 and 6.67%) in (normal concrete) and (1.0% fiber concrete) but for (2.0% fiber concrete layer) there was an increasing in flexural stress of about (6.67%) as shown in Table 9 and Figure 14.

Table 9. Flexural stress and percentage decreasing or increasing in flexural stress for third vertical construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | Load (kN) | Flexural stress (Mpa) \(=\text{P*L/abh}^2\) | (\%) Decreasing or Increasing percentage |
|---------------|--------------------------------|-----------------------------|-----------|---------------------------------------------|------------------------------------------|
| S1            | --                             | Monolithic                  | 15        | 4.5                                         | 0                                        |
| S6            | Third Vertical                 |                             | 13        | 3.9                                         | -13.33                                   |
| S6F1          | Third Vertical                 |                             | 14        | 4.2                                         | -6.67                                    |
| S6F2          | Third Vertical                 |                             | 16        | 4.8                                         | 6.67                                     |

Figure 14. Flexural stress for third vertical construction joint.

- For construction joint is made at (middle-inclined) there was a decreasing in flexural stress of about (13.33 and 6.67%) in (normal concrete) and (1.0% fiber concrete layer) but for (2.0% fiber concrete) there was an increase of about (6.67%) as shown in Table 10 and Figure 15.

Table 10. Flexural stress and percentage decreasing or increasing in flexural stress for middle inclined construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (\%) Decreasing or Increasing percentage |
|---------------|--------------------------------|-----------------------------|------------------------------------------|
| S1            | --                             | Monolithic                  | 0                                        |
| S7            | Middle                         | Inclined 45°                | -13.33                                   |
| S7F1          | Middle                         | Inclined 45°                | -6.67                                    |
| S7F2          | Middle                         | Inclined 45°                | 6.67                                     |

Figure 15. Flexural stress for middle inclined construction joint.

- For construction joint is made at (two third-inclined) there was a decreasing in flexural stress of about (20.0 and 13.33%) for (normal concrete), (1.0% fiber concrete layer) but no changes for (2.0% fiber concrete layer) as shown in Table 11 and Figure 16.

Table 11. Flexural stress and percentage decreasing or increasing in flexural stress for two third inclined construction joint.

| Specimens No. | Construction joints Locations | Type of construction joint | (\%) Decreasing or Increasing percentage |
|---------------|--------------------------------|-----------------------------|------------------------------------------|
| S1            | --                             | Monolithic                  | 0                                        |
| S8            | Two third                      | Inclined 45°                | -20.00                                   |
| S8F1          | Two third                      | Inclined 45°                | -13.33                                   |
| S8F2          | Two third                      | Inclined 45°                | 0.00                                     |
8. Conclusions

1. A construction joint is used in cases of machinery breakdown, an unexpected shortage of materials, bad weather conditions, mass area concrete pouring, and future expansion.

2. When two concrete members cast at different times, an interface will be formed between the contact surfaces of the two members. The bond between the old and new concrete usually presents a weak link in the repaired structure.

3. The factors affecting the position of joints in the construction of concrete fundamental components are investigated laboratory. These factors incorporate construction joint positions and types.

4. Three main properties of hardened concrete are considered with three mixes (normal concrete, normal concrete with 1.0% steel fiber and normal concrete with 2% steel fiber), with fiber effect increasing percentage of (0, 10.34 and 17.24%), (0, 12, 18.42%) and (0, 20, 26.67%) for compressive strength, splitting and flexural tensile strength respectively.

5. For all non-fibrous specimens, the first crack initiated from the bottom of the prism in the mid-span where the maximum bending moment occurred, just the tensile stresses exceeded the concrete rupture modulus and split the prism into two separated parts.

6. For non-fibrous specimens, vertical and inclined construction joints with different locations ought an insignificant influence on the overall performance of concrete prism following flexural mode.

7. For non-fibrous specimens, it was observed that prism with joints in construction at zero shears functions more reliable than prism including a construction joint at different locations.

8. When steel fiber is added to concrete, the flexural strength of the composite is increased to about 20% and 26.67 % depending on the proportion of fibers added and the mix design. Steel fiber technology transforms a brittle material into a more ductile one.

9. The effect of higher percentage fiber reduces the effect of the construction joint, not only is that but also gives higher loads compared to the non-construction joint prism (solid).

10. Failure of concrete is virtually eliminated because the fiber continues supporting the load after cracking occurs and better crack resistance, increase the friction, stronger joint, improved fatigue strength, higher crack strength and reduced maintenance costs.

11. For fibrous concrete prism with a higher percentage of the fiber of horizontal construction joint with a different location, it was found that the crack changes its direction to another line of action, which means for two strength of concrete the crack changes the direction to another line of action.

12. For fibrous concrete prism with vertical or inclined construction joints at a different location, the failure position was changed depending on the fiber percentage where sometimes failure occurs at the region without fiber (normal concrete), at the weak concrete parts.

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