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Effects of Steel Fiber and Compaction Process on the Flexural Strength of Reinforced Concrete Beams with Longitudinal Cold Joints

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Abstract: Due to many reasons, concrete may not be poured in a single connected operation and therefore joints are formed in locations of old-new concreting. This study discusses the behavior of Reinforced Concrete (RC) and Fiber Reinforced Concrete (FRC) beams containing longitudinal cold joints under two compaction scenarios. The first layer in the first scenario is compacted prior pouring of the second layer, while the other scenario investigates the effects of leaving the first layer uncompacted. It is believed the compaction of the first layer has an important effect on the bonding characteristics between both concrete layers as it may affect the roughness of the joint interface. The study also investigates the time elapsed before pouring of the second layer. The cold joint was located at compression fiber at 0.7h from bottom. Under the four-point load testing, ten 100×160×1000 mm RC beams have been tested and evaluated. Three groups of beams were separated from one another. Four beams make up the first group; one uses as a control, while the other three have horizontal cold joints, the second group consists of three beams with horizontal cold joint and without compacted first layer. whereas the third group consists of three beams with horizontal cold joint adding steel fiber to strengthen the samples that have the least load. The results showed a decrease in ultimate load, ductility and energy absorption capacities for specimen B1.5-RC-NC, B3.0-RC-NC and B4.5-RC-NC, ultimate load, ductility and energy absorption capacities were decreased (9.03%,50.5%,50.9%), (23.4%,31.5%,33.3%) and (27.7%,84.0%, 85.6%) respectively in comparison with control beam. While the decrease in ultimate load, ductility, energy absorption capacities for specimen with steel fiber B1.5-FRC-NC, B3.0-FRC-NCand B4.5-FRC-NC were (5.02%,37.0%, 38.3%), (19.2%,21.1%,21.6%) and (26.5%,58.4%, 58.5).

Keywords: Cold joint, steel fiber, flexural strength, compaction process, time elapsed.

1.Introduction .

Due to its strength and durability qualities, economic advantages, and protection of the reinforcement in reinforced concrete structures, concrete is the most widely used building material in the world. t's critical to behave slightly and in a defined way throughout all processes, from choosing the right materials to achieving the required strength, if the concrete is to be of the appropriate quality. The strength and durability of the concrete are affected by differences from standard practices during design, mixture, advancing even if the production stage in particular appears to be straightforward[1, 2]. To prevent the formation of a joint between pours, concrete should be poured continuously and all at once. [3]. Because it is not practical to cast concrete continuously, the casting process stops at construction junctions, also known as cold joints. The amount of concrete that can be produced at once is greatly influenced by the strength of the formwork and the capacity of the mixers. As a result, the process of casting concrete might be stopped and started multiple times, beginning the constructing joints.[4]. When concrete is compacted, air that has been trapped between the aggregate particles and the freshly put concrete is released, increasing the density of the concrete. It significantly increases the durability of concrete and improves the connection between reinforcement. Additionally, it lessens the permeability of the concrete, improves its overall durability, and lessens its ability to shrink and creep [5]. However, due to incorrect compaction, concrete can sometimes contain some voids, which considerably affects the strength of the material. In other words, especially for low w/c ratios, the strength of inadequately compacted concrete is significantly lower than that of completely compacted concrete. For instance, when concrete has 5% voids, its strength is reduced by over 30%[6]. Discrete low-aspect ratio fibers are randomly inserted into the concrete mixture to serve as crack-controlling devices in fiber-reinforced concrete, a composite material. The most advantageous basics that make fibers a good choice for strengthening concrete are their high tensile strength and their capacity to absorb external force energy. Several international standards, including [7], By resisting tensile loads or limiting crack limits, fibers can enhance the performance of concrete members, enhancing the concrete's longevity. Additionally, fibers have the ability to increase the ductility, durability, and structural stiffness of RC members without increasing the amount of steel reinforcing required. [8]. Flexural capacity of concrete is one of the most crucial factors in concrete design. A beam or slab that is loaded transversely, as well as columns and walls that are being loaded eccentrically or lateral loads will bending or flexural the most in a structure. [9]. The response of structural members with construction joints to the quasi-static loading was the subject of numerous studies. Paramasivam et al. [10] investigated how different types of joints behave in ferrocement construction in terms of tensile and flexural behavior. The maximum moment capacity is drastically decreased. Test results were presented by Djazmati- et al. [11] for unreinforced concrete slab shear resistance with constructing joints. According to the research, cold joint slabs exhibit the same initial stiffness to monolithically cast slabs. Nagib et al. [12] investigated the flexural behavior of single reinforced concrete beams with vertical construction joints by an experimental research. The reduction in the flexural strength of such beams for concrete of a typical strength was predicted using charts. An experimental study was presented by Jang et al. [13] to advance construction joints using ultra-high-performance concrete (UHPCThe results show that grooved geometry and steel fibers have a substantial impact on shear resistance. Issa et al. [14] examined how the vertical construction joints affected the rupture modulus. It was shown that adding a vertical joint significantly reduced the rupture modulus, which ranges from 24 to 83%.Abdul-Majeed et al. [15] used the simulation software (ANSYS) to present a nonlinear three-dimensional finite element study to analyze seven beams, one of them is constructed without a transverse joint, while the others have variously shaped transverse construction joints at the mid-span. The construction joint types for these beams: (vertical, inclined, joggle, and L-shaped construction joints**).** It has been concluded that. due to the greater interlocking between the old and new concrete, the beams with Joggle joints had a higher load-carrying capacity. In contrast, 45° inclined joint connection had the lowest load-carrying capacity due to joint failure**,** it has been noticed that the performance of the jointed beam was enhanced, the vertical joint is strengthened, and crack propagation was prevented. The shape of jointed reinforced concrete beams had an effect on their strength, ductility, and manner of failure. Abbas et**.** [16] studied the behavior of reinforced concrete beams under the effect of longitudinal construction joint. The construction joints were placed at three distinct levels in the beam section, which are measured from the bottom of the beam, at 70 mm, 140 mm, and 210 mm. By pouring the bottom layer of concrete, waiting 30 days, and then pouring the top layer. The findings indicated that ultimate load, first fracture load, and stiffness all reduced during the course of the study, with stiffness decreasing by 15.4%, 14.7%, and 28.7%, respectively, at the 70 mm level in contrast to monolithic beam. When compared to a monolithic beam, the reduction in ultimate load, first crack load, and stiffness at 210 mm level was 26.2%, 22.9%, and 66.5%, respectively. Qassim and Sultan[17] investigated experimentally the effect of steel fiber on concrete construction joints of Prism. The purpose of the current study is to identify how steel fiber affects construction joints and to explain how the types and locations of construction joints affect the structural performance of concrete prisms. The research findings Depending on the amount of steel fiber added and the mix design, the flexural strength of the composite increased by between 20% and 26.67% when steel fiber was added to concrete.

2.Experimental Program

It took two steps to complete the experimental work. The behavior and flexural capacity of beams with horizontal cold joints are evaluated in the first stage. In the second stage, strengthen the joint interface with steel fiber of 1% volume ratio as a trial to enhance the behavior of the joint interface. For the two-layer, one layer was cast first, while the other was cast later (1.5 hr, 3hr, 4.5hr).

2.1. Materials and Concrete mix design

The plain concrete was designed to conform ASTM-C94 [18]to achieve a characteristic cylinder strength of 25MPa at 28 days. The obtained mix proportion is presented in Table (1)

Table 1: Mix design proportion ratios

Coarse Aggregate (Kg)	Fine Aggregate (Kg)	Cement (Kg)	Water (L)
1050	750	430	180

The water to cement ratio (W/C) was (0.5).The type of cement complied with ASTM-C150 requirements.[19]. The coarse and fine aggregate complied with ASTM-C33 requirements [20]. According to ASTM-A615, Testing of the steel reinforcement [21]. Table (2) displays the properties of the materials that are used.

Table 2: properties of the materials

Material		Property	Result
Normal concrete		Compressive strength fc (MPa)	25
Steel	Ø10	Yield strength (MPa)	544.04
		Ultimate strength (MPa)	647.01
	Ø8	Yield strength (MPa)	340.07
		Ultimate strength (MPa)	515.13
Steel fiber		Length(mm)	50mm
		Diameter(mm)	1mm
		Geometry	Hooked end
		Tensile strength (MPa)	1049

2.2.Experimental Procedure

To achieve the goals and objectives of the research, Ten RC beams will be casted and tested under two-point load. The first group includes three beams with longitudinal cold joint. The second group included three beams with cold joint Studying the effect of compaction of the first RC layer on the flexural behavior of RC beams, the third group includes three beams with cold joint strengthening steel fiber of 1% volume ratio as a trial to enhance the behavior of the joint interface. All experimental beams were identical in geometry and reinforcement ratio. The reinforcement details of beams are displayed in **Fig. 1**.

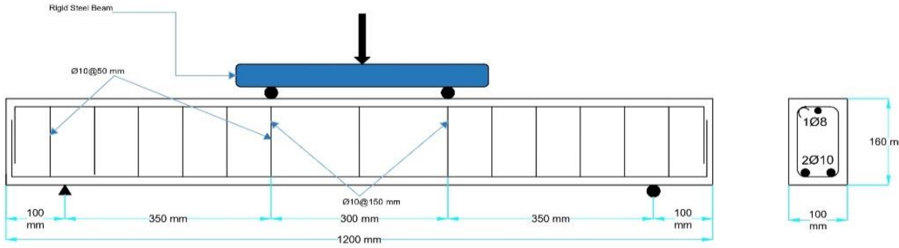


Fig. 1: Sample dimensions and details of steel reinforcement

Table 3: Details of Tested Beams

Beam ID	Details of beams	Delay of second pour (Hours)
CB	Without cold joint and Full compaction	--------------------
B1.5-RC-C	Cold joint-RC-First layer had been compacted	1.5
B3.0-RC-C		3.0
B4.5-RC-C		4.5
B1.5-RC-NC	Cold joint-RC-First layer had not been compacted	1.5
B3.0-RC-NC		3.0
B4.5-RC-NC		4.5
B1.5-FRC-NC	Cold joint-FRC-First layer had not been compacted	1.5
B3.0-FRC-NC		3.0
B4.5-FRC-NC		4.5

2.3. Casting and curing

For a non-fibrous normal concrete mix, the dry constituents, such as cement, sand, and gravel, were first combined for a specified amount of time before the water was added to create a homogeneous mixture. In order to distribute equally, the fiber is added last to the mixture containing it. High tensile strength steel fiber, were used with hooked end with Round Shaft having (50mm) length and (1mm) diameter. Earlier to molding, to avoid and prevent the bonding of hardened concrete to the inner molds surface, all molds' components were thoroughly cleaned, compacted appropriately, and lightly oiled. When the casting process is finished, the homogenous mixture is transported to the molds and filled with two layers. the electric vibrator was used to compress the beams. Not all of the beams have been compacted, and the compaction method is an experimental variable. The vibrator was employed to ensure that sufficient concrete was applied to all confined spaces and to fill any gaps. The specimens were immediately covered in polyethylene sheeting in order to prevent shrinkage and the loss of hydration water during hardening. After 36 hours, the mold has been eliminated. the samples were kept submerged in water basins at room temperature for 28 days. The samples were then removed and readied for testing once the water from the treatment basins had been drained.

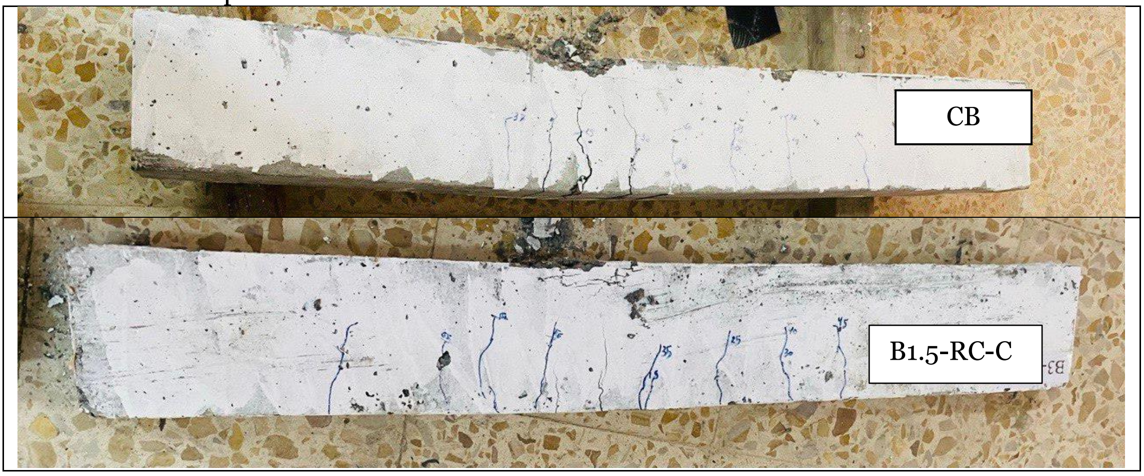
1

3.Results and Descussion

The results of flexural testing on ten RC beams are shown and discussed in this section. For each of the tested beams, the information includes the load capacity, mid-span deflection, crack pattern, mode of failure, and reduction in load capacity

3.1. Crack and Failure Patterns

Figure (6) shows the crack pattern of tested beams.



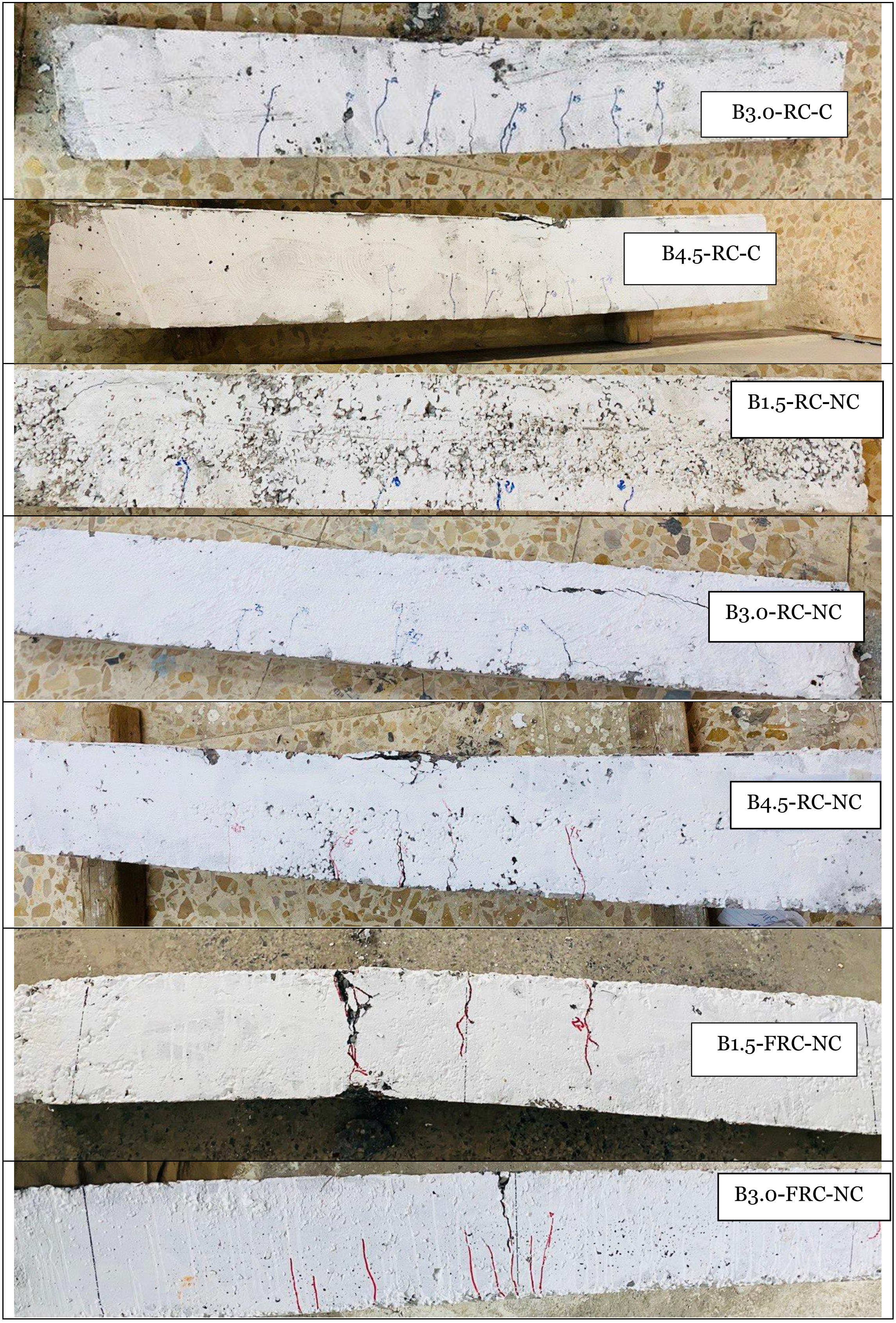

B3.0-RC-C
B4.5-RC-C
B1.5-RC-NC
B3.0-RC-NC
B4.5-RC-NC
B1.5-FRC-NC
B3.0-FRC-NC

Fig. 2: Crack patterns of all beams

All beams failed in flexural except for the beams (B1.5-RC-NC, B3-RC-NC) the failure had shear failure and this is because the cold joint weakens the shear stress. Shear reinforcement does not make this weakness better, and this is consistent with the reference. [22]. The control beam's (CB) and the other beams' initial cracks appeared approximately at an 18 kN load. The existing cracks grew larger and moved closer to the beams' compression fiber when the applied loading was increased, and new cracks also began to appear. Testing showed the appearance of a few small flexural-shear cracks. The ultimate load capacity of "cold joints) tested beams depends on the location of cold joints and the time delay between first and second pour, compaction first layer and steel fiber. In general, the flexural cracking continued to progress as the load is increased until the ultimate capacity of each beam is reached.

3.2. Load-Deflection Relationships

The load-deflection relationships of both CB beam and beams with horizontal cold joint with and without steel fiber are shown in Fig 3-5.

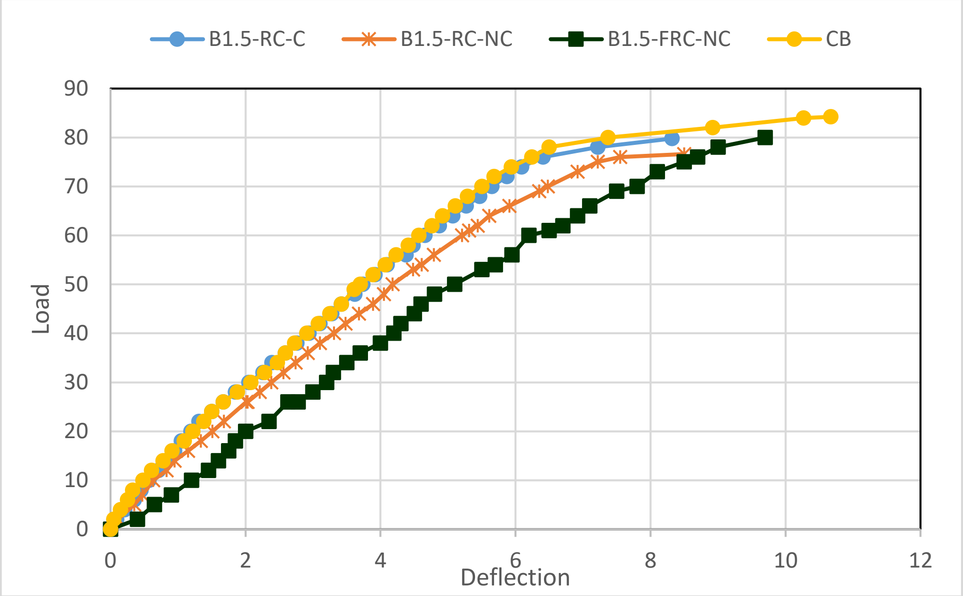


Fig 1: Load-deflection for beams was cast after 1.5 hours (first layer had been compacted, first layer had not been compacted, first layer had not been compacted, and with steel fiber) compared to control beams.

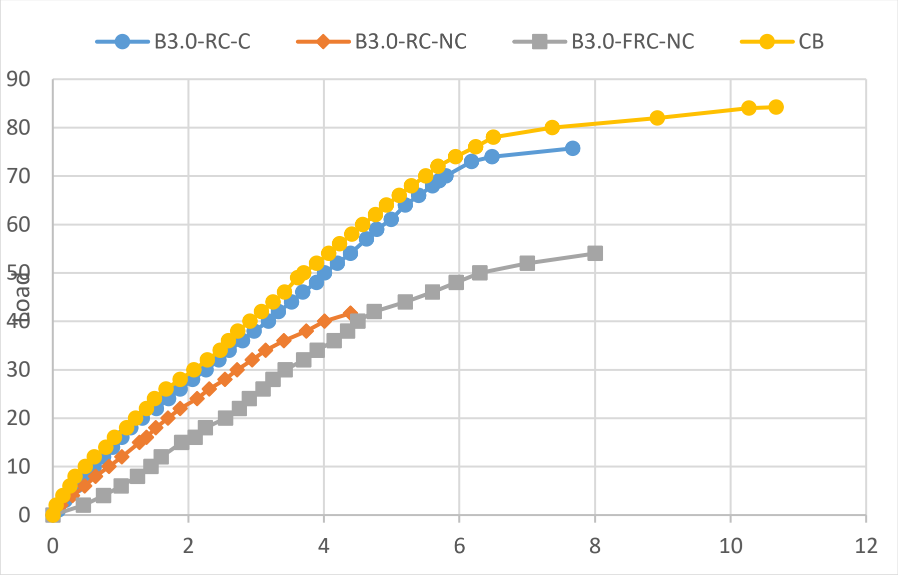


Fig 2:Load-deflection for beams was cast after 3 hours (first layer had been compacted, first layer had not been compacted, first layer had not been compacted, and with steel fiber) compared to control beams**.**

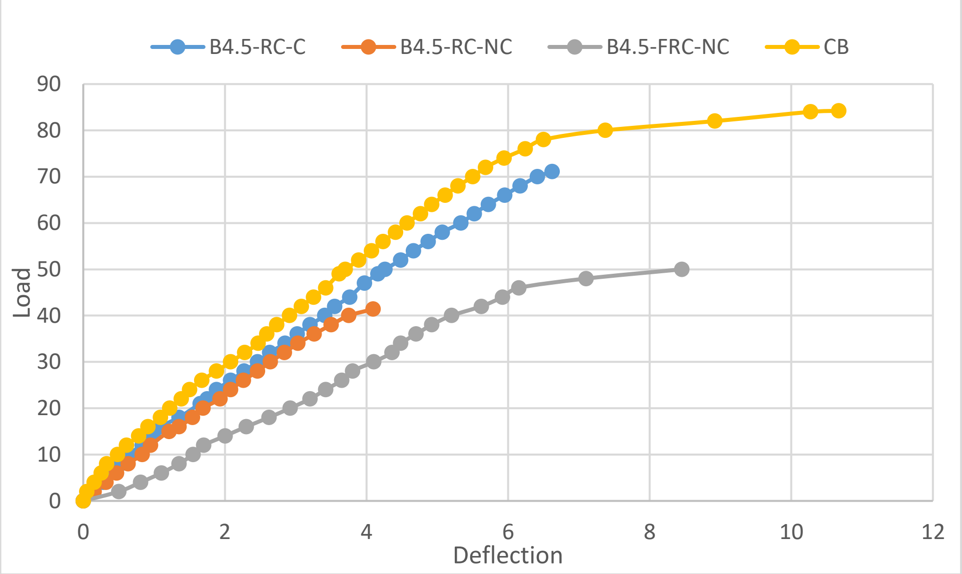


Fig 3: Load-deflection for beams was cast after 4.5 hours (first layer had been compacted, first layer had not been compacted, first layer had not been compacted, and with steel fiber) compared to control beams

The load-deflection curves typically exhibit a linear behaviour during the elastic stage without cracks, which is followed by a nonlinear section of the curve with an elastic cracking behaviour. It is clear that beams with and without steel fiber have lower load-carrying capacities when longitudinal cold joints are present. It is obvious that the beams with a cold joint showed lower deflection values than the control beam, compared to the control beam, the beams with the cold joints were less stiffness and strength.

3.3: Ultimate Load and Displacement

Table 4 provides an overview of the experimental findings' substance. The ultimate load (Pu), yield load (Py), and cracking load (Pcr),

Table 4: provides a summary of the test results for the beams.

NO	Beam specimen	Yield state Py (KN) Δy (mm)		Ultimate state Pu (KN) Δu (mm)		First crack	Mode of failure
1	CB	76	6.24	84.23	10.67	18	Flexural
2	B1.5-RC-C	74	6.09	79.79	8.32	18	Shear
3	B3.0-RC-C	73	6.18	75.72	7.67	18	Shear
4	B4.5-RC-C	66	5.70	71.10	6.62	18	Flexural
5	B1.5-RC-NC	70	6.48	76.62	8.5	20	Flexural
6	B3.0-RC-NC	38.8	3.74	41.65	4.39	15	Flexural
7	B4.5-RC-NC	38	3.6	41.39	4.09	18	Flexural
8	B1.5-FRC-NC	73	7.02	80	9.7	22	Flexural
9	B3.0-FRC-NC	48	7.1	54	9.6	22	Flexural
10	B4.5-FRC-NC	46.8	5.95	50	8.45	20	Flexural

For tested beams (B1.5-RC-C), (B3.0-RC-C) and (B4.5-RC-C), which cast after 1.5, 3 and 4.5 hours from pouring the first layers and with compacted first layer, the decrease in strength was 5.27%, 10.10% and 15.59% as compared with that of the control beam (CB). For tested beams (B1.5-RC-NC), (B3.0-RC-NC), and (B4.5-RC-NC), where the first layer had not been compacted, the decrease in strength was 9.03%, 50.5%, and 50.9%, respectively. While for tested beams (B1.5-FRC-NC), (B3.0-FRC-NC) and (B4.5-FRC-NC), which had time elapsed between first and second layers 1.5 ,3 and 4.5 hours , the first layer had not been compacted and had a steel fiber content of 1%, the decrease in strength was 5.02%, 37.0%, and 38.3%, which clearly indicate that the increase of time between the first and second layers and the fact that you don't use a vibrator to compact the first layer can cause a greater reduction in ultimate capacity. Adding steel fiber to samples for which the first layer had not been compacted led to improved ultimate load and ultimate deflection.

Table 4: Percentage of decrease in Pu % and Δu (%)

NO	Beam Specimen	Decrease in Pu (%)	Decrease in Δu (%)
1	CB	-----------	-----------
2	B1.5-RC-C	5.27%	22.0%
3	B3.0-RC-C	10.10%	28.1%
4	B4.5-RC-C	15.59%	37.9%
5	B1.5-RC-NC	9.03%	20.3%
6	B3.0-RC-NC	50.5%	58.9%
7	B4.5-RC-NC	50.9%	61.7%
8	B1.5-FRC-NC	5.02%	9.1%
9	B3.0-FRC-NC	37.0	10.0%
10	B4.5-FRC-NC	38.3	20.8%

3.3.1: Ductility

When there is a construction joint in concrete members, one of the most crucial considerations that must be made is the ductility. As shown in Table (6).

Table 5: Ductility Index of Tested Specimens

Specimen	Ultimate deflection (mm)	Yield Deflection (mm	Ductility index	
CB	10.67	6.24	1.71	R*
B1.5-RC-C	8.32	6.09	1.37	19.9%
B3.0-RC-C	7.67	6.18	1.24	27.5%
B4.5-RC-C	6.62	5.70	1.16	32.2%
B1.5-RC-NC	8.5	6.48	1.31	23.4%
B3.0-RC-NC	4.39	3.74	1.17	31.5%
B4.5-RC-NC	4.09	3.5	1.14	33.3%
B1.5-FRC-NC	9.7	7.02	1.38	19.2%
B3-FRC-NC	9.6	7.1	1.35	21.1%
B4.5-FRC-NC	8	5.95	1.34	21.6%

When compared to reference specimens, specimens with a horizontal cold joint had a lower ductility index. The proportion of ultimate deflection to deflection at yield load is known as the ductility index

3.3.2: Energy Absorption Capacity

A crucial factor in the design of the beams is ductility. The area under the load deflection curve is used to calculate the amount of energy that the specimen has absorbed. The energy absorption values for various beams are displayed in Fig 6.

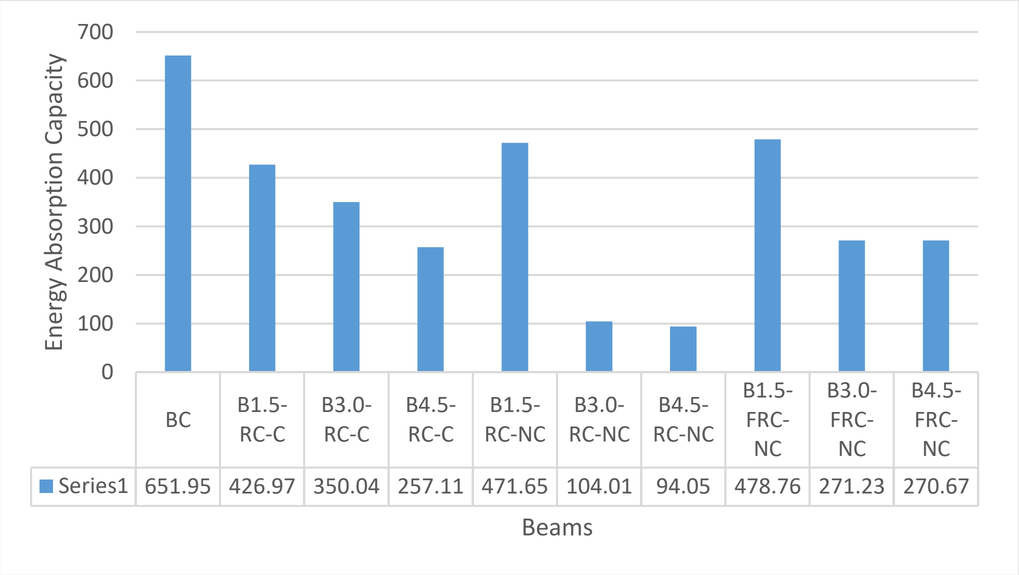


Fig 6: Energy absorption capacities of different beams

Table 6: Reduction in Energy absorption capacities

Specimen	Reduction in Energy absorption capacities
CB	-----------
B1.5-RC-C	34.5%
B3.0-RC-C	46.3%
B4.5-RC-C	60.5%
B1.5-RC-NC	27.7%
B3.0-RC-NC	84.0%
B4.5-RC-NC	85.6%
B1.5-FRC-NC	26.5%

B3.0-FRC-NC	58.4%
B4.5-FRC-NC	58.5%

4.Conclusions

This research was intended to investigate the Effects of Steel Fiber and Compaction Process on the Flexural Strength of Reinforced Concrete Beams with longitudinal cold joint.

- The presence of cold joints has not affected the cracking load regardless of the compaction process, steel fiber and the time elapsed between pours. Conversely, the ultimate load has been greatly influenced by the presence of cold joints, compaction process, steel fiber. It has been shown that the ultimate strength decreases as the time elapsed between concrete pours is increased and not compacted the first layer, where the percentage decrease in the flexural strength was 5.27%, 10.10%, and 15.59%for B1.5-RC-C, B3.0-RC-C and B4.5-RC-C respectively. Similarly, the percentage decrease in strength for beams with cold joints and without compacting the first layer was 9.03%, 50.5%, and 50.9% for beams B1.5-RC-NC, B3.0-RC-NC, and B4.5-RC-NC, respectively.
- Stiffness and energy absorption decrease with increase the time elapsed between pouring from 1.5 to 4.5 hours. The reduction percentages of ductility and energy absorption capacity reached 32.2% and 60.5%, respectively, compared to the control beam.
- In comparison to the reference be, the final deflection has decreased due to the presence of horizontal cold. For instance, compared to the control beam, the percentage decrease in mid-span deflection of beam "B4.5-RC-NC" was 61.7%. For samples where the first layer was compacted (RC-C) and samples where the first layer was not compacted (RC-NC),
- The ultimate strength, deflection, ductility, and energy absorption capacities of beams with longitudinal cold joints indicate that the presence of joints in samples where the first layer was not compacted is more critical than the joints in samples where the first layer was compacted. This is because the first layer was not compacted, leaving spaces.
- When steel fiber was added to samples whose first layer had not compacted, the samples' ultimate load, ductility, and energy absorption capacities were improved in comparison to the samples' respective capacities for the same first layer that had not compacted. For beams B1.5-FRC-NC, B3.0-FRC-NC, and B4.5-FRC-NC, the percentage decline in strength was 5.02%, 37.0%, and 38.2%, respectively, for beams with a cold joint and steel fiber.

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