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The Flexural Behavior of Confined Beams Reinforced with Tension Lap Splice and Cast with Fibers Concrete

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ABSTRACT

The function of the (lap splice) technique in structural building has become widely used in structural buildings. This study aims to investigate the flexural behaviour of the confined concrete beams with tension spliced bars. Eight concrete beams, each and every one measured 150 × 220 ×1200 mm, were tested under two-point loads. All the spliced beams were built up with the same splice length 300 mm and 20 mm concrete cover. The study parameters were the type of the concrete (normal of fibres), the confinement of the splice area, and the forms and proportions of fibres (hooked-steel and polypropylene fibres). The beams were divided into seven spliced beams, and the eighth one was manufactured with a beam which was built up with non-spliced bars for comparing purposes. The result showed that the use of the fibres concrete led to improving the overall structural behaviour compared to the normal concrete. Adding hooked-steel fibres, in general, resulted in a significant improvement in the bond strength and the stress transmission efficiency, leading to an enhancing in the flexural properties. In contrast, adding the polypropylene fibres increased the ability to deformation as it controlled the micro-cracks with limited effect on strength development. Confining the spliced zone prevented the lateral expansion of the spliced bars, led to a significant improvement in the post-cracking load, the ultimate strength and the toughness. The use of 0.4% of steel fibers resulted in the most balanced behaviour in terms of ductility and toughness. Compared with the non-spliced beam the study findings demonstrated that using the variables made the structural behaviour of the spliced beams closer to the non-spliced beam.

1. Introduction

Concrete was widely used in building materials .It has a competitive property. This property is the ability of its components to interact with binding materials for producing concrete with certain properties. The name of the final concrete varies from one type to another, depending on the binder, used in concrete mixture. Currently, fibers of the different types and dimensions are considered commonly binding material, frequently used to enhance the features of reinforced concrete [1, 2]. The fibers concrete is a tough composed material consisted from mixing the reinforced bars and the fibers to strengthen the concrete mass. These fibers (typically short, lack of continuity and unequally dispersed throughout concrete matrix) are not a substitute for reinforcing bars, but rather serve as a complimentary role in improving the tensile strength through hybrid action of bars and

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fibers, it is also categorized as (the hybrid concrete)[3,4,5].

Applying continuous traditional reinforcement throughout all the elements of the concrete structure is almost impossible, due to the manufacture of reinforcement bars in certain length in addition to the difficulty of transportation; therefore, engineers resorted to splicing the reinforcing bars. Lap splices method, considered one of the most widespread methods used for connecting reinforcing bars. This method executed by placing one reinforcing bar above another one in a parallel way through a specified splice length, its strong bond resistance leads to facilities transfer of stress from one bar to another within the surrounding concrete and carries out the desires efficiency which could be affected by several factors such as overlapped length, type of concrete, bar diameter, concrete cover, etc., if these mentioned factors are inadequate, the bond fails and the longitudinal cracks develop along the splice area and eventual concrete cracks [6, 7].

Over the years, numerous experimental and analytical studies have been carried out to evaluate the bond strength and the flexural behavior of tension lap splice under the influence of various parameters. An early contribution to bond strength effectiveness was conducted by Türk et al., (2003) [8], who discovered that the bar diameter had a significant impact on bond strength, with a large sized diameter, the bond strength and the ductility decreased while the stiffness increased. Through a limited study on the effectiveness of stress transmission in short lap splices with confinement Pandurangan, et al., (2010) [9] showed that the presence of stirrups within the spliced area enhanced the stiffness and the bond strength of the short spliced area. Consequently, the beams were failed in gradual and ductile manner.

New insights were explored by El-Azab and Mohammed, (2014) [10] who was found that the mode of failure was unaffected by the length of spliced bars. Furthermore, it was found out that using the longest splice length led to more ductility in their investigation. Abdul-Kareem et al., (2015) [11], recommended that the effect of transvers reinforcement surrounding the spliced area should be taken into account in the design equation of the splice length. While, Mousa, (2015) and , Mabrouk and Mouni (2017) [12, 13] discovered that providing the transverse reinforcement had a positive effect on bond strength; as a consequence, the spliced beams without transverse reinforcement strongly failed along the length of the overlap bars area.

Ibrahim and Ahmed (2020) [14] showed that increasing the number of stirrups with small spacing led to achieving more ductility in the beams. To better understand the behavior of implicating lap length shorter than required limits, further empirical study was conducted by Gillani et al., (2021) [15], It was concluded specimens of inadequate length fail in brittle way due to loss of bond between bars and concrete, while beams with adequate length were more ductile at failure and to provide further findings, Turk and Bassurucu (2022)[16] came out with the results, which concluded that strengthening the beams, especially with both (micro and macro) steel fibers, led to more ductility, load capacity, and energy absorption for beams, even if the overlapped bars embedded with forty percent less than required in various codes. Through employing recycled coarse aggregate (RCA), Attab (2024) [17] was revealed that the presence of transverse reinforcement within the splice region had a notable impact on short lap lengths, contributing to raised ductility, as well as enhanced failure load and bond strength. However, if the lap lengths were sufficient for stress transferring effectively, the effect of confining the spliced region was slight or insignificant.

Despite these outcomes, the researchers have not clearly explained the impact of using fibers and its interaction with the transverse reinforcement. This investigation, aimed to achieve a balance between efficiency and cost by using a short lap length cast in fibers concrete beam, evaluating its behavior when designed in the tension zone and assessed how the parameters affect the spliced region.

2. Experimental Program

2.1 Beam Specimens Description

Eight simply supported RC beams were cast and tested under two-point loading test to achieve the objective of this study. These mention specimens were constructed with dimensions of 150 mm width, 220 mm depth and with whole span length of 1200 mm. All beams were designed to resist the shear failure and fail in flexural according to the American Concrete Institute (ACI 318-19) [18] requirements.

The tensile beam specimens were reinforced longitudinally with two compressions steel bars of 6 mm and three tension steel bars of 12 mm lapped at the beam mid-span with 300 mm length.

Table 1: Tested Beams Details

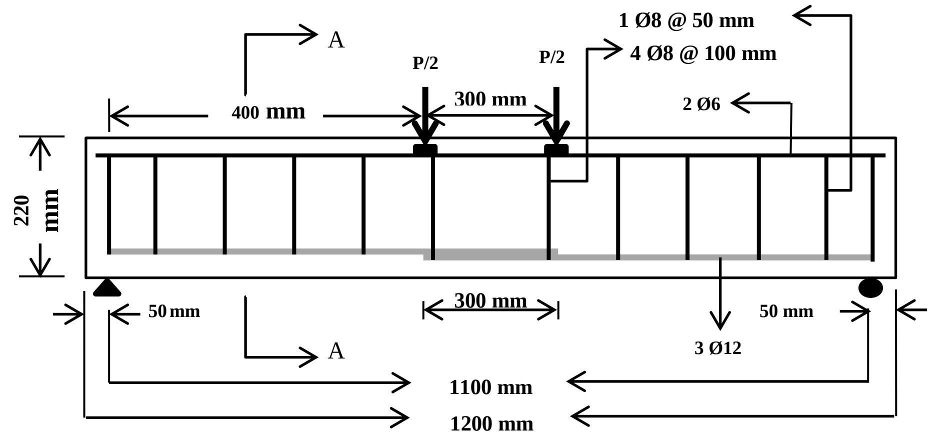
Reinforcement Condition	Specimens	Type of Spliced bars	Located of Spliced Bars	F. content (%)	P. content (%)	(ls) (mm)	Stirrup on splice region
Spliced	B1RST	Steel	Tension	-	-	300	-
	B3SF1T	Steel	Tension	0.25	-	300	-
	B4SF2T	Steel	Tension	0.40	-	300	-
	B5SP1T	Steel	Tension	-	0.2	300	-
	B6SP2T	Steel	Tension	-	0.3	300	-
	B11SS1T	Steel	Tension	-	-	300	Stirrup
	B12SLT	Steel	Tension	-	-	300	Links
Non-Spliced	B23RSWT	Steel	-	-	-	-	-

Note: All beam dimensions (150×220×1200) mm, splice length for all spliced beams (ls) = 300 mm, content of steel fibers (F) = (F1 (0.25) or F2 (0.40)) % by volume ratio, content of polypropylene (P) = (P1 (0.2) or (P2 (0.3)) % by volume.

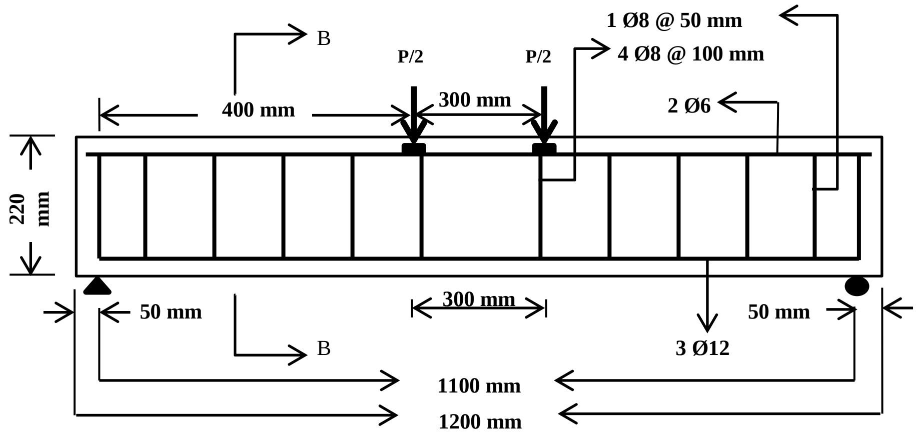
Longitudinal reinforcement design as the aforementioned detailed of the tensile reinforced spliced beams. A total of eight tested beams were confined with steel shear reinforcement (stirrups) of 8 mm, single one spaced at 50 mm center to center from the first stirrup of the shear zone, and the other four ones arranged with 100 mm spaced from center to center out of the spliced zone.

The tested beams properties details are provided in Table 1, and the geometric properties and reinforcement layout of the previously described beams are illustrated in Figure 1.

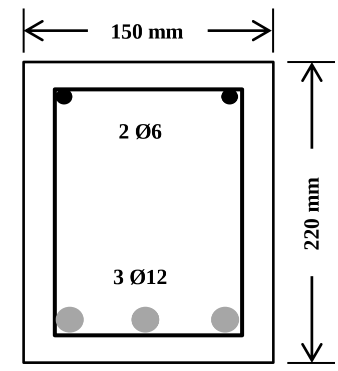
As listed in Table 1. The first beam was modeled as the reference cast with normal concrete, then the two followed beams were designed to includes (0.25 or 0.40) % of hooked-steel fibers, whereas the other two beams designed to contains (0.2 or 0.3) % of polypropylene fibers. The sixth and seventh beams were detailed with presence of confined reinforcement through the splice area as additional stirrup or links and cast with normal concrete. The eight beam designs to evaluate the behavior of non-spliced steel bars.



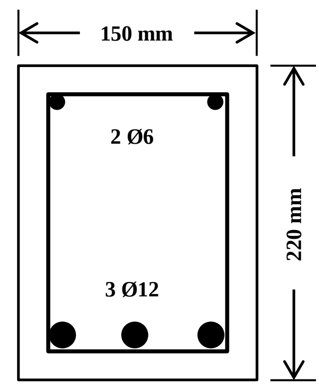
a) Schematic show longitudinal and shear reinforcement for tensile beams reinforced with steel lapped bars (one extra stirrup of Ø8 @ 100 mm was applied if any confined the spliced region).



b) Schematic show longitudinal and shear reinforcement for beam reinforced without lapped bars.



a) Cross -Section A–A
● Steel bars/ non-spliced
● Spliced bars



b) Cross-Section B–B
● Non-spliced steel bars.

Figure 1: Design Details of the Tensile Spliced and Non-spliced Tested Beam Specimens

2.2 Material Properties and Mix Proportions

Five concrete mixes were prepared: the normal concrete, the normal concrete with steel or polypropylene fibers added in different proportions. The normal concrete was employed using the proportions listed below with a slump equal to 115 mm. Details of the mixtures proportions are shown in Table 2. The material used to produce these mixtures ordinary Portland cement (OPC) type (I) grade

Table 2: Concrete Mixes Design Proportions

Mix No.	Cement Kg/m³	Gravel Kg/m³	Sand Kg/m³	Water Kg/m³	Superplasticizer* L/m³	F. Fibers* by Volume Fraction V_f%	P. Fibers* by Volume Fraction V_f%	W/C Ratio	Slump (mm)	f_{cu} MPa
1						-	-		115	32
2						0.25	-		110	33.5
3	360	1116	685	144	3	0.40	-	0.4	103	35.01
4						-	0.2		111	33.6
5						-	0.3		109	34.67

*The Superplasticizer was added about 0.9% by cement weight. F. refers to steel fibres, and P. refers to polypropylene fibres. The f_{cu} refers to the average of three 100 ×100 ×100 mm cubes for each mixture tested after 28 days of curing.

Hooked-Steel Fibers Polypropylene Fibers

Figure 2. Fibers Forms Used in this Study

(42.5R), natural and well-graded fine aggregate was classified within zone (1) and with 3.4 Fineness Modules, natural and crushed gravel with particle sizes grading between (5-14) mm and superplasticizer as a percentage of the cement weight to improve the mixtures workability.

Hooked-end loose steel fibers and polypropylene fibers as shown in Figure 2 were used in two different ratios for each type of fibers.

2.3 Tested Specimens Preparation

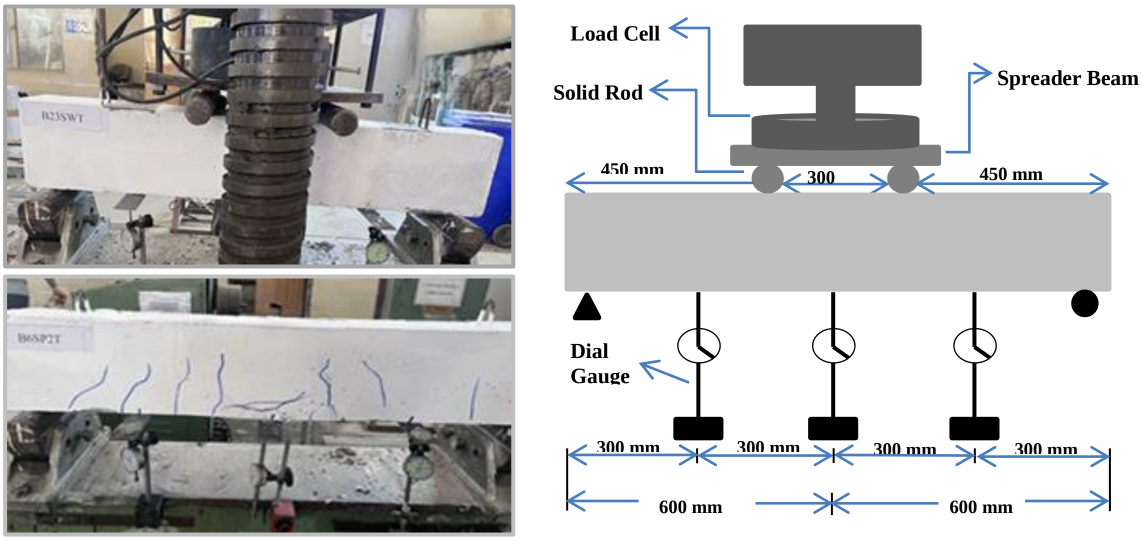
High quality wooden molds were made with ply wood boards, 18 mm thickness and 2000 mm length. These mention boards were used to produced molds with 1200 mm length, 150 mm width and 220 mm depth. They were all well-locked and at the same time easy to be disassembled after the concrete is well-hardened. It was made sure that all the wooden molds were perfectly clean with a light layer of oil before starting the casting process and the reinforcements were firmly fixed using the engineering construction plastic spacers, 20 mm size. The concrete mix was manually poured inside the molds and it was compacted by using Needle electric vibrator, leveling the face of the surface by using the steel trowel. After 48 hours from the casting molds, the molds were disassembled from two sides to take the hardened specimens out of the molds. Then the specimens were covered with burlap. The curing process continued with watering the burlap covers daily for 28 days. As shown in Figure 3. Once the curing process was done and allowed the specimens to dry, the beams were painted with plastic paint, a day earlier right before the testing day.

Figure 3. Specimens Preparation

2.4 Test Setup and Procedure

All the beam specimens were practically tested using a 2000 KN electric universal hydraulic machine type (M.F.L system) to assess the flexural performance of the beams. Each beam was tested as simply supported beam with the whole span length of 1200 mm and subjected to two-point loads, located symmetrically at 450 mm apart from each edge of the beam, so that the span length between

the two point loads is 300 mm. Additionally, for the vertical deflection measurement, three dial gauges were used with an accuracy of 0.01 mm and 30 mm measuring range. The dial gauges were set at 300 mm, 600 mm (mid-span) and 900 mm. The load was applied as a monotonic load with a gradual increasing. At each level the load was increased with rate (5kN/s); the value of the deflection was record, with the beam surface monitored to record the first crack. The applied load continued to increase until the ultimate load was reached and the beam failed. In the final stage, the crack patterns were highlighted to make the cracks more visible and to clearly demonstrate the failure modes of the beams. Figure 4 illustrates the test setup and procedure.



Symbols: P_{cr} =First crack load, P_u = Ultimate load, P_f = Failure/ residual load (approximately equals to 0.85 P_u), Δ_{cr} = Crack load deflection, Δ_u = Ultimate load deflection, and Δ_f = Failure load deflection. F. refers to hooked-steel fibers and P. refers to Polypropylene fibers.

Figure 4. Testing Setup and Procedure before and after Testing

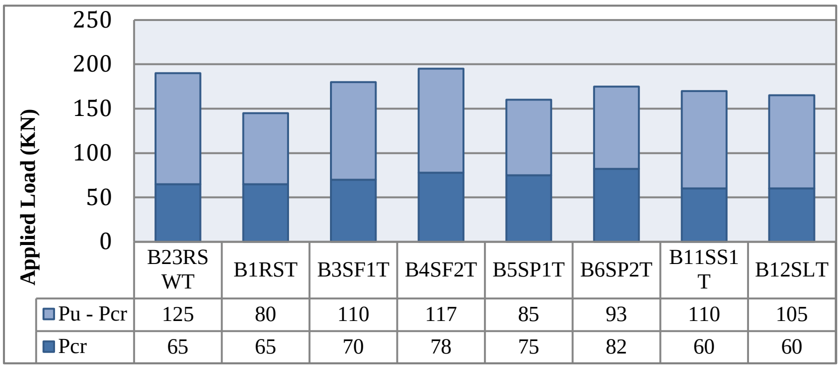
3. Test Results and Discussion

3.1 Structural Behavior of Tested Beams

The seven beams were designed to investigate the performance of steel lap splice in the tension zone. The first mentioned spliced beam was considered to be the reference beam for the spliced beams, while the other six beams were fabricated to assess the influence of the concrete type, forms and proportions of the fibers, in addition to evaluate the presence of the transverse reinforcement within the splice region on the splice behavior of this group. While the eighth beam is the non-spliced beam cast with normal concrete. Table 3 illustrates the properties of the beams and the experimental results, obtained from the flexural testing, while Figure 5 shows the relation between the ultimate load (P_u) and the increasing in the post-cracking load (P_u-P_{cr}) of the all tested beams and Figure 6 shows the load- deflection relationship.

Table 3: Experimental Results Values of The Tested beams

Type of Design	Beams	F. content (%)	P. content (%)	Stirrup on Splice Region	Applied Load (kN)			Deflection (mm)			Failure Mode
					(P_{cr})	(P_u)	(P_f)	(Δ_{cr})	(Δ_u)	(Δ_f)	
Spliced	B1RST	-	-	-	65	145	125	1.46	6.1	7.79	Flexural
	B3SF1T	0.25	-	-	70	180	150	2.25	7.50	9.10	Flexural
	B4SF2T	0.40	-	-	78	195	165	2.27	7.45	9.30	Flexural
	B5SP1T	-	0.2	-	75	160	135	2.55	7.56	9.22	Flexural
	B6SP2T	-	0.3	-	82	175	150	2.65	7.43	8.83	Flexural
	B11SS1T	-	-	Stirrups	60	170	145	1.85	7.40	9.00	Flexural
	B12SLT	-	-	Links	60	165	140	1.74	7.36	8.60	Flexural
Non-Spliced	B23RSWT	-	-	-	65	190	160	1.96	8.38	9.90	Flexural and Crushing Concrete



	B23RSWT	B1RST	B3SF1T	B4SF2T	B5SP1T	B6SP2T	B11SS1T	B12SLT
Pu - Pcr	125	80	110	117	85	93	110	105
Pcr	65	65	70	78	75	82	60	60

Figure 5. The Load-Carrying Behaviour of Beams of all Tested Beams

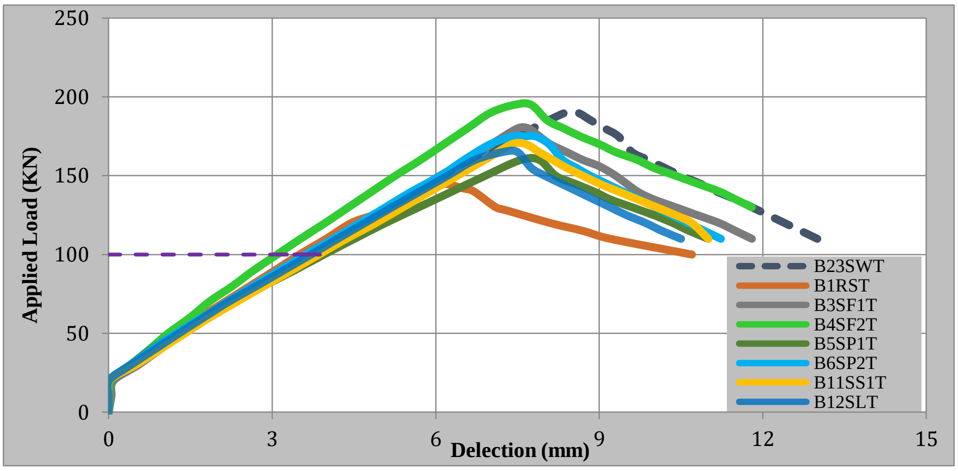


Figure 6. Load- Mid Span Deflection Relationship of all tested Beams

As compared with the reference non-spliced beams"B1RST", increase the inclusion of steel fibers from 0.25% to 0.4% led to an improvement in the (P_u) and the first crack load (P_{cr}),by about 34% and 20%, respectively. Meanwhile the ultimate load increased in about 21% when incorporating 0.3% of polypropylene fibers with a rising up in the (P_{cr}) by about 26 %. Confined the spliced region with stirrup or links the (P_u) increased by about 17 % and 14 %, respectively, while the(P_{cr}), decreased by about 8%. The significant comparison of mid-span deflection is made depending on the value of the service load, and compared to the reference spliced beam. At the service load, the (Δ_u) declined by 12% in the conclusion of 0.4% steel fibers while the central deflection exhibited a slight augmentation when inclusion the polypropylene fibers or confined the spliced region. In general, the effect of both types of fibers and confining the splice area had a positive impact on the performance of this group beams, which was linked to the extent of the influence of the mentioned variables on the load transfer efficiency. The results confirmed the role of steel fibers in enhancing the stiffness and the strength rather than the polypropylene fibers, which its mixing effects more on the ability of resistance cracks with more flexibility. As for confining the splice area, although its application led to decreasing in the first crack load and the primary stiffness of the beams, it simultaneously had a positive effect in enhancing the bonding in the splice area compared to the reference beam, thus developing the ultimate load and the post-cracking load, which led to an improvement in the flexural behavior of the beams.

As compared the spliced beams with the non-spliced beam “B23RSWT”. The reference non-spliced beam “B1RST” decreased by about 22% in (P_u) with the same (P_{cr}). With Emerging 0.25% of steel fibers led to decreasing in the (P_u) by about 6 % and an increasing in the (P_{cr}) by about 8 %, while the incorporating 0.4% of steel fibers, which led to an improvement in the (P_u) and the (P_{cr}) by about 3% and 20%, respectively. With adding of 0.2% - 0.3% of polypropylene fibers recorded a decrease by about 16%, 6% in (P_u) and 15%, 26% increasing in the (P_{cr}), respectively. When confined the spliced region with stirrup or links, the (P_u) decreased by about 9% and 13%, respectively, while the (P_{cr}) decreased in by about 8%.

Overall, the splicing beams showed a decreasing in the initial stiffness and the ultimate bearing capacity with change in the deflection, comparing to the non-spliced beam. The degree of the behaviour was changed in accordance with the difference in the effect of the variable, used to improve the performance of the spliced area. The emerging of the steel fibers reclaim part of the strength, and the post-cracking stiffness even more, which was lower due to the splicing, that made it achieve approximately (95-100 %) of the maximum capacity of the non-spliced beam. Meanwhile, the emerging of the polypropylene fibers put most of its effect mainly on the initial ductility, controlling on the presence of the cracking, with less development in stiffness and ultimate load. As for the confinement of the spliced area, although it contributed relatively less initial stiffness, still the role of the confinement was more efficient in improving the transferring of the stress on a high level on efficiency at the splicing area, which in turn was the main reason why the flexural performance was improved after cracking, thus the strength of the beams was increased.

3.2 Cracks Patterns and Mode of Failure of the Tested Beams

This section highlights the cracking patterns of the tested beams and explains how the cracks developed from the initial crack until failure. It also shows how the study variables affected the type of failure and the ability of the beams to resist the applied loads until they reached the final failure. The predominant failure pattern in all the spliced-beams was flexural failure. Although the spliced weakened the stiffness bond, it did not affect the final failure behavior. The pattern followed the same main direction in all beams are: the first flexural crack appeared in the tension zone near the mid-span of the beams after the tension stresses exceed the strength of the concrete. As the load increased, the cracks dispersed upwards, transferring more stresses to the reinforcement bars. When the bars reached their maximum capacity, the deflection began to accelerate rapidly and until the beam failed. The fibers inclusion resulted in better containment of the spliced zone, delaying first crack appearance and distributing them more evenly while controlling their width. The fibers using also allowed increasing the beam capacity with good ductility. Furthermore, the confinement of the splice zone controlled the propagation of lateral splitting cracks, which could reduce the efficiency of the bond and lead to bar slippage, the stirrup or links within the splice area enabled the beams to resist higher loads with more deformability.

As for the non-spliced beam, the cracks pattern was the same as described above with changing in the failure mode. As for the “B23RSWT” failed with flexural and crashing concrete, this was originated to the strength and the higher stiffness of the tension zone, causing the concrete to reach its maximum strength before the reinforcement yield and led to the failed of compression zone controlled by flexural. Figure 7 shows the cracks patterns of the tested beams.

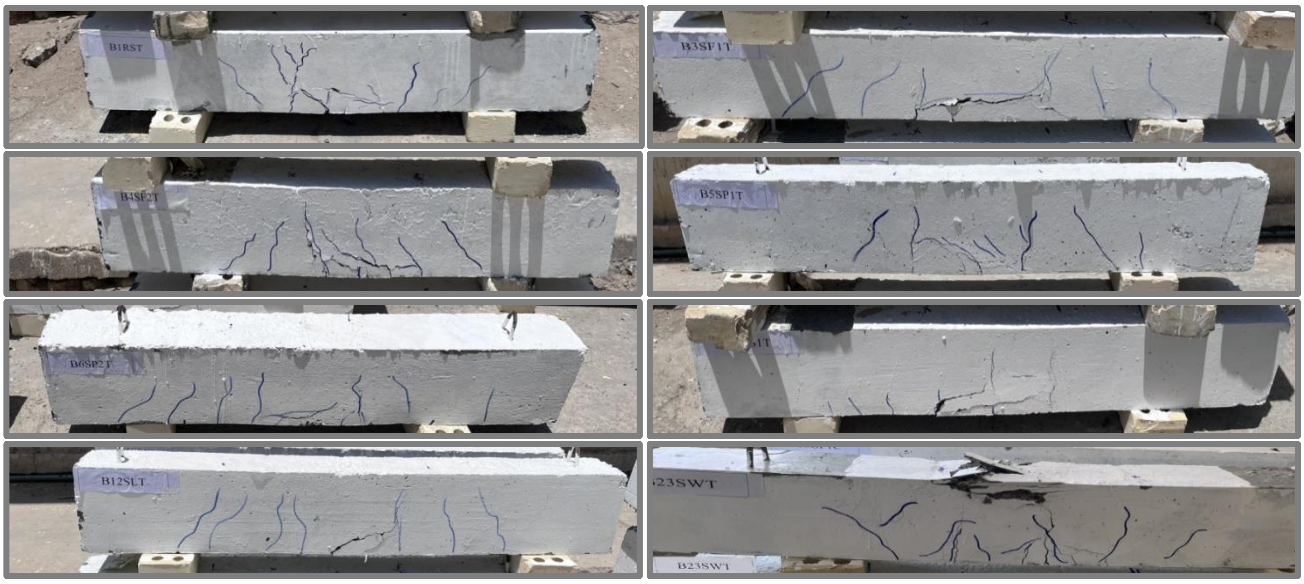


Figure 7. Cracks Patterns of All Tested Beams

3.3 Flexural Ductility, Stiffness and Toughness of the Tested Beams

These mentioned mechanical properties are crucial parameters for understanding the flexural behavior of the reinforced concrete member under the mounting loads. Ductility reflects the ability of member to deform beyond their elastic limits while maintaining acceptable load-bearing capacity without sudden failure, it is represent by the ductility factor (μ), which represents the ratio of the failure deformation to the deflection corresponding to the first yield deflection, as illustrated in equation (1).

$$\mu = \frac{\Delta_f}{\Delta_y} \tag{1}$$

Where:
μ: The ductility factor;
Δ_f: The failure deflection (mm);
Δ_y: The yield deflection (mm).

In this study, the failure load was defined as the point on post-peak part of the load-deflection curve that decreased by 85% of the maximum load capacity of the beam, and the corresponding deflection was considered (Δ_f). Yield deflection was determined by projecting the vertical line at the point of intersection between the tangent line on the first elastic part of curve and the horizontal line extending from the beam ultimate load. (Rakshanmehr et al, 2014; Attab, 2024) [17, 19], as shown in Figure 8.

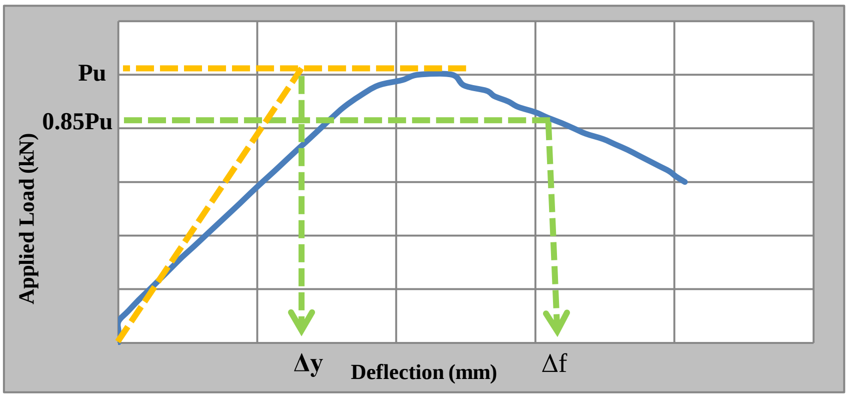


Figure 8. Definition of Δy and Δf

As for stiffness, it expresses the ability of a structural member to withstand deformation under the influence of applied loads until the first cracking of concrete begins. Initial stiffness represents the state of the member in its fully elastic state and is represented by the first elastic slope on the load-deflection curve (first liner portion) before the appearance of the first crack, while the service stiffness expresses the stiffness of the structural member under the influence of the service loads expected to be resisted by the member and is represented by the slope on the upward part of the load-deflection curve between two points equal to (50 and 80) % of the ultimate load of the beam specimen, (Alhassan et al, 2017) [20].

Table 4: Stiffness, Ductility and Toughness Results of Tested Beams

Type of Design	Beam	Initial Stiffness (kN/mm)	Service Stiffness (kN/mm)	Deflection (mm)		Ductility	Toughness
				(Δ_y)	(Δ_f)	(Δ_f/Δ_y)	(kN.mm)
Spliced	B1RST	33.85	29.00	3.5	7.79	2.22	1081
	B3SF1T	31.11	27.10	4.65	9.10	1.96	1373
	B4SF2T	34.36	30.95	4.41	9.30	2.11	1546
	B5SP1T	29.41	28.35	3.95	9.22	2.33	1186
	B6SP2T	30.94	26.63	4.60	8.83	1.92	1296
	B11SS1T	32.43	24.39	4.88	9.00	1.84	1226
	B12SLT	34.48	27.50	4.20	8.60	2.05	1149
Non-Spliced	B23RSWT	33.16	25.19	5.28	9.9	1.88	1593

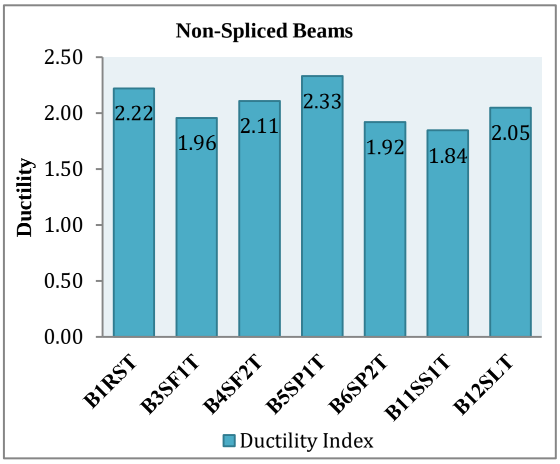
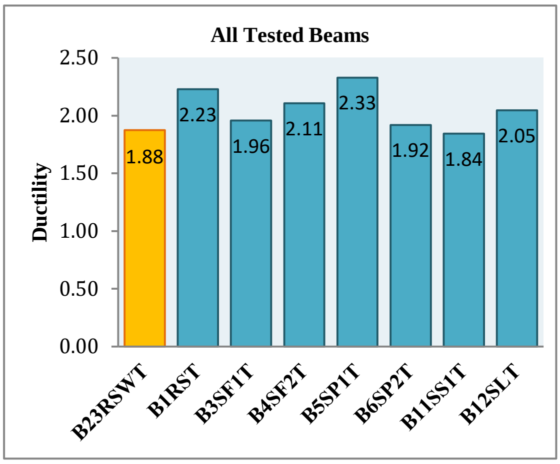


Figure 9. Variation in Ductility of All Tested Beams

The flexural toughness refers to the ability of structural element to absorb energy and plastic
deformation under increasing loads until the point of failure.

On the load-deflection curve, the toughness of the each beam represents the total entire area under the curve up to the point of fracture, as this area expresses the ductility and ability of the beam to resist cracks until failure, (Alhassan et al, 2017, AlShami, 2022) [20, 21]. The area under curve calculated for each beam using the (Trapezoidal Rule) method based on the load and deflection data recorded during the test and by using the Microsoft Excel program.

The results of these mechanical properties, which were defining above are listed in Table 4, to further clear comparison Figures 9 to 11 illustrate the differences between the beams and the effect of each variable on the stiffness, ductility and absorb energy for each tested specimens.



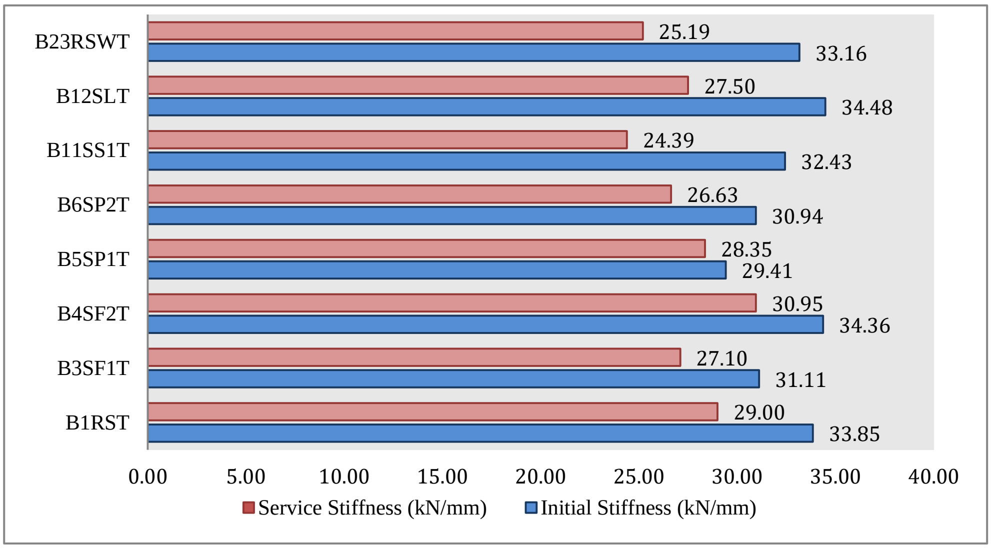


Figure 10. Variation in Initial and Service Stiffness of All Tested

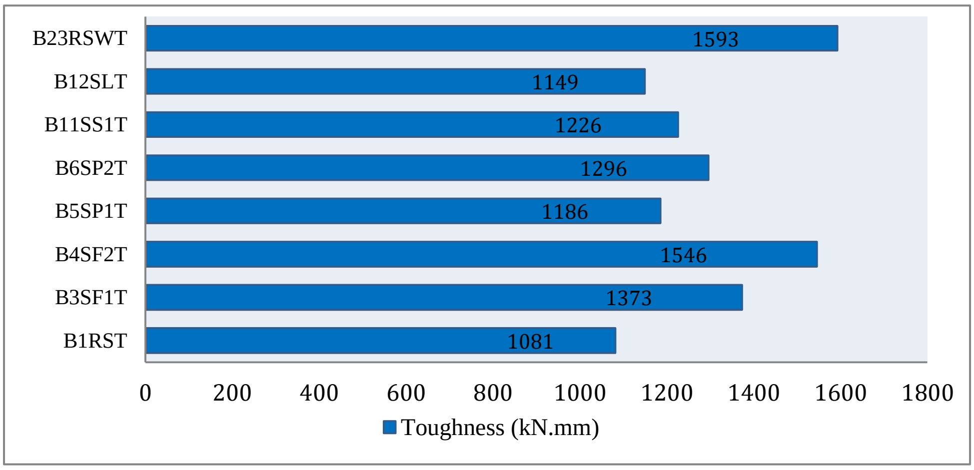


Figure 11. Variation in Toughness of All Tested Beams

The results presented above indicate that the structural properties, or in other words the flexural behavior of the beams were influenced by the proportions and type of fibers, concrete type and splice area confinement. As for steel tension spliced bars, there was a slight variation in stiffness relative to the reference beam; in other words, the tension splice and performance-enhancing variables did not affect the behavior of the beams in the initial stages, but their impact was significantly evident in post-cracking behavior and deformability. The ductility ranged between 1.96 to 2.33, meaning that the tension splice did not effect on deformability when the appropriate length was provided for load transfer and bond enhancing in the splice area. The greatest impact was observed on the energy absorption of the beams, the inclusion of hooked-steel fibers achieving an improvement approximately 27-43%, while the addition of polypropylene achieving 10-20%, the use of 0.4% of steel fibers resulted in the most balanced behavior in terms of ductility and toughness.
Compared to the tension non-spliced beam, it exhibited higher ability to absorb energy and strength with flexural stiffness that varied in similar values, but lower ductility at failure. This is attributed to absence of splice, which increased the bond between the steel and the surrounding concrete and achieving 1593 kN.mm in toughness and 33.16 kN /mm in stiffness. The use of fibers and confined the splice area contributed positively, resulting in beams exhibiting about 75-80% of the structural performance of a non-spliced beam.

4. Conclusion

Below are the key findings from the experimental program of this study:

1. All the spliced beams failed in flexural mode of failure, confirming that the chosen splice length was sufficient to achieve a good bond between the surrounding concrete and the reinforcement bars which allowed efficient stress transfer through the spliced zone.
2. The non-spliced beam failed in different failure modes, the beam failed due to crushing of the controlled by flexure, which explains the control of the tension zone over the failure mode.
3. The use of fibers concrete led to an improvement in the overall behavior of beams compared to the normal concrete, as the fibers contributed in controlling the cracks, its distribution and width, which positively impacted the durability of the beams and the ability to absorb energy without affecting the mode of the failure.
4. The effect of the fibers on the ultimate load (P_u) was noticeably evident in the steel beams with tension spliced bars, reached up to 35% compared with the normal concrete.
5. The study showed that emerging the hooked-steel fibers contributed to an increasing in the bond efficiency and stress transferring by strengthening the concrete surrounding the spliced area, which led to an improvement in the stiffness, and the pre-post cracking behavior, along with an increasing in the ability of the beams to absorb energy, thus increasing overall strength. While, the adding of the polypropylene fibers had a direct effect

   Mainly on controlling the appearance of micro-cracks and allowed the beams to withstand loads with more deformability, however their contribution to improving stiffness, energy absorption, and the ultimate beam capacity was less significant, compared with adding the steel fibers.
6. Increasing the steel fibers content from 0.25% to 0.4% volumetric ratio resulted in a more stable splice behavior in all the tension spliced beams, leading to a significant enhancement in flexural response. The study showed that this increase was generally directly proportional to increase the stiffness and ductility, thus improving the ability of the beams to absorb energy and consequently enhancing the ultimate strength.

7. Despite the confining of the spliced area led to a decline in the (P_{cr}), its application helped preventing the spreading of splitting cracks and prevent the bar slippage from happening, therefore, it was reflected in improving the bond strength, and post cracking load, and overall improvement in the flexural behavior.
8. The non-spliced beam, achieved higher (P_{cr}), and (P_u) along with more stiff behavior and greater energy absorption, but they exhibited less ductility as compared to spliced beams, which shows that the non-spliced bars do not necessarily lead to increasing the ductility.
9. The study showed that the inclusion of the fibers or confining the spliced area in the steel spliced beams, reclaim part of the flexure behavior even more, which was lower due to the splicing. This convergence in structural performance does not contradict the difference in failure mode; rather, it indicates a difference in the mechanism that that dominated and led to final mode of failure.

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