International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Annales de Chimie - Science des Matériaux
Vol. 48, No. 4, August, 2024, pp. 519-527
Journal homepage: http://iieta.org/journals/acsm

Performance of Steel Spliced Reinforced Concrete Beams Having Construction Joints

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https://doi.org/10.18280/acsm.480409

Received: 3 May 2024
Revised: 8 August 2024
Accepted: 20 August 2024
Available online: 30 August 2024

Keywords:
construction joints, flexural test, reinforcements, R.C beam, steel bars, splice

ABSTRACT

Many problems may occur during constructing the reinforced concrete structures during the implementation process, so this study has focused on one of the problems that often occur during implementation, especially in large buildings where these building needs to pump large quantities of concrete at one time, and this is often not possible, so it creates an interface between the old and new concrete is called a construction joint. Also, large areas need reinforcement of large lengths, and here we will need reinforcement splices to obtain the required lengths. Many studies examine these two problems separately, but few of them mean studying them together, that is, the construction joint occurs at the area of reinforcement splices. Therefore, this study dealt with an experimental program from nine concrete beams reinforced with steel to study the structural performance of reinforced concrete elements in the presence of a construction joint (having various interfaces 45º inclined and L-shaped), with reinforcement splice of three different lengths. The results showed that the presence of a construction joint with a reinforcement splice of sufficient appropriate splice length reduced the load capacity by 37% for the inclined joint beam while an insufficient splice length of 180 mm reduced the load capacity by 59% compared to the reference. It is shown that concrete beams lose their ductility in the presence of the construction joint at the splice reinforcement splice reinforcement region. Also, it should be considered the outcome of this study when designing mega-reinforced concrete structures.

1. INTRODUCTION

The integrity and stability of concrete structures is an important matter. Therefore, the presence of construction joints and reinforcement splices are critical points in the structure, as they can be a cause of cracks and collapse under the influence of different loads. As it is possible for concrete pouring operations to stop suddenly for several reasons, such as weather conditions, problems with the pump or molds, workforce capacity, etc. If the concrete pouring operations stop in the reinforcement connection area, it will constitute a greater problem because the presence of the building joint reduces the load capacity of the beams. Likewise, reinforcement connections may cause a negative impact on the structure's performance and there are few studies that deal with this problem. Therefore, this study aims to know the amount of deterioration occurring in the flexural strength of structural elements in the presence of construction joint with reinforcement splice at the middle of the beam.

There are several factors that can affect the bond strength of reinforcement splices. According to a study [1], 40 reinforced concrete beams were tested to determine the effect of the splice length and the reinforcement ratio on the splice strength, the results showed that the strength of the splice is proportional to the square root of the splice length. It also showed that increasing the percentage of reinforcement increases the splice strength.

Darwin et al. [2] also tested 83 samples of beams with reinforcement splice with different diameters and different relative rib areas, and using two different types of coarse aggregate. The results showed that the relative area of the ribs, the diameter of the bar, the transverse reinforcement, and the type of aggregate affect the splice strength, as the reinforcement bars have a high relative rib area reduces splice length by 26%.

As Canbay and Frosch [3] showed, the effect of the concrete cover on the performance of the splices. The greater the thickness of the concrete cover, the less efficient the reinforcement splice. This is due to the distribution of tensile stresses on the concrete surrounding the spliced bars, were not constant.

Hassan et al. [4] showed that the presence of transversal reinforcement and its effect on the bond strength of splice are more evident for large-diameter bars compared to normal-sized ones.

Pay et al. [5] tested a 41 reinforcement concrete beams, reinforced with glass fiber rods and other carbon fiber-reinforced polymer rods, in addition to steel rods to study the effect of the splice length, modulus of elasticity, surface deformations, axial rigidity, and placement of the rods on the bond strength. The results showed that the design expression ACI Comment 440 for bond strength is not sufficient, as there is a need for a new design equation. The study also showed that the bond strength is directly proportional to the axial rigidity of the reinforcement.

Researchers [6-9] investigated the effect of CFRP sheets in the exterior on the adhesion behavior of reinforcing splices in reinforced concrete beams. The results showed that the CFRP sheets enhanced the adhesion strength of the reinforcement splices whereas CFRP can enhance the capacity of insufficient splice length.

Also, 18 simple beams with a length of 2200 mm were tested with different reinforcement splice lengths (0, 300, 500, 700) mm, with steel bar diametre of 12 and 16 mm, and different amounts of transverse reinforcement, to know the effect of the reinforcement splice on the beam's response, crack load, and elongation the results showed that it is possible to obtain appropriate elongation 91% of the reference beam using an appropriate amount and distribution of cross reinforcement [10].

To evaluate the effect of the splice length on the mechanical properties of the reinforcement steel, Muin and Sholeh [11] conducted tests on samples of reinforcement steel with a diameter of 10 using reinforcement splices with a length of 1.3 ld and 1.2 ld with concrete with a compressive strength of 35 MPa and 42 MPa. The results showed that the lap splice length can stabilize the mechanical properties of the reinforcement steel. Fracture occurred in the rebar in all samples with concrete with a compressive strength of 35 MPa, but using concrete with a strength of 42 MPa and the same lengths of the splice, where the fracture in the connection after exceeding the yield stress of the rebar, the difference is due to the tension closest to the final stress of the rebar.

While CFRP sheets were used along the length of the splice to study the effect of the bond strength of GFRP reinforcement splice and steel reinforcement in another study using carbon fiber reinforced polymer sheets to determine their effect on the splice length, the innovative splice method proved greater efficiency in GFRP splice compared to the usual splice method [12, 13].

Karkarna's study [14] aimed to determine the effect of increasing the length of the reinforcement overlap splices on the strength and ductility of concrete beams. Tests were conducted on concrete beams under different conditions in terms of the length of the splices and the type of reinforcement. A digital model was also developed to simulate the behavior of the beams under different loads. The results showed that increasing the length of the overlap splice increased the strength and ductility of the beams are a certain extent, while increasing the length of the splice more than that does not lead to an additional increase in strength.

Fayed et al. [15] presented a comprehensive study of the various methods for strengthening reinforcement connections in reinforced concrete beams. It discusses a number of methods that are done before pouring concrete, such as confining them with steel stirrers or carbon fiber, and some that are done after pouring concrete, such as increasing the thickness of the concrete cover, external reinforcement with fiber-reinforced polymers, or prestressing the bars. Reinforcement and high-performance concrete. The results of this study showed that the length of the overlap and the materials used in reinforcement have a significant impact on the performance of the connection. Many methods have proven effective in strengthening reinforcement connections, which helps improve the performance of concrete structures.

On the other hand, the presence of a construction joint at the reinforcement splice area is expected to have a significant impact on the performance of the structure, as studies have shown that the presence of a construction joint in a structural member would reduce the load capacity and increase cracking and deflection at these points depends on the shape and location of the construction joint.

A study conducted by Mehrath [16] investigated the effect of the presence of a construction joint of more than one type in two different locations (at the middle and at three ends of the beam), on the flexural behavior of reinforced concrete beams. It showed that the presence of the joint in the beam forms a weak area and allows the concrete to crack easily in this area. It also reduces the bending stiffness of the beam. Especially in the post-cracking stages, where the percentage of reduction in the crack load and maximum load reached 21% and 27%, respectively, compared to the reference beams.

The compressive strength of concrete is a factor affecting the bending bearing capacity of the structural element. The greater the concrete compressive strength, the greater the effect of the construction joint and causing more loss in the bending bearing capacity of the structural element [17].

Sultan in 2019 [18] investigated the effect of the construction joint on the behavior of reinforced concrete one way slabs through experimental tests that included pouring eight slabs and using different types of construction joints (vertical, inclined, key) in different shapes and locations. The results showed that these joints have different effects on concrete cracking and on the carrying capacity and the maximum load response, as the transverse inclined construction joint had the greatest effect on the maximum carrying capacity by 24.6%.

Mathew and Nazeer [19] examined the bending behavior of reinforced concrete beams with construction joints in different locations using different concrete grades (M20, M40, M60). Nine samples were prepared, three samples for each mixture. The moment carrying capacity of specimen M40 without construction joint had the highest value, while concrete M20 had a higher load-carrying capacity.

Ismael and Hameed [20] studied the impact of construction joints on the flexure behavior of reinforced self-compacting concrete slabs. L-shape construction joints showed the best behavior, reducing first crack load by 15% and maximum load by 9.5%, while horizontal construction joints had the highest effect.

Vanlalruata and Marthong [21] determined the extent of the loss of the flexural strength of reinforced concrete beams in the presence of a construction joint under the influence of two variables, one of which is the use of concrete mixtures with different strengths and the other is a different age of the construction joint. It was shown that the loss in flexural strength when there is a construction joint in the reinforced concrete beam is between 2% to 22%, depending on the concrete mix and the age of the joint. The ductility of the beam also decreases by approximately 8% to 26%, depending on the concrete mix and the age of the joint.

The study [22] examined the impact of horizontal construction joints on reinforced concrete beam behavior in ten rectangular samples. Results showed flexural failure, increased ultimate deflection, and decreased loading capacity. The placement of the joints significantly influenced ultimate load and deflection, with mid-depth joints reducing ultimate load by 89%.

Bekem Kara's study [23] examined the impact of construction joints on concrete properties. Concrete was tested for strength, durability, and bond strength. Results showed significant changes in strength and durability, particularly when exposed to harsh conditions. Construction joints had a greater effect on split tensile and bending forces.

This study deals with an experimental program from nine concrete beams reinforced with steel bars to study the deterioration in structural performance of reinforced concrete elements in the presence of a construction joint that they have various interfaces 45° inclined and L-shaped between the old and new concrete, also reinforcement overlapping splices of three different lengths (standard and insufficient splices).

2. EXPERIMENTAL WORK

The concrete mixture was prepared using crushed gravel, fine sand with a maximum size of 4.75 mm and ordinary Portland cement (Type I) to obtain a normal compressive strength of approximately 33 MPa at 28 days of age, details of the mixture are shown in Table 1. This was done according to the specifications of the ACI 211.1 [24], and all samples were reinforced to fail to bend to achieve the goal of this study using deformed steel bars using 12 mm diameter for longitudinal bars, 6 mm diameter for upper bar and transversal reinforcements bars, the steel reinforcements properties are shown in Table 2.

This research will study the analysis of nine concrete beams reinforced with steel, with dimensions of 1200 mm in length by 200 mm in height and 150 in width. The beams were chosen with these dimensions because they are suitable for the required work.

Table 1. Trail mix proportion

(W/C) Ratio	Mix Proportions (kg/m^3)				Slump (mm)	(f'c) 7 Days	(f'c) 28 Days
	W	C	G	S			
0.44	200	450	975	690	80	26	33

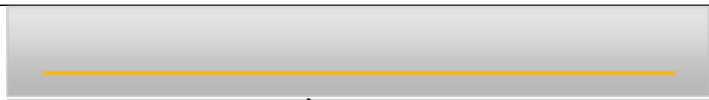
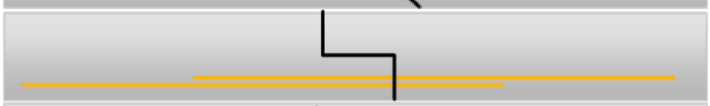
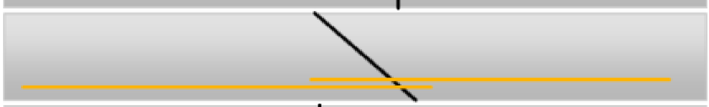
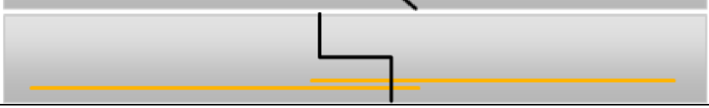
Table 2. Steel reinforcements properties

Steel Bar Diameter	f_y (MPa)	f_u (MPa)
Φ12	550	650
Φ6	520	590

Two types of construction joints were applied, I 45, because it is the most common and used and easy to implement on site, and the L-shape joint because it has a less negative impact on the performance of the structure compared to other joints. As for the lengths of the reinforcement splices, the standard length of the splice specified in the American code, which is 300 mm, was taken, and the other lengths are a substandard of the original length to study the effect of the length of the reinforcement splices with the presence of construction joints.

Three concrete beams were reinforced with full longitudinal reinforcement, one of them as a reference beam, and the other two beams each containing construction joint, one of them have an inclined shape at an angle of 45, and the other with a construction joint in the L-shape in the middle of the beam. As for the remaining six beams, they were reinforced along their length using different lengths of steel reinforcement in the length of the overlap at the middle as shown in the Table 3, in addition to a construction joint.

Table 3. Details of the tested beams

Beam Name	Symbol	
Reference steel reinforcement	Ref.	
Beam with inclined 45 joint	I	
Beam with L-shape joint	L	
Beam with inclined 45 joint and 25d_b splice length	I+300	
Beam with L-shape joint and 25d_b splice length	L+300	
Beam with inclined 45 joint and 20d_b splice length	I+240	
Beam with L-shape joint and 20d_b splice length	L+240	
Beam with inclined 45 joint and 15d_b splice length	I+180	
Beam with L-shape joint and 15d_b splice length	L+180	

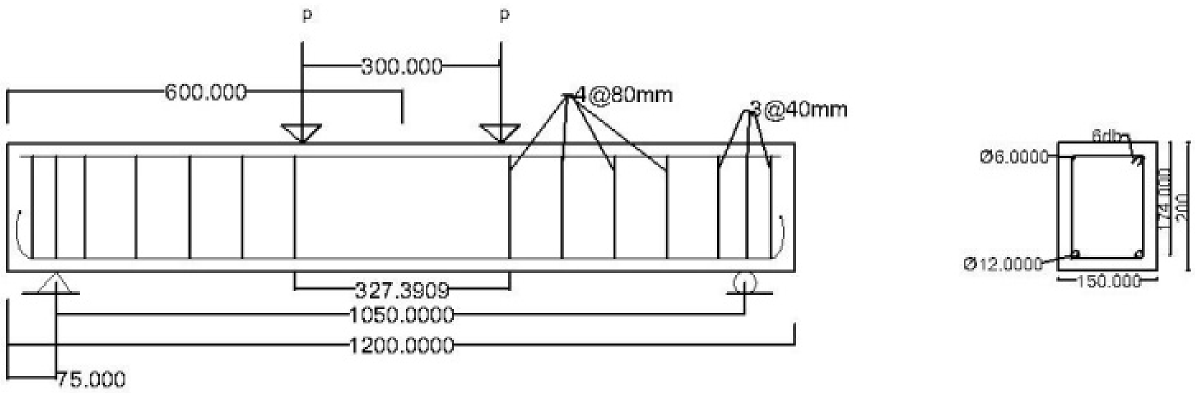


Figure 1. Details of reference designed beam

(a) The reinforcements cages | (b) Casting the first part of construction joint | (c) Casting the second part of construction joint

Figure 2. Specimen preparation

Strain gauges was also used for steel at three points in the middle, at a distance of 150 mm and 300 mm from the center for tension steel reinforcement, in addition to the strain gauge on the middle for the compression steel, the strain gauges were installed after smoothing the steel surface slightly and adding the adhesive, then installing the strain gauge TML sensors (Tokyo Sokki Kenkyujo) with a length of 6 mm and covering it with wax and tape to prevent the arrival of moisture. A Japanese-made TML (Tokyo Sokki Kenkyujo) LVDT has a measuring capacity of up to 120 mm with a high accuracy of 0.000001 mm. It has been installed at the middle, 150 mm from the left, and right of the support.

All samples were tested as a simply supported with a distance between the supports of 1050 mm under two point load, each 300 mm apart from the other, at a loading rate of 1 kN per second, and load until failure as shown in Figure 1.

The construction joint was made of wood and fixed with rebar. It was placed in the prepared molds, then the concrete mixture was prepared by adding a little water to the mixer to moisten it and prevent adhesion of the materials, then adding the coarse and fine aggregate and mixing them together for a few minutes, then adding the cement and mixing it with the aggregate dryly, followed by gradually adding water to the mixture while continuing to mix until a cohesive concrete mixture was formed. Slump test was done before starting the casting process to ensure its suitability for use, then starting the casting process for the reference beam and other beams.

The first part of the concrete was poured, and after 24 hours the second part of the concrete was prepared in the same way as before and poured after the wooden interface was raised and cleaned well using air power, then it was left to dry and it was placed in the curing for 28 days, by immersed in a basin of water at laboratory temperature, and after the end of the treatment period, it was taken out and left to dry, then painted from all sides in white so that the shape of the cracks would be clear during the examination, so that it was tested at the age of 31 days as in the Figure 2.

All reinforced concrete beams are tested under a static load using a hydraulic flexure machine with a maximum capacity of (500 kN). This machine was used to evaluate the behaviour of simply supported beams under load with a total and clear span length of (1050) mm at a load rate of 1 kN/sec loading carried out at two points with a distance of 300 mm between them at the middle of the span. The specimens were loaded until failure occurred, and data from the LVDT and strain sensors were linked with a data logger to translate values to the computer and recorded in a data excel sheet by the LabVIEW software program.

3. EXPERIMENTAL RESULTS AND DISCUSSION

First crack, ultimate load and mid-span deflection for beams test results recorded in Table 4.

For beams with a construction joint but without reinforcing splice, the cracking load is reduced by 50%. Likewise, for beams with reinforcement splice of 240 mm length with inclined joint and 180 mm with an inclined and L-shape joint. In the beam with L-shape construction joint and 240 mm reinforcement splice length, the first crack load is lower by 62.5% and 40% than the reference beam and the beam with L-joint, respectively.

This could be due to the shape of the joint and its critical area, as it is very close to the end of the splice free end, approximately 2 cm, so the first crack occurs at this point. So, it was greater weakness point than the other beams.

As for the two beams with a 300 mm splice length, there was a lesser effect on the first crack load, as its performance was like a continuous length, but its effect was clear and significant on the ultimate load capacity, as it occurred at a rate of 37% and 36% for beam with inclined joint compared to the reference beam and its counterpart beam without splice. Respectively, at a rate of 31% and 23% for the with L-joint compared to the reference beam and its counterpart without splice, respectively. Here it appears that the construction joint in L-shape or with a sufficient splice length has a better performance than an inclined 45 joint.

The effect on the load capacity of the two beams with 240 mm splice length was 45% compared to the reference beam, and 42% and 38% compared to each of them with its counterpart in joint.

As expected, for the 180 mm splice length, it gave a lower loading capacity. The maximum load capacity for inclined 45 construction joint was 65 kN and 60 kN for the beam with L-joint with a deterioration rate of 55% and 59%, respectively, compared to the reference beam, and 54%, for the two beams comparing each of them with its counterpart in the joint.

3.1 Crack propagation

Figure 3 shows the pattern of cracks in all the beams studied, the loads at each crack occurred during the examination was recorded, and all the beams failed to bend, but there is a difference in the beginning of the formation of cracks and their distribution, as the cracks began to appear along the bending area in the reference beam, so that these cracks grow and connect together. Among them is the cause of failure with a crack width of 5.1 mm.

Table 4. Test results for first crack load, load capacity and mid-span deflections

Specimens	$P_{c\,test}$ (KN)	Mid-Span Deflection (mm)	$P_{u\,test}$ (KN)	Mid-Span Deflection (mm)
Ref	40	1.18	145	11.11
I	25	0.4	140	9.31
L	25	0.62	130	12.95
I+300	30	0.72	90	2.28
L+300	40	0.77	100	2.91
I+240	25	0.38	80	2.3
L+240	15	0.29	80	2.87
I+180	25	0.46	65	1.47
L+180	25	0.49	60	2.05

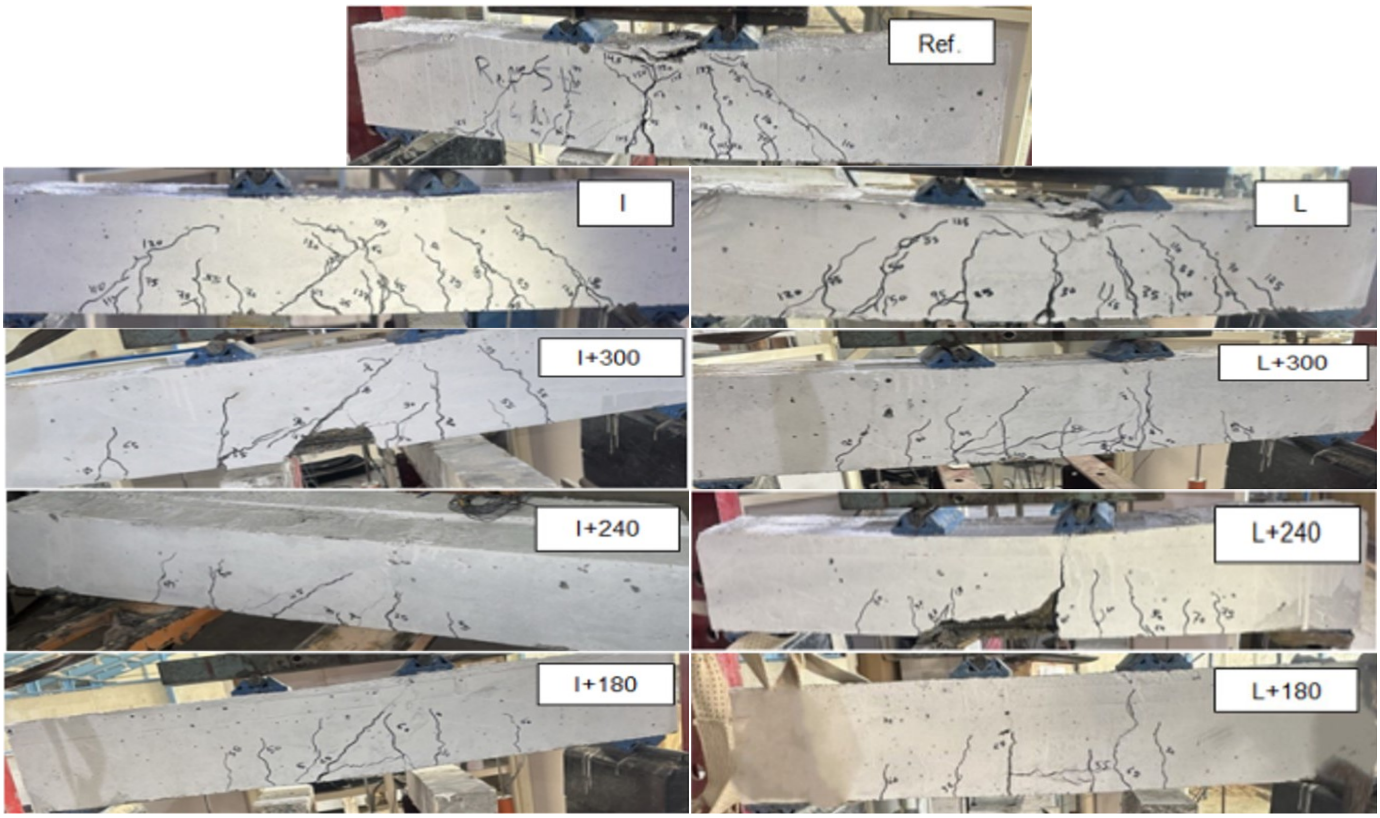


Figure 3. Crack patterns of the tested beams

The two beams without splice, a crack appears at the beginning of the joint at the level of (25, 30) kN. In the L-joint beam cracks are distributed over the bending area, forming a crack with a thickness of 2.7 mm in the middle of the beam at failure. As for the inclined 45 beam, the crack occurs at the joint, it expands to take the shape of the joint (the shape of the joint is clear), but the crack at the middle is more extensive, extending and meeting the number of cracks in the joint at a load of 45 kN and continuing to extend until failure occurs, with a crack width of 1.4 mm at the middle.

The first crack appeared at both ends of the splice in the two beams with a 300 mm splice length, then a crack at the joint, then other small cracks on both sides, causing it to fail with a crack width 0.85 mm and 2.6 mm for the L-joint and inclined 45 joint, respectively, with the observation that part of the concrete cover fell at the splice area for the inclined 45 joint beam, that is, as it was observed, the spread of less cracks at the same beam compared with L-joint beam.

In the other four beams, the beginning of the crack was at the joint, then two cracks at the two free ends of the splice, but in the beam with a 180 mm splice length the first crack was at the joint, which is the same point that represents one of the two free ends of the splice. Failure occurred in this beam with a small number of cracks and their extensions, so that the shape of the joint is clear, with a crack width 0.95 mm at failure, and a crack width 0.3 mm for the L-joint beam.

As noted, the part of the concrete cover at the splice area of the L-joint and 240 mm splice length beam, and crack width 0.95 mm at the middle, and a larger crack width 2.8 mm at the end of the joint near the free end of the splice, and a 1.2 mm crack in the middle length of the inclined 45 mm and 240 mm splice length beam.

It is worth noting that in beams containing a construction joint with splice, that the number of cracks formed is less and close in its width. The low load capacity (60-100) kN may be a reason for this.

3.2 Failure mode

The cracks were distributed in the bending region, with cracks continuing to appear in advanced stages of loading until bending failure occurred with a wide crack in the middle of the length of the beam. While the beams with a construction joint (I, L), their behavior was similar to the reference beam, but there was an additional crack at the beginning of the joint, and the shape of the joint appeared clearly in the beam I 45º.

The failure mode for spliced reinforcement beams with a construction joint in the form of I 45º and L, where the beams with sufficient and insufficient reinforcement splice length failed by bending with transverse cracks appearing between the bending cracks, and some of the beams the concrete cover fail at the area of splice length therefore it is possible that these beams fail called bending-splitting. Part of the concrete cover of the beam (L+240) falling in the area between the end of the free space near the beginning of the joint and the end of the joint, and also for the beam (I+300), shows transverse cracks below the beam in the area of the reinforcement splices. As for the beam with the L-joint (L+300), the splitting cracks are at the area of the beginning of the joint and the far end of the splice reinforcement.

However, in beams spliced to an insufficient length of reinforcement, the splitting cracks were at the beginning of the joint and the far end of the reinforcement splice, as this area formed the weakest section due to the proximity of the reinforcement splice end to the construction joint, which reduces the tensile strength of the concrete between the two faces causes splitting failure.

3.3 Load-deflection behavior

The load-deflection curve is divided into three parts, which are the pre-cracking region and the post-cracking region, which continues until the yield point. The last region is the post-yield region. The tensile strength of the concrete is controlled in the first stage in this curve. As for the different behavior of the beams, it appears in the second stage, as it represents the stiffness of the beam. The third stage shows the beam's ability to deform until failure.

The deflection at the center of the beam was measured using LVDT. The load-deflection curve is shown in Figures 4-7.

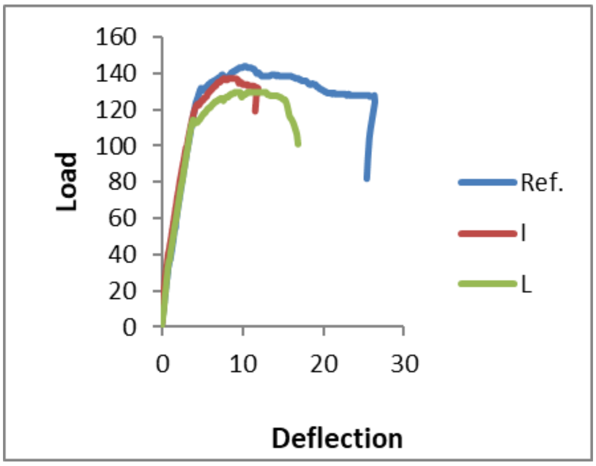


Figure 4. Load-deflection curve for reference, inclined and L-joints beams

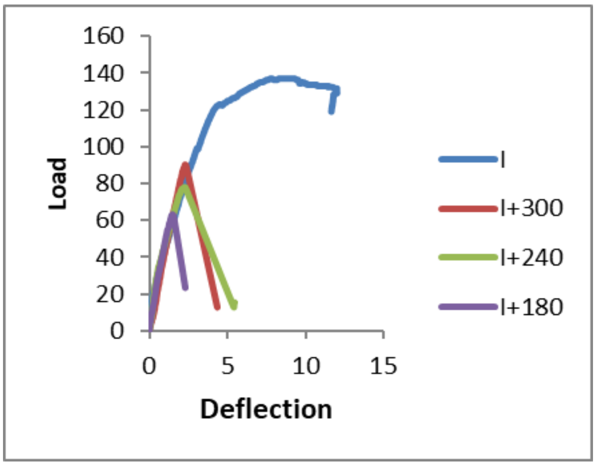


Figure 5. Load-deflection curve for inclined joint beams

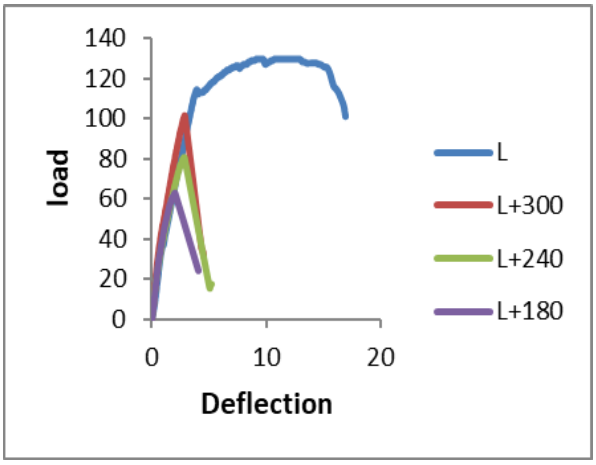


Figure 6. Load-deflection curve for L-joint beams

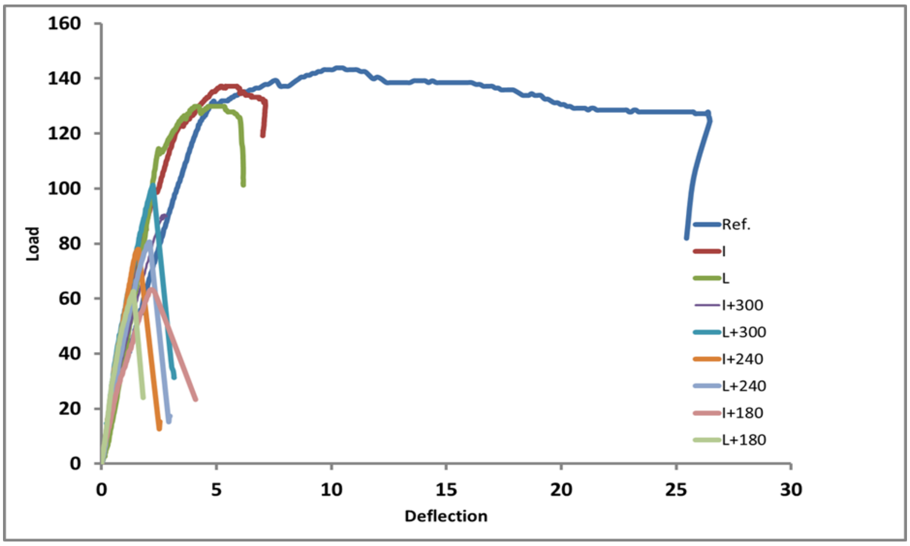


Figure 7. Load-deflection curve for all tested beams

The presence of a construction joint reduces the deflection by 66% and 47% compared to the reference beam for the inclined joint and L-joint beam respectively.

Likewise, for all the beams examined the deflection reduced at a different rate between 35% and 75%.

While the deflection for the beams increased for inclined 45 joint beams by 80% and 15% for 300 mm and 180 mm splice length, respectively compared to their counterparts in the joint while the decreased in 240 mm splice length beam by 5%.

As for the beams with the L-joint, the deflection decreased by 53% and 21% for the two beams with 240 mm and 180 mm splice length (L+240, L+180) respectively compared to their counterparts with the joint, while it increased by 24% for 300 mm splice length.

In beams 240 mm splice length with inclined 45 and L-joint, and 180 mm splice length with L-joint, the beginning of the cracking was at both ends of the splice reinforcement, which led to the absorption of energy and accelerating the occurrence of final failure, as these three beams failed with a final load of 60 kN and 80 kN compared to similar ones that failed at loads of 140 kN and 130 kN. It may be possible that the reason for this different performance for tested beams in this study is the presence of the joint and the reinforcement splice at the same region. Therefore, there is a great need for much research to understand this performance.

3.4 Load-strain relationship

Table 5 records the strain sensor readings for steel-reinforced beams. the two beams (St+I, St+L) are with construction joints without a reinforcement splice, the strain of tension steel in L joint beam is greater than it for the I 45º joint beam, this is another reason that confirms that the behavior of beams with L joint is of higher ductility and better performance than with the I 45º joint.

The presence of construction joints with reinforcement splices reduces the strain values of the tensile steel to a level lower than the strain of the steel used in different proportions depending on the length of the reinforcement splice and the shape of the construction joint, except for the beam with L joint, and with a sufficient splice length reinforcement (St+L+25d_b), its reinforcement strain increased by 19.32%.

For beams with an I 45º joint, the decline in steel strain was 9.25% for the beam with sufficient splice length, reaching 60.25% with a splice length of 15d_b, which caused de-bonding between the reinforcement and the surrounding concrete for these beams, the two beams with the L joint with insufficient splice length by 20% and 40% the reduction in steel strain was equal, at a rate of 33.5% for both. It is clear that the effect of the construction joint in the form of L may give better performance than the I 45º joint for beams with or without a reinforcement splice, and by a rate that may reach 50% for beams with insufficient splice length reinforcement, and 30% for beams with sufficient splice length reinforcement.

3.5 Ductility index

Depending on the load-deflection curve, it is possible to know the ability to deform after the yield point before failure occurs. By knowing the deflection at the maximum load and the deflection at the yield point for each beam, to obtain the ductility of beams. As Table 6 shows, the ductility of the two beams without a reinforcement splice is higher than that of the reference beam. This is due to the presence of the construction joint in the middle of the beam, which allows greater movement at the joint, which increases its ductility.

While other beams fail before they reach the yield point, except for the 300 mm splice length with L-joint beam, the beam fails when it reaches the yield point, this shows that even with a sufficient length of splice reinforcement, the presence of the construction joint poses a problem. That means failure in the bond strength and failure of the joint due to the negative effect of the construction joint at the reinforcement joints area.

Based on the results of this practical study, the results were discussed, and it was not possible to compare them with other studies, as there were no practical studies linking construction joints and reinforcement connections. Rather, the available studies were concerned with studying each of them separately, either construction joints or reinforcement connections. Therefore, comparison with those studies is not possible. It is considered true. It is also possible to conduct a special statistical analysis of the results obtained. At the present time, work is underway to develop a design equation for this study, but there is no room to mention it in this paper, and it may be for future research.

Table 5. Strain sensor readings for steel-reinforced beams

Tension Mid	Tension 150 (mm)	Tension 300 (mm)	Compression Mid
0.0609355	0.005531	0.0048502	-0.0016782
0.00954921	0.00524874	0.0026139	Nil
0.0372459	0.00512468	0.0017075	-0.0036428
0.00249546	0.00410894	0.0035488	-0.0009384
0.0032813	0.00441976	0.0046795	-0.0010261
0.00090915	0.00226765	0.0011745	-0.0008694
0.00182666	0.00481519	0.0038748	-0.0012122
0.00109307	0.00331892	0.0017138	-0.0007503
0.00183084	0.00366795	0.0023240	-0.0004807

Table 6. Test results for first crack load, load capacity and mid-span deflections

Specimens	$P_{y\,test}$ (kN)	Mid-Span Deflection (mm)	$P_{u\,test}$ (kN)	Mid-Span Deflection (mm)	Ductility Index
Ref.	76	2.73	145	11.11	4.07
I	72	1.95	140	9.31	4.77
L	71	2.18	130	12.95	5.9
I+ 300	-	-	90	2.28	-
L+300	100	2.91	100	2.91	1
I+ 240	-	-	80	2.3	-
L+ 240	-	-	80	2.87	-
I+ 180	-	-	65	1.47	-
L+ 180	-	-	60	2.05	-

4. CONCLUSIONS

In this research, the behavior of spliced steel reinforced concrete beams was studied within construction joint of two type (inclined 45, L-shape) joints for three lap splice lengths to estimate the amount of deterioration of these beams. From this study the following can be summarized:

- The highest deterioration rate occurs with the minimum insufficient lap splice length of 0.6 splice length, at 59%. This means that the bond between the concrete elements is not strong enough, which causes damage to the buildings.
- The construction joint allows greater movement, which increases the ductility of the beams without splice. But this can increase the risk of cracking and failure.
- Concrete beams become brittle even with sufficient splice length because of presence of construction joint, which makes it susceptible to damage, and therefore the recommended standard splice length is not sufficient in the presence of a construction joint.
- Bond strength failure and joint failure occur at the splice zone before the yield stress is reached, which means a significant decrease in the bearing strength and the occurrence of bond-splitting failure of the spliced reinforcement beams in the presence of construction joints.
- The presence of a construction joint with reinforcement splice at mid span caused a significant increase in stiffness, leading to failure before the steel reached its yield point. Therefore, more efficient structural connections must be designed, combining the required ductility and stiffness.

Additional studies are needed to deepen understanding of the behavior of reinforced concrete buildings and improve their design. Practical studies can also be conducted using additional reinforcing materials in the joint areas to increase the bond strength. Studies can also be conducted to develop computer models to analyze the behavior of concrete buildings and evaluate the effect of changes in design on the performance of the structure.

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