State of Art of Construction Joints of Reinforced Concrete Beams

Sara I. Ammar[1*], Dr. Akram S. Mahmoud[2]

[1]Civil Engineering Department- College of Engineering - Anbar University (Sar22e1006@uoanbar.edu.iq)
[2]Civil Engineering Department- College of Engineering - Anbar University (Dr.akramsh1@uoanbar.edu.iq)

Abstract: The human needs for mega structure made the designer need to pump large quantities of concrete, and pouring these large quantities at once is not possible from a practical point of view, so the construction joint must be formed, which are the places where the old concrete meet the new concrete. These places will form weak points in the concrete structure, so it is important that these places between the old and new concrete perform their function in transferring forces through the construction joint. In this study, 394 previous researches were downloaded, more than 138 papers selected for reading. There were a number of variable parameters according to the type of study required, grade of concrete $f\bar{c}$, yield point of longitudinal reinforcement fy, in addition to the shape and the location of the construction joint. After analyzing and comparing the results, the results showed that increasing the compressive strength of concrete has a negative impact on the performance of the construction joint, and the shape, location, and reinforcement ratio of the beam has a significant impact on increasing the flexural strength.

Keywords: Construction Joint; beam; new concrete; old concrete.

1. Introduction

Concrete structures are subject to several and variable conditions when they are poured on site and during their service life. Therefore, it is necessary to calculate the impact of these changes as factors affecting concrete and to include them or add them as variables when designing and not to ignore them because of their great impact on the performance and safety of the structure.

A change In temperature, for example, exposes the structure to a change in size and to shrinkage and expansion. To control such changes, we will need a so-called functional joint [1, 2] such as Expansion Joints and Contraction Joints[3]

it is often not possible to pour concrete for the entire structural structure at once for many reasons, such as weather conditions, the ability of the workforce, the creation of molds, and the pumping of concrete, then the so-called construction joint will be formed, which we will focus on in our study, as it is necessary to find an appropriate solution For problems that occur on site to maintain the performance of the facility.

Also composite construction overlay; slabs supported by precast beams; floor slabs formed on

filagree elements; If the need to increase load carrying capacity arises, it is also applied to existing structures. This could be the result of a need to reinforce the structure or for new functional requirements, poor execution, or technical deterioration. In these situations, extra reinforcement is added to the concrete overlay to compensate for any decrease in load capacity[4].

This paper presents an extensive historical literature review on construction joints, covering what has been published until 2024. The comparison and identification of several milestones is done that can see in table (1). This review aims to help understanding the mechanism of construction joint work in concrete structure. the methodology adopted in this study is shown in Figure 1, which shows the steps followed to write this review.

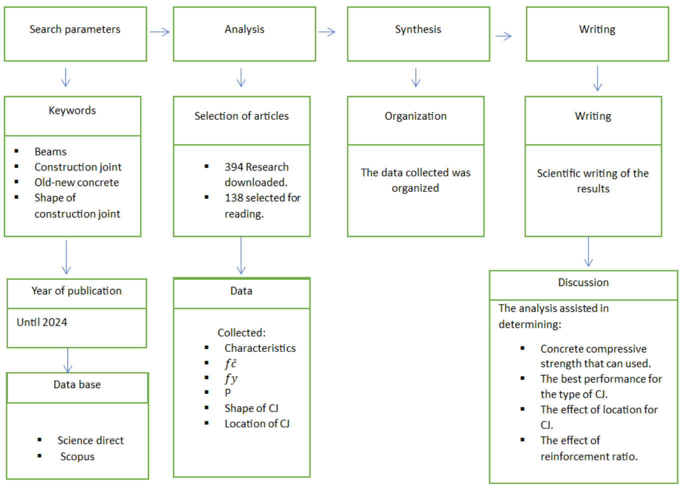

Figure 1. Steps Of Literature Review

2. Construction Joints

In concrete structures, especially the large ones, it is difficult to pour concrete in a continuous process, so if the concrete pouring process is stopped for a period longer than the initial sitting time of the concrete and then the pouring operations are repeated, then in these places the so-called construction joint will be formed[14].

The main purpose of the joints is to ensure the continuity of the transmission of flexural and shear capacity, as the flexure continues through its transmission through the longitudinal reinforcing steel. As for the shearing force, it is transmitted through the joint through friction between the two faces of the old and new concrete and through action function; many researchers have conducted experimental studies on shear forces and their transfer between the surfaces of old and new concrete[15-18]. A good construction joint In homogeneous concrete must provide continuity of bending and shear through the joint, in addition to the necessity of being watertight. If this possibility is not available, a weak area is produced that can perform the contraction joint function, and not the construction joint[19].

To obtain the required bonding between the hardened concrete and the fresh concrete, it should be noted that some things must be confirmed before placing the fresh concrete, as the surface of the hardened concrete must be clean and free of impurities[19, 20]

But if it is a few hours between stopping the concrete pouring operations and adding the new concrete, we need a visual check to make sure the face of the hardened concrete is clean, then repeat the concrete pouring operations, which are associated with the hardened concrete, while making sure to use the vibrator for fresh concrete. But we will need to prepare the surface of the hardened concrete with additional steps in the case of the old joints, where the face of the concrete is cleaned using air- water jet or a wire broom if the concrete is hardened enough so that it does not lead to the loss of aggregates[19, 20]. In addition to wetting the face of the concrete before pouring the fresh concrete, and leaving pools of water at the time of the process of pouring the fresh concrete will form a weak bonding strength due to the increase in the ratio of water to cement in the fresh concrete at the interface, so the interface of hardened concrete must be wet only[19].

Table 1. Data And Parameter From Previous Studies.

Ref.	bmm	h mm	L mm	F_c^{-} Mpa	ρ	f_y Mpa	f_t Mpa	splice	Copler	Construction joint						
										30°	45°	60°	vertical	L-shape	joggle	horizontal
[5]	100	100	500	32*	-	-	3.17*	-	No	-	-	-	L/2	-	-	-
[3]	150	250	2000	26*	-	420	2.85*	-	No	-	-L/2 -2L/3	-L/2 - 2L/3	-L/2 -2L/3	-L/2 -2L/3	-L/2 -2L/3	-
[6]	100	100	500	16.26 19.4667 23.7067 32.225 35.3667 38.7533 41.475	-	-	2.26* 2.47* 2.73* 3.18* 3.33* 3.486* 3.606*	-	No	-	-	-	L/2	-	-	-
[7]	100	200	1000	34.5*	0.0092	648.2	3.3	-	No	-	-SIM** -SIS -SIMS	-	-	-	-	- SHT *** - SHC - SHTC
[8]	200	200	950	20	0.007*	572	2.5*	-	No	- L/2 - L/3	-L/2 - L/3	-L/2 - L/3	-L/2 - L/3	-L/2 - L/3	-L/2 - L/3	-
[9]	One way slab 450	70	1000	32.6	0.004545	607	2.95	-	No	-	- transversal -plane	-	-Mid section - on sides	- Transversal -plane -long in plane	-	-
[10]	125	150	1000	32	0.01446*	482	3.8	-	No	-	-	-	-L/2 -L/4	-	-	-L/2
[11]	150	200	1650	M20 41 M40 50 M60 73	0.0062*	579	3.58* 3.96* 4.78*	-	-	No	-	-L/2	-	-	-	-
[12]	150	150	700	M15 21.39	-	530	2.58*	-	-	No	-	-L/2	-	-	-	-

				M20	27.86			2.96*									
				M25	32.84			3.2*									
				M30	36.19			3.37*									
[13]	Two way slab			28		-	474	3.5	-	No	-	-	-	-L/2	-L/2	-	-L/2
	450	60	450														

*Assumed

**-SIM: Maximum moment (mid-span)
-SIS: Shear span (min. moment)
-SIMS: Shear span & maximum moment

***- SHT: Tension zone
- SHC: Compression zone
- SHTC: Tension and compression

Structural joints may be required for the purposes of expansion in buildings and facilities. Structural joints are required in beams, slabs, etc. And because structural joints are practical requirements in concrete structures, preparing the joints correctly through advance planning if possible and showing them in the construction drawings. Also, the study of construction joints helps in preparing the joints. Resulting from unexpected circumstances during work, such as stopping machines or heavy rain, etc., advance planning makes us ready to face these problems. Preserving the homogeneous nature of the structure in facilities that require contraction and expansion joints. This is done by making the construction joints coincide with the expansion and contraction joints, and this will reduce the number of joints in the structure [6], and thus the construction joints do not constitute weak points for the structure.

Structural joints are classified according to type, they may be vertical, horizontal and inclined at an angle (30˚,45˚,60˚) and may be in the form of a key as in Figure (2). usually it is not recommended to use horizontal construction joints in beams[19].

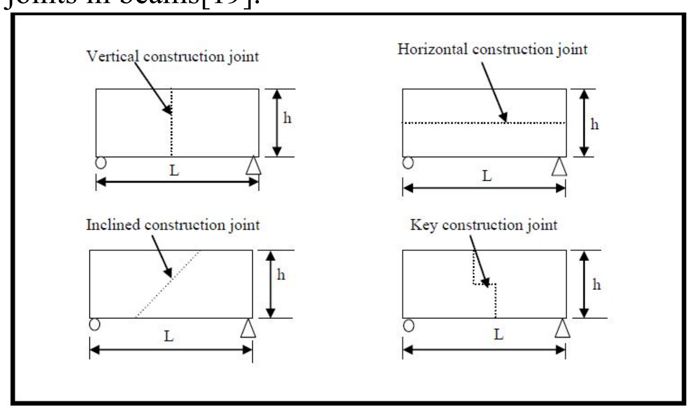

Figure 2. Types Of Construction Joint[21-23]

As for the location of the construction joint, the capacity of concrete production, the site conditions and the type of work are determinants of the location of the construction joint, as the construction joints are not required to accommodate the movement. On the contrary, all efforts must be directed to prevent the occurrence of movement in these joints. The shear forces are low, and to ensure the good performance of the structure and the acceptable appearance, the location and size of the joint must be chosen according to the type of structural structure[8]. While ACI 224 [19] specified that minimum shear points and counter-bend points are the best locations for connections placed perpendicular to the main reinforcement the joints can be placed in the middle of the span or in the middle third of the span, making sure to provide adequate shear transfer and continuity of bending across the joint by continuing the reinforcement of sufficient length at the joint.

In order to increase the interlocking between the old and new concrete, which provides a better transfer of shear forces, the concrete casting molds for the construction joints must contain shear key blocks, and the special molds containing these shear keys blocks are removed before the continuation of the casting, and in the event of sudden unexpected reasons that lead to the cessation of casting In areas of high shear strength, dowel bars are provided, in which case it is not necessary to make shear keys[6].

2.1 Effect of construction joint

Before starting the implementation of any construction work, it is necessary to know the problems that occur on the site, and the construction joint is one of these problems. Therefore, knowing its effect reduces a lot of effort and time during work. Therefore, many previous experimental studies were collected to understand and know this effect.

T.Waters [24]

Discuss the advantages of Different techniques can be used to remove the surface of hardened concrete before laying fresh concrete, such as scraping with a brush hammer or pneumatic hammer, wet sandblasting, or rough tamping. The best procedure for construction joints is wire brushing and cleaning with compressed air. Retarding agents may be used to make surface removal easier. Roughening the surface while still flexible is also an option, such as by brushing with a stiff broom or half-immersing stones. also show The age of the hardened concrete does not affect the joint strength .

Vanlalruata & Marthong [12]

The study examined the impact of cold joints on the bending ability of reinforced concrete beams using different concrete mixtures and construction joint ages, with 40 beams cast, 32 cold joint and 8 controlled beams. Cracks in monolithic beam samples appeared in the flexural zone, increasing with load. Cold jointed beams also showed fracture patterns, with early cracks in the direction of joints. The severity of cracks is greater for specimens cold joined for 21 and 28 days, and higher concrete grades. Flexural strength loss varies between (2-20)%, energy dissipation capability losses range from (2-7)% for one day and (20-25)% for 28-day this varies depending on joint composition and age. While ductility decreases from (8-12)% to (16-26)% at 28 days.

Abdulmajeed [2]

The ANSYS (V.9) computer program used the finite element method for experimental analysis of beam behavior with vertical construction joints and a horizontal construction joint model. Six samples with and without construction joints were analyzed, comparing theoretical and practical results [3]. It turned out that the finite element method is a powerful and economical tool for predicting structural element responses, with a theoretical difference of(5.77- 6.83)%.

Ismael, M. Hameed& J. Abd[10]

Researchers studied the performance of reinforced self-compacting concrete beams with construction joints. Four samples were prepared, each with a different construction joint. The samples had a compressive strength of 32 MPa. Initial cracks started in the middle of the beam, but behavior changed over time. The horizontal construction joint sample showed the most significant reduction in crack load and ultimate load compared to the reference sample, with a 6.7% decrease in the first crack load and 26.7% decrease in ultimate load. The vertical construction joint at On Fort Span showed a 16.7% and 56.2% decrease in ultimate deflection, respectively. The ultimate deflection decreased by 9.5% for samples with horizontal joints, 14.3% for vertical joints in the middle, and 41.7% for vertical joints on the fourth span compared to the reference sample. So the sample with a horizontal joint has better performance compared to other cases.

Abass [8]

The study examined the performance of construction joints in concrete structures by varying the location and type of joint. 19 square samples were prepared, with one without a joint and others with different joint locations and shapes. The study recorded deformation for each stage of a 1000 kN beam using a computer control. Results showed that the beam with the mid-span construction joint performed better than the third point, with a 2-15% reduction in loading capacity. The presence of stirrup significantly affected loading capacity, with a 7-15% increase in capacity and a 20-48% decrease in ultimate deflection. The key joint samples showed similar results to the reference sample, and the mid-span construction joint had little effect.

Gerges Issa& Fawaz [6]

The study examined the flexural bending capacity of reinforced concrete beams, comparing homogeneous and construction joint models, with varying compressive strength. 42 beams were cast, with six models, three monolithic and three with a mid-span joint. The study found that the flexural bending capacity of concrete decreases with increased compressive strength, with a ratio of (77.95-98.67)%.

Al-Rifaie, Al-Hassani& A. Shubbar[14]

The study examined the impact of horizontal construction joints on reinforced concrete beam behavior in 10 rectangular samples, with different levels and numbers. All samples under Two Point Load showed flexural failure, increasing ultimate deflection by (108-133)% and decreasing loading capacity by (83-97)%. The results indicated the location of the horizontal construction joint affects ultimate load and deflection, A mid-depth construction joint decreases ultimate load by 89% compared to a reference beam, with an increase in ultimate deflection 114% for specimen with construction joint below mid-depth and 83% from the reference sample with an increase for ultimate deflection 126%from reference for the specimen with two horizontal construction joints below mid-depth.

Mehrath & M. Al-Hassani [3]

The study examines the impact of transverse construction joints on the structural performance of reinforced concrete beams, involving 23 samples, three without a construction joint, and 10 samples with different shapes and locations, including an additional stirrup. The study found that samples with mid-length construction joints and 2L/3 joints experienced the most significant reduction in ultimate load while those with additional stirrup showed the least reduction.

Jabir, Salman& mhalhal [7]

The study examines the behavior of reinforced concrete beams with various types and locations of construction joints, including horizontal and inclined joints, and compares seven samples with and without construction joints for reference. Samples with horizontal construction joints in the tensile region experience a (5-7)% decrease in loading capacity compared to the reference sample, while the ultimate strength remains unaffected by joint in the compression region, so If constructing a horizontal joint, it is advisable to place it in the compression area. The samples with an inclined construction joint showed a decrease in flexural failure and hardness compared to the reference sample, with a decrease in load capacity of (1.25-2.5)%.

Issa, Gerges& Fawaz [5]

The study investigates the impact of vertical construction joints on the modulus of rupture, revealing a correlation between concrete strength and the modulus of rupture for plain concrete. 42 samples were created from seven mix designs, six models, three monolithic and the other half with a vertical construction joint at mid-length beam. The study found that beams with construction joints experienced less than a 55% decrease in flexural strength compared to beams without const-ruction joints, Therefore, a new relationship was estimated

$fr = 0.28\sqrt{fc'}$

Gerges Issa& Fawaz [25]

The study investigated the relationship between concrete's compressive strength and splitting tensile strength for concrete beams with construction joints. Seven mix designs were prepared, and nine cylinders were cast to test compressive, splitting tensile, and vertical construction joint strength. From that, The splitting tensile strength of concrete samples with construction joints decreased by 55% compared to monolithic samples, suggesting a relationship between compressive strength and splitting tensile strength

$TCJ = 0.25\sqrt{fc'}$

Therefore the recommendation is to increase the reinforcements for construction joints to compensate for the decrease in splitting tensile strength.

Abbas & Sultan [9]

The study investigates the behavior of reinforced concrete one-way slabs with various construction joint types and locations, using eight samples, One of these samples is homogeny-eous and the seven samples are with different shapes and locations of construction joints. All samples showed flexural failure, except one with two joints in higher shear zones. The sample with the vertical joint had the highest reduction ratio for the crack load it was 38.9% compared with the reference. The sample with an inclined joint showed the highest reduction in loading capacity at 24.6%, while the key Long joint-in-plane manner sample had the lowest reduction at 5.6% and 1.8% for crack load and loading capacity respectively. The specimen with an inclined in-plane joint closely matched the reference sample in load-deflection, while the specimen with a vertical middle and inclined transversal joint became softer in advanced stages.

Mathew and Nazeer [11]

The study 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 M 40 without construction joint had the highest value, while concrete M20 had a higher load-carrying capacity.

Ismael &Hameed[13]

Researchers cast four reinforced models with construction joints to study the effects of construction joint on the flexure behavior of reinforced self-compacting concrete slabs. The existence of a construction joint has a lesser impact on ultimate strength than the first crack load. The sample with a L-shape construction joint showed the best behavior, reducing first crack load by 15% and maximum load by 9.5%, while the sample with a horizontal construction joint had the highest effect, reducing first crack load and maximum load capacity by 40% and 22.8% respectively due to the separation between the two layers, which was different from other cases.

Al-Mamoori [26]

study the effect of using sugar molasses to reduce the effect of vertical and horizontal construction joints in high-strength concrete beams. Some mechanical properties of concrete were studied in its fresh and hard state using different percentages of sugar molasses with a test of 24 samples. The results showed that molasses helps improve the compressive strength of concrete by about 11.2%. It also delays the first hardening time of concrete by 277 minutes.

Laskar et. al [27]

Study of the bending behavior of construction joints of reinforced concrete beams consisting of two layers of Portland Cement Concrete (PCC) and alkali activated Concrete (AAC). The study included experimental work and finite element analysis of the beams due to four different beams, the first as a reference and the second with a horizontal joint (the first layer is AAC and the second is PCC). As for the two beams, they are both with a vertical joint, one of which is of PCC for the two parts, and the other half is of PCC and the other is of AAC. Experimental results showed that the adhesion of the two layers of concrete increases with the alkali activated concrete. Also, using it in the bending area leads to improving the strength and ductility of the concrete beams. The study also showed that the use of finite element analysis is appropriate to predict the behavior of concrete beams.

Kara [28]

evaluate the effect of the presence of construction joints on the properties of concrete, the strength was tested by pouring concrete in two stages with an interval of zero 60, 120, and 180 minutes, and the samples were tested for compression, bending, split tension, and pull-up test for strength of bond between concrete and rebar. As for the durability test, it was done by preparing two type of concrete and exposing the samples to different conditions and high temperatures the samples were examined for weight loss and split tensile strength, and it was found that the strength and durability of concrete were noticeably affected, especially when exposed to harsh environmental conditions. It was also noted that a greater effect of construction joints on split tensile and bending forces was observed.

Zega et. al [29]

study tested the effect of cold joints on both the compressive and flexural strengths of concrete using three types of concrete: normal concrete and high-strength concrete with plasticizer, and concrete with Polypropylene fiber as an additive. The concrete was poured in two stages at an interval of 120 and 240 minutes, and the tests were conducted on casting molds, according to the measurement of compressive and flexural strength, it was noted that increasing the casting stop time will negatively affect the strength, while concrete containing Polypropylene fibers showed somewhat better resistance.

Ibrahim et. al [30]

study of the effect of construction joints on the shear resistance of reinforced concrete beams without shear reinforcement by pouring five reinforced beams without shear reinforcement in different shapes and locations of construction joint. The results showed that shear resistance is greatly affected by the presence of the construction joint, and type and location of the joint have a major impact.

Mahdi &sultan [31]

study examined the behavior of reinforced concrete beams with horizontal construction joints using two types of concrete (normal concrete and another by adding steel fibers to strengthen the specimens that have the least load). It also studies the effect of leaving the first layer of concrete Without compression. The results showed a decrease in the ultimate load, ductility and energy absorption capabilities, as they affect The without compression first layer negatively affects the properties of the specimen, while the steel fibers help improve the properties of the beam with the construction joint.

Akin & Guz [32]

An experimental study of the effect of different angles of construction joints in the shear zone on the behavior of reinforced concrete beams, where seven reinforced concrete beams were cast, one of them as a reference, while the remaining six beams contained building joints with different angles (0, 45, 90) in the shear zone with and without additional reinforcement at the joint, after subjecting the prepared specimens to the test, it was revealed that the clear effect of the construction joints and their varying angles on the mechanical behavior of the reinforced concrete beams also confirmed that strengthening the plane of the construction joint with steel induces a change in the cracking of the concrete within the joint area.

Khalaf et. al [33]

aimed at evaluating the behavior of reinforced concrete beams that include construction joint between old concrete and new concrete, four beams with three different shapes,(45, 60, and L) shape. The results showed that the inclined joint at 45 is the most effective in transferring loads between the old_ new concrete, as showed that the presence of construction joints reduces the ductility and toughness of reinforced concrete beams, except for the sample with the L joint, which increased by 40%.

Figure 3 shows some pictures of experimental work and the stages of preparation and casting for some of the studies reviewed above.

(a) 1. first part of concrete

(b)

(a) by Akin & Guz [32]
(b) by Ibrahim et. al [30]

2. beams after cast second part of concrete.by Akin & Guz [32]

3. beams before testing. By Abass [8]

Figure 3. experimental for some of the studies

3. Discussion

The literature review conducted , aiming to identify the contributions given by researchers for the assessment of the flexural behavior of concrete beams with construction joint , showed that several milestones could be defined; and how this parameters can effect on the behavior of concrete structure. Previous studies have demonstrated that joints significantly reduce ultimate load, and some results are summarized in tables (2,3,4) for comparison. Table 2 shows maximum load reduction percentages ranging from 0-60.117%, with the lowest in Study [8] and highest in Study [5]. Other studies show similar percentages, with mid-span reductions ranging from (1.84-38)% and forth span reductions at 56.2%.

Table 2. Percentage Decreasing Of Ultimate Load With Vertical Construction Joint.

Ref	**Percentage decreasing of ultimate load**			**comments**
	L/2	**L/3**	**L/4**	
[2]	2.5*	-	-	Finite element analysis
[3]	1.84*	-	-	-
[6]	+8.987*	-	-	$f\bar{c}$= 16.26
	3.3198*			$f\bar{c}$= 19.46
	4.5*			$f\bar{c}$= 23.7
	6.62*			$f\bar{c}$= 32.22
	14.54*			$f\bar{c}$= 35.36
	8.569*			$f\bar{c}$= 38.75
	14.39*			$f\bar{c}$= 41.47
[5]	55.62*	-	-	$f\bar{c}$= 31.42
	30.7*			$f\bar{c}$= 39.22
	48.45*			$f\bar{c}$= 34.03
	35.9*			$f\bar{c}$= 34.78
	60.117*			$f\bar{c}$= 28.57
	47.41*			$f\bar{c}$= 28.06
	37.99*			$f\bar{c}$= 29.22
[8]	0	12.5	-	Without stirrups
	-	0		With stirrups
[10]	38	-	56.2	Self compacting concrete
[13]	14.3	-	-	Self compacting concrete two way slab
[9]	15.8	-	-	One way slab

Table (3) reveals the optimal performance of an inclined construction joint at a 45-degree angle at mid-span(no shear forces), resulting in a decrease in ultimate load of (2.01-24.6)%. The study indicates that inclined construction joints outperform vertical joints due to greater overlap between old and new concrete surfaces and freedom of movement, tensile forces. while construction joint with an L-shape in the middle showed the best performance in Table (4), with a reduction percentage ranging from (0 - 12.3)%. The maximum load reduction percentage decreased from (60.117 -12.3)%, which is considered a positive change. This indicates that the vertical type construction joint is sharper in its performance than other types. Studies by [7, 14] highlight the significant importance of horizontal construction joints in ensuring the safety of concrete structures. Joints in the compression zone perform better due to concrete's higher compressive strength and reduced structural issues, determined by the structure's nature and applied loads. Studies show most samples fail in flexure, with a small percentage failing in shear. Studies[2, 3, 8] demonstrated that increasing the reinforcement ratio at the construction joint can mitigate shear failure, as it yields the same value as the reference sample, as studies [30] and [32] showed the presence of transverse reinforcement is important in the presence of the construction joint, as the shear resistance is greatly affected by the type and location of the joint, in addition to changing the shape of the crack depending on the shear reinforcement, as the presence The joint reduces cohesion and allows movement between the two faces of the concrete, thus reducing the shear resistance that depends on friction between the two faces

Waters' study[24] found that joint strength doesn't depend on concrete time intervals, while Vanlalruata and Marthong's study [12] found cracking worse with longer intervals, resulting in loss of flexural strength and ductility. In general, Shorter time intervals between old and new concrete bonding improve flexural strength. However, too short can cause weak joints. It's recommended to leave a 24-hour interval between hardening old concrete and pouring new concrete, depending on environmental conditions and concrete type.

Studies[6, 11, 12] show that increasing concrete's compressive strength reduces the flexural strength of beams with construction joints, as the construction joint weakens the concrete, allowing compressive deformations to spread more easily, increasing the likelihood of cracks.

There are many studies that work to improve the adhesion between the two layers of new and old concrete, it is possible to increase the initial sitting time of the concrete mixture by adding some additives such as glucose, as in Study [26] without affecting the properties of the concrete,

Table 3. Percentage Decreasing Of Ultimate Load With Inclined 45˚Construction Joint.

Ref	Percentage decreasing of ultimate load			comments
	L/2	L/3	L/4	
[12]	2.01	-	-	M 15
	2.99			M 20
	4.84			M 25
	6.44			M 30
[11]	0.2788*	0.159*	-	M 20
	10.77*	6.56*		M 40
	3.82*	4.67*		M 60
[2]	15*	-	-	Finite element analysis
[5]	14.11*	-	-	-
[8]	12.5*	25*	-	Without stirrups
	-	12.5*		With stirrups
[9]	24.6	-	-	One way slab

Table 4. Percentage Decreasing Of Ultimate Load With L-Shape (Key) Construction Joint.

Ref	Percentage decreasing of ultimate load			comments
	L/2	L/3	L/4	
[2]	2.38 *	-	-	-
[5]	1.84 *	-	-	-
[8]	0	12.5	-	Without stirrups
		0		Without stirrups
[14]	9.5	-	-	Self compacting concrete two way slab
[9]	12.3	-	-	One way slab

as well as using alkali-activated cement concrete with ordinary Portland cement concrete in Study [27], which gave better flexural and ductile performance at the joint, improved adhesion between the two layers of concrete, as it gave a longer initial sitting time and reduced shrinkage, which made the adhesion between the two layers better. On the contrary, adding superplasticizers reduces the performance at the construction joint due to reducing the initial sitting time, as in study [29].

Also, Adding steel fibers to concrete would improve the flexural and ductile performance of the beam at the construction joint, where the steel fibers act as a bridge to transfer stresses between the two parties, as shown in studies [29] and [31].

4. Conclusion

The presence of construction joints in concrete structures is a necessity. Therefore, studying the effect of these joints on the behavior of structural elements is of great importance. As it was shown in previous studies,

1. Preferred location of construction joint in mid span. due to The center having the largest ultimate load.
2. Vertical construction joint with 90˚ not recommended due to its effect on decreasing load capacity and flexibility.
3. The level of the horizontal construction joint is important as it affects the flexural strength of the beams so it prefer to be in compression zone.
4. The presence of a adhesion material can improve the performance of the construction joint.
5. Increasing the compressive strength of concrete significantly decreases the flexural strength of the construction joint. Due to it is an effect on adhesion between two surface.
6. The decrease in flexural strength can be improved by increasing the longitudinal and transversal reinforcement ratio at the joint.
7. It is possible to increase the initial sitting time of concrete to improve the cohesion between the two faces of concrete by adding some additives without affecting the strength and thus reducing the effect of the construction joint.

In addition to that mentioned above about construction joints and the possibility of improving their performance and reducing the negative impact, It has been noted that there are few studies on the performance of construction joints in Reinforced beams with FRP so that it necessary to study construction joints in reinforced beams with FRP due to the importance and widespread use of FRP in many facilities.

References

1. Critchell, P.L., *Joints and cracks in concrete.* (No Title), 1968.
https://cir.nii.ac.jp/crid/1130000798285601280

2. Abdul-Majeed, Q., *Evaluation of Transverse Construction Joints of Reinforced Concrete Beams.* Engineering and Technology Journal, 2010. 28(14): p. 4750-4773.
https://www.iasj.net/iasj/download/5628bc2059b4102a

3. Mehrath, H., *Flexural Behavior of Reinforced Concrete Beams having Transverse Construction Joints*, 2008, M. Sc. Thesis, University of Technology.
4. Gołdyn, M., *Shear capacity of the interface between concretes cast at different time in the light of experimental investigations and codes of practice.* Archives of Civil Engineering, 2022. 68(1).
DOI 10.24425/ace.2022.140168

5. Issa, C.A., N.N. Gerges, and S. Fawaz, *The effect of concrete vertical construction joints on the modulus of rupture.* Case Studies in Construction Materials, 2014. 1: p. 25-32.
https://doi.org/10.1016/j.cscm.2013.12.001

6. Issa, C.A., N.N. Gerges, and S. Fawaz, *The effect of construction joints on the flexural bending capacity of singly reinforced beams.* 2016.
http://dx.doi.org/10.1016/j.cscm.2016.09.004

7. Jabir, H.A. and T.S. Salman, *Effect of construction joints on the behavior of reinforced concrete beams.* Journal of Engineering, 2017. 23(5): p. 47-60.
DOI: https://doi.org/10.31026/j.eng.2017.05.04
8. Abass, Z.W., *Effect of construction joints on performance of reinforced concrete beams.* Al-Khwarizmi Engineering Journal, 2012. 8(1): p. 48-64.
https://www.iasj.net/iasj/download/5c1515fbe18777d4

9. Sultan, W.H., *Effect of type and position of construction joint on behavior and capacity of reinforced concrete one way slabs.* Journal of Engineering and Sustainable Development, 2019. 23(2): p. 22-41.
https://doi.org/10.31272/jeasd.23.2.3
10. Ismael, M.A., Y.M. Hameed, and H.J. Abd, *Effect of construction joint on structural performance of reinforced self-compacting concrete beams.* International Journal of Civil Engineering, 2019. 10(1).
https://iaeme.com/Home/issue/IJCIET?Volume=10&Issue=1
11. Mathew, A.A. and M. Nazeer, *Flexural behavior of Reinforced Concrete Beams with Construction Joints.*
12. Vanlalruata, J. and C. Marthong, *Effect of cold joint on the flexural strength of RC beam.* Journal of Structural Integrity and Maintenance, 2021. 6(1): p. 28-36.
https://doi.org/10.1080/24705314.2020.1823556

13. Ismael, M.A. and Y.M. Hameed. *Effect of Construction Joint on Flexural Behavior of Reinforced Self compacting Concrete Two Way Slabs*. in *IOP Conference Series: Materials Science and Engineering*. 2020. IOP Publishing.
DOI 10.1088/1757-899X/888/1/012040

14. Al-Rifaie, A., H. Al-Hassani, and A.A. Shubbar. *Flexural behaviour of reinforced concrete beams with horizontal construction joints*. in *IOP Conference Series: Materials Science and Engineering*. 2021. IOP Publishing.
DOI 10.1088/1757-899X/1090/1/012003

15. Yamada, K., A. Satoh, and S. Ishiyama, *Evaluation of adhesion characteristics of joint in concrete by tension softening properties.* Proceedings of “Fracture Mechanics of Concrete and Concrete Structure, 2007. 3: p. 1753-1759.
https://framcos.org/FraMCoS-6/45.pdf

16. Clark, L. and B. Gill, *Shear strength of smooth unreinforced construction joints.* Magazine of Concrete Research, 1985. 37(131): p. 95-100. https://doi.org/10.1680/macr.1985.37.131.95

17. Satoh, A., K. Yamada, and S. Ishiyama, *A discussion on major factors affecting crack path of concrete-to-concrete interfacial surfaces.* Engineering fracture mechanics, 2010. 77(11): p. 2168-2181. https://doi.org/10.1016/j.engfracmech.2010.03.005

18. Pedro, M. and N. Eduardo. *Assessment of the shear strength between concrete layers*. in *Proceedings of the 8th fib PhD Symposium in Kgs, Lyngby, Denmark*. 2010. https://www.researchgate.net/profile/Eduardo-Julio-3/publication/268817145_Assessment_of_the_Shear_Strength_between_Concrete_Layers/links/54789deb0cf293e2da2b28ca/Assessment-of-the-Shear-Strength-between-Concrete-Layers.pdf

19. Halvorsen, G.T., et al., *Joints in concrete construction.* American Concrete Institute, ACI, 1995. 224.

20. American Concrete Institute, C.S. and A.C.I.C. 311. *ACI manual of concrete inspection*. 2008. American Concrete Institute.

21. Fintel, M., *Handbook of concrete engineering.* (No Title), 1974.

22. Mattock, A.H., *Cyclic shear transfer and type of interface.* Journal of the structural division, 1981. 107(10): p. 1945-1964. https://doi.org/10.1061/JSDEAG.0005795

23. Kadhum, S.B. and S.R. Al-Zaidee, *A Review of Previous Studies on the Construction Joints in Reinforced Concrete Beams.* Design Engineering, 2021: p. 16464-16472. https://www.researchgate.net/publication/359710400

24. Waters, T., *A study of the tensile strength of concrete across construction joints.* Magazine of Concrete Research, 1954. 6(18): p. 151-153. https://doi.org/10.1680/macr.1954.6.18.151

25. Gerges, N.N., C.A. Issa, and S. Fawaz, *Effect of construction joints on the splitting tensile strength of concrete.* Case Studies in Construction Materials, 2015. 3: p. 83-91. https://doi.org/10.1016/j.cscm.2015.07.001

26. Al-Mamoori, F.H.N. and A.H.N. Al-Mamoori, *Reduce the influence of horizontal and vertical cold joints on the behavior of high strength concrete beam casting in hot weather by using sugar molasses.* Int J Eng Technol, 2018. 7(4.19): p. 794-800. https://www.academia.edu/download/74118068/8_Reduce_the_Influence_of_Horizontal_and_Vertical_Co.pdf

27. Laskar, S.M., H. Reja, and S. Talukdar, *Behaviour of cold jointed and layered Portland cement–alkali-activated reinforced concrete beams.* Asian Journal of Civil Engineering, 2020. 21: p. 1193-1204.
https://doi.org/10.1007/s42107-020-00269-528.

28. Bekem Kara, İ., *Experimental investigation of the effect of cold joint on strength and durability of concrete.* Arabian Journal for Science and Engineering, 2021. 46(11): p. 10397-10408.
DOI: 10.1007/s13369-021-05400-5

29. Zega, B.C., et al., *Effects of cold joint and its direction on the compressive and flexural strength of concrete.* GEOMATE Journal, 2021. 20(82): p. 86-92.
https://doi.org/10.21660/2021.82.J2086

30. IBRAHIM, M.S., et al., *EFFECT OF CONSTRUCTION JOINT ON THE SHEAR BEHAVIOR OF REINFORCED CONCRETE BEAMS.*

https://www.researchgate.net/publication/346446848

31. Mahdi, M.A. and A. Abd Sultan, *Effects of Steel Fiber and Compaction Process on the Flexural Strength of Reinforced Concrete Beams with Longitudinal Cold Joints.* Texas Journal of Engineering and Technology, 2023. 25: p. 81-91.
https://zienjournals.com/index.php/tjet/article/view/4575

32. AKIN, S.K. and G. Hediye, *An Experimental Study on the Behavior of Reinforced Concrete Beams Having Different Angled Cold Joints in the Shear Zone under.* International Journal of Engineering Research and Development, 2024. 16(1): p. 496-506.
DOI: 10.29137/umagd.1408221

33. Khalaf, J.A., Z.M. Ali, and A.S. Mahmoud. *Flexural behaviour of various construction joints for different ages reinforced concrete beams*. in *AIP Conference Proceedings*. 2024. AIP Publishing.
https://doi.org/10.1063/5.0190548