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Impact of Construction Joints on the Structural Performance of Reinforced Concrete Beams: A Comprehensive Review

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ABSTRACT

This review examined the effects of construction joints, particularly cold joints, on reinforced concrete beams' structural performance and integrity. Cold joints, which form when concrete is poured in stages rather than continuously, are often seen as weaknesses that can compromise the strength and durability of concrete structures. The review explored how cold joints impacted key properties like flexural strength, ductility, and energy dissipation capacity, drawing on numerous experimental studies. It was found that cold joints generally reduced the flexural strength of beams, with the extent of the reduction varying depending on the joint's location, orientation, and the time between pours. Additionally, factors like the type of reinforcement and joint angle played a significant role in mitigating the adverse effects of cold joints. The paper also discussed the importance of proper surface preparation and specific reinforcement techniques to enhance the performance of construction joints. The review of early and recent studies highlighted how cold joints affected tensile strength, shear, and bending capacities in reinforced concrete beams.

1. Introduction

Construction joints, commonly known as cold joints, frequently arise in reinforced concrete beams when concrete is poured in phases rather than continuously. These joints can profoundly affect the structural integrity and performance of concrete beams. Cold joints are often regarded as structural weaknesses due to the likelihood of inadequate bonding between various concrete layers, resulting in diminished strength and longevity. Cold joints can influence multiple mechanical properties of reinforced concrete beams. Research indicates that cold joints might diminish flexural strength and ductility. The flexural strength of beams with cold joints is frequently reduced, as the joint may serve as a locus of vulnerability where cracks can develop under stress [27, 24, 8]. The energy dissipation capacity and initial stiffness of beams with cold joints are frequently diminished compared to those without joints, potentially impairing the beam's capacity to endure dynamic loads, such as those encountered during seismic events [27, 28]. Numerous elements affect the efficacy of cold joints, including the duration between consecutive concrete placements, the orientation of the joint, and the ambient conditions throughout the curing process. The flexural capacity of beams diminishes with extended intervals between pours, mainly when the junction is situated in the

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beam's compression zone [24]. The angle of inclination of the cold joint significantly influences load capacity, with specific angles resulting in more substantial reductions [29].

1.1 Types of Joints in Concrete

Concrete joints can be broadly categorized based on their function and construction method:

1.1.1. Construction joints:

Construction joints are implemented at points where concrete installation is halted, facilitating the resumption of work at a subsequent period. Construction joints are prevalent in extensive concrete pours and precast-cast-in-place projects, linking concretes of varying ages, kinds, or strengths. The efficacy of these joints is contingent upon surface preparation and reinforcement, with transverse reinforcement demonstrated to augment their bearing capacity under shear stresses [14, 30].

1.1.2. Expansion and Contraction Joints:

Expansion and Contraction joints facilitate the accommodation of concrete's expansion and contraction resulting from temperature fluctuations and shrinkage, thereby averting uncontrolled cracking. In pavement and bridge applications, longitudinal and transverse joints are frequently sealed to prevent water infiltration, which could otherwise result in early structural failure [31, 32].

1.1.3. Control Joints:

Control Joints are deliberately formed grooves or separations in concrete designed to regulate the positioning of cracks caused by shrinkage during the curing process.

1.1.4. Bonded Joints:

Bonded Joints are used in repair and reinforcement applications. Joints are established between new and existing concrete or between concrete and other materials, such as fiber-reinforced polymers (FRP). The efficacy of these bonded joints is crucial for the success of repairs and retrofits, as the interface qualities affect load transfer and failure mechanisms [33, 34].

1.1.5. Specialised Joints:

Specialised Joints are used in precast concrete construction, and advanced joint configurations, including headed bars, supplementary reinforcement layers, or the relocation of plastic hinges, are engineered to augment collapse resistance and boost overall joint efficacy [35].

1.2 Uses and Importance of Concrete Joints

Structural Performance: Adequately built joints guarantee the load-bearing capacity and longevity of concrete structures, particularly at connections including beam-column joints, slab-beam joints, and column joints [34, 35, 36].

Durability and Maintenance: Sealed joints in pavements and bridges inhibit the infiltration of water and harmful substances, thereby mitigating corrosion risk and prolonging service life [31, 32].

Repair and Retrofitting: Joints are essential in repair situations, where new materials are affixed to existing concrete. The selection of joint type and repair material can profoundly influence the strength and durability of the repaired structure [33, 34].

Facilitating Movement: Expansion, contraction, and control joints permit movement resulting from temperature fluctuations, shrinkage, and other variables, reducing the likelihood of uncontrolled cracking and structural damage [31, 32].

2. Previous research

This chapter reviews previous research on construction joints (cold joints) and their effect on structural members.

Waters (1954) [10] studied the tensile strength of concrete across construction joints. Several batches of concrete were cast for each one. Three specimens (briquettes) were used as control specimens, cured in 62°f water, and tested at 28 days old. The average of the results was 503 lb/sq.in. Nine half-briquettes were also cast and cured for 7 days, then the second half was poured and allowed to cure for 28 days before being tested. Three briquettes were cast for each treatment method, and the average stress was calculated. Several surface treatments were used and the ratio of stress at the specimen with a joint to stress of the original concrete specimen, this ratio proves that for any method used a dry surface for the first half gives better results and that is due to the dry half absorbing the water from the newly placed fresh concrete which decreases the water/cement ratio also the finer granules of the cement in the new concrete were absorbed into the dry half. Wire brushing and wet sandblasting are better options than scabbling as they do not produce cracks on the concrete. Results also show that the time interval between casting the first half and the second half has little to no effect on the strength of the specimen.

Mehrath and Al Hassani (2008) [19] investigated the effect of transverse construction joints on reinforced concrete beams. A total of twenty-three reinforced concrete beams were cast with the exact dimensions (150x250x2000) mm, three beams were cast with no joints (reference beams) will the other twenty had one transverse construction joint (90° vertical, 45° inclined, 60° inclined, joggle, or L shaped) each either in the mid-span or one-third of the span as well as containing additional stirrups or not. Two-point loading was applied until failure. The results concluded that having a transverse construction joint creates a weak zone in the beam and allows cracks to develop easily, reducing the ultimate load and crack load for the samples with no additional stirrups. Moreover, having a single additional stirrup through the joint improved the beam's ultimate and crack load considerably. The best location for the vertical construction joint is at the location of minimum shear and maximum bending moment.

Aziz and Ajeel (2010) [5] studied the effect of existing flange openings and cold joints on the shear behaviour of reinforced concrete T-beams. Eight T-beams were cast with similar dimensions, concrete properties, and longitudinal reinforcement, while no transverse reinforcement was used to ensure shear failure. The first reinforced concrete T-beam was cast monolithically (reference beam), the second and fifth had a single flange opening. In contrast, the third, fourth, and sixth had two flange openings, the seventh had a single cold joint at one-third of the span, while the eighth had two opposite cold joints at one-third of the span. One-point loading was used to cause maximum shear throughout the reinforced concrete T-beam. The experimental results found that the shear strength for reinforced concrete T-beams decreased by about 22% to 32% for one flange opening, 17% to 39% for two flange openings, and 27% for one or two cold joints.

Abdul-Majeed (2010) [11] analysed reinforced concrete beams with a transverse construction joint; ANSYS computer software (v. 9) was used to analyse available experimental results. Seven reinforced concrete beams with identical dimensions were studied, one reference beam and six beams with various transverse construction joints at mid-span. The reinforcement ratio for the beams was similar, except for one beam having an extra stirrup at the joint. The reinforced concrete beams were subjected to a two-point load. The results show that the modelling of the beams resulted in an ultimate failure load difference of 5.77-6.83%. Joggle-shaped joints showed better behaviour prediction. This can be the cause of a better connection between the old and new concrete, while the joint with 45 angle had the lowest capacity due to the joint failure. Adding one additional stirrup in the joggle joint beams increased the capacity by 2.4%.

Ghaddar et al. (2010) [12] examined the effect on reinforced concrete beams with several horizontal construction joints. Four reinforced concrete beams with the exact dimensions were analysed using ANSYS computer software (v.11), one reference beam without any joint, and the other three beams having one, two, and three horizontal construction joints. The reinforcement of the beams was identical. The model used two-point loading on the beams. The results showed that the maximum difference in ultimate load for all beams was 8.2-10.4 %. The modelling results also show that having one, two, or three horizontal construction joints decreased the cracking load by 97%, 85%, and 80%, while the ultimate load was 96%, 89%, and 84% compared with the reference beam.

Abass (2012) [6] studied the effect of construction joints on the performance of reinforced concrete beams. Nineteen reinforced concrete beams with dimensions (200x200x950) mm, similar concrete properties, and longitudinal reinforcement were fabricated. One reinforced concrete beam was cast monolithically (reference beam). At the same time, the other eighteen were tested with several variables, which are the location of the construction joints (at mid-span or one-third of the span of the reinforced concrete beam), type of construction joints (vertical, inclined, and key construction joints), and presence of stirrups at these joints. Two-point loading was applied until failure occurred. The deflection of the reinforced concrete beam was measured at each load step under the centre span or the construction joint location. The results indicated that the best possible location of construction joints is at the point of minimum shear. The range of ultimate load reduction for vertical construction joints was 0% to 5%, whereas inclined construction joints were 8% to 20%. The addition of stirrups at the joints is an important variable that influences the type of failure and load carrying capacity, which is supported by experimental data that show an increase in capacity in the range of 7% to 15% while also showing a decrease in deflection by 20% to 48%.

Issa et al. (2014) [13] conducted a research study on the effect of concrete vertical construction joints on the modulus of rupture. Forty-two plane beams in total where cast, six plane beams were cast for each concrete mix, of which there were seven different mix designs ranging in compressive strength (31.42, 39.22, 34.03, 34.78, 28.57, 28.06, 29.22) MPa, three specimens where poured monolithically will three where poured in two stages. Two-point loading was applied until flexural failure occurred. The results show that the ACI code underestimates the modulus of rupture always, and having a construction joint in the middle of the plane beam negatively impacts the modulus of rupture of concrete by (24-83) % ،dowels are recommended for the continuity of strength across construction joints in plane beams.

Gerges et al. (2015) [14] studied the effect of construction joints on the splitting tensile strength of concrete. Sixty-three cylinders in total where cast of which there were seven different types of concrete mix designs (36.62, 39.26, 34.15, 30.91, 30.22, 28.22, 25.88) MPa for each mix design nine cylinders were cast, six cylinders poured monolithically three of which were tested for compressive strength will the other three were tested for splitting tensile strength the remaining three specimens were cast with a construction joint vertically placed at the center. The experiment was conducted according to ASTM standards. The results indicate a reduction in splitting tensile strength by approximately 55% if a construction joint is present.

Gerges et al. (2016) [7] studied the effect of construction joints on the flexural bending capacity of singly reinforced concrete beams for various compressive strengths. Seven mix designs (18, 21, 24, 27, 30, 33 and 35) MPa were used, for each mix six RC beams similar in dimensions and reinforcement ratio were cast in which three reinforced concrete beams had a vertical construction joint at mid-span while the other three had non (reference beams). Forty-two RC beams were tested under two-point load until failure to observe the effect on flexural strength. Test results proved that as the concrete compressive stress increases, the bending capacity decreases.

Jabir et al. (2017) [2] studied the effect of construction joints on the behaviour of reinforced concrete beams. Seven reinforced concrete beams were cast with dimensions of (100x200x1000) mm, similar concrete properties, and reinforcement ratio. One reference beam was cast monolithically, while two beams were fabricated with one horizontal construction joint positioned in the tension zone or the compression zone; also, the fourth beam was cast with two horizontal construction joints positioned at the tension and compression zones. In contrast, the remaining beams were fabricated with one or two inclined joints placed at the beam’s mid-span or shear span. The beam was subjected to a concentrated central load until failure. The results indicated that in the presence of a horizontal construction joint, the range of reduction in ultimate load was 0% to 7.5%. In comparison, the increase in central deflection at service load ranged from 4.8% to 16.7% compared to the inclined joint, which had a decrease in ultimate load ranging from 1.25% to 2.5% and an increase in central deflection at service load by 22.2% to 43.7%.

Al-Mamoori and Al-Mamoori (2018) [18] studied the effect of sugar molasses on high-strength concrete plane beams with cold joints. Twenty-four plane concrete beams with similar dimensions (110x110x650) mm were cast. Three variables were used in the research study first the sugar molasses content in the concrete mix varied (0, 0.05, 0.1, 0.2, 0.3) % by weight of cement, the second horizontal and vertical joints were placed in various depth and lengths on the beam and the third two type of surfaces textures were used smooth and rough. Two-point loading was applied until failure. The results indicate that a 0.2% sugar molasses increase the compressive strength by 11.2% at 28 days as well as delay initial setting time by 277 minutes without having any adverse effect on the concrete, vertical cold joints is recommended to be placed in the middle third will the placement of horizontal cold joints was best in the tension zone, the texture of the joint had more of an influence on plane concrete beams without sugar molasses.

Ismael et al. (2019) [4] investigated the effect of the construction joint on the structural performance of reinforced self-compacting concrete slender beams. Four specimens of dimensions (125x150x1000) mm were fabricated with similar concrete properties, longitudinal reinforcement, and transverse reinforcement. The first beam was fabricated with no construction joint, the second beam had a single horizontal construction joint at mid-height of the beam, the third and fourth beams contained one vertical construction joint at mid-span (maximum bending moment point) and fourth-span (maximum shear region). Two-point loading was applied until failure. The following experimental findings showed that the decrease in ultimate load and deflection for the second beam was 6.7%, 9.5 %, while for the third beam, 33.4%, 14.3%, for the fourth beam, 16.7%, 41.7%.

Abbas and Sultan (2019) [15] conducted a research study on the effect of the type and position of construction joints on the behavior and capacity of reinforced concrete one-way slabs. Eight specimens were poured and tested; each slab had similar dimensions of (1000x450x70) mm. The first slab was cast monolithically, the second had a construction joint with a 90° degree angle in the middle (in vertical manner), the third had a construction joint with a 45° degree angle in the middle (in vertical manner), the fourth slab had a 45° construction joint along the face of the slab (in plane manner), the fifth had a key joint (in vertical manner), the sixth also had a key joint (in plane manner), the seventh had a key joint (in plane manner) starting at the shear zone from one end and continuing to the flexural zone and the shear zone at the other end and the last slab had one vertical joint (in plane manner) in the shear zone at each side. One concrete mix design was used with a compressive strength of 32.5 MPa. Two-point loading was applied until failure occurred. The results show that the vertical inclined joint had the highest effect on ultimate capacity, reaching a reduction of 24.6%, while the key joint had the lowest reduction of 1.8%. The slab that was inclined in plane had the lowest load deflection compared to the reference slab, while also having few and narrow final cracks. Side joint showed a sudden failure in shear, while the remaining slabs had stiff behaviour in the early stages of loading but became softer.

Vanlalruata and Marthong (2020) [8] investigated the effect of the construction joint on the flexural strength of reinforced concrete beams. Forty reinforced concrete beams were fabricated with dimensions (150x150x700) mm, similar longitudinal and transverse reinforcement, while varying in compressive strength (15, 20, 25and 30) MPa. Eight reinforced concrete beams were monolithically cast (reference beams). In contrast, the rest of the reinforced concrete beams had a single construction joint at mid-span at a forty-five-degree angle in which the time interval between the first and the second pour was varying (1, 2, 21, and 28) days. The experiment used a two-point load to observe the effect on the flexural strength. The results showed decreased flexural strength of reinforced concrete beams for different mix designs and joint ages, ranging from 2% to 20%. In comparison, the range of loses in energy dissipation capacity for a single day construction joint was 2% to 7% and 20% to 25% for a 28-day construction joint. In contrast, the ductility ranged from 8% to 12% for a single-day construction joint and 16% to 26% for a 28-day construction joint.

Mathew and Nazeer (2020) [16] researched the flexural behavior of reinforced concrete beams with construction joints. Three concrete mix designs were used (M20, M40, and M60), and three beams with similar dimensions (150x200x1650) mm were cast for each mix. The first for each mix was monolithically cast, the second at one-third of the length, and the third had a joint at the center. The reinforcement ratio of all the specimens was the same. Two-point loading was applied until failure occurred. The results conclude that the beam's ultimate load carrying capacity with construction joints in one-third span was moderately higher for M20 and M40 than for specimens with joints in the middle span.

Ismael and Hameed (2020) [17] conducted an experimental study on self-compacting two-way slabs with construction joints. Four slabs with similar dimensions (450x450x60) mm ، reinforcement, and concrete mix design were cast. The first slab had no construction joints (reference specimen), the second had a 90°-degree vertical construction joint in the middle span, the third had a horizontal construction joint in the middle depth, and the fourth had a key-shaped construction joint. The results concluded that the effect of the construction joint on the crack load is more apparent than on the ultimate load. The key-shaped construction joint presented the best results for first crack load (15% reduction compared to the reference), ultimate load (9.5% compared to the reference), and load-deflection curve. Construction joints reduce the stiffness after the first crack compared to the reference slab.

Laskar et al. (2020) [20] studied the bending behaviour of cold-jointed and layered Portland cement–alkali-activated reinforced concrete beams. Four beams were cast, experimented on, and analyzed using finite element software. The first beam was the reference, the second beam had a single horizontal construction joint made up of two layers the first layer consisted of Alkali Activated Concrete (AAC) while the second layer consisted of Portland Cement Concrete (PCC), the third beam had a vertical construction joint with both half’s consisting of PCC and the fourth beam also had a vertical construction joint with the first half consisting of PCC while the other half is of AAC. The experimental results showed that the adhesion between the layers increases with Alkali Activated Concrete (AAC) while also improving the strength and ductility in bending. Using finite element modeling is appropriate to predict the behavior of the beams.

Sirage et al. (2020) [23] studied the construction joint location and inclination on the shear behavior of reinforced concrete beams. Five slender beams with the exact dimensions (200x200x1400) mm and reinforcement ratio were cast and tested until shear failure. The first and second beams had a 35 and 45-degree angle construction joint, the third and fourth had a 90-degree vertical construction joint (one near the middle span and the other in the shear span), while the fifth beam was monolithically cast and used as the reference beam. The experimental results conclude that a 9.97% reduction in shear capacity was observed for the beam with a vertical construction joint near the middle span. The one in the shear zone showed a 10% increase in shear capacity. In comparison, for the beam with a 35 degree inclined construction joint showed an increase in shear capacity by 31.8% (the beam behaved like a deep beam and failed in the compression strut this change is believed to be the cause of the increase in shear capacity) and the shear capacity for the beam with a 45 degree inclined construction joint showed similar results to the reference beam.

Kara (2021) [21] conducted an experimental investigation of the effect of cold joints on the strength and durability of Concrete. The experimental investigation was split into two parts: strength properties were investigated first, and several durability properties were investigated in the second part. The first part investigated the compressive, flexural, splitting tensile, and steel rebar pullout tests for these molds were filled up to half of the mold to create a cold joint, and the rest of the mold was filled after a set duration of time (0, 60, 120, 180) minutes. The second part investigated the effect of drying-wetting, freezing-thawing, and high temperatures (300, 600, and 900 °C) on the concrete specimens poured with two different types of concrete with and without cold joints, as well as testing for weight loss and splitting tensile strength. The experimental results showed a decrease in the compressive, splitting tensile, flexural and pullout strength when increasing the time between the first and second pour, drying-wetting and freezing-thawing strength losses was significantly higher with a cold joint than without a cold joint while subjecting the specimens for either types of concrete to high temperatures showed similar losses in strength.

Zega (2021) [22] conducted an experimental study on the effects of cold joints and their direction on concrete's compressive and flexural strength. Three types of concrete were used (normal strength, high early strength, and concrete containing polypropylene fiber as an added material). The compressive and flexural strength were tested on specimens with horizontal and vertical cold joints, where the period between the first and second concrete pour was poured is (120 and 240 minutes, and the tests were conducted at time intervals (3, 7, 14, and 28 days. The test results concluded that the longer the interval between the first and second concrete casts, the lower the compressive and flexural strength. In contrast, specimens cast using concrete with polypropylene fibers showed increased compressive and flexural strength compared to standard concrete cast without a cold joint.

Al-Rifaie et al. (2021) [1] examined the flexural behaviour of reinforced concrete beams with horizontal construction joints. Ten simply supported reinforced concrete beams were cast with a similar rectangular cross section, concrete properties, and reinforcement (longitudinal and transverse reinforcement). Two beams were cast monolithically, serving as the reference beams, while the other eight were cast at various stages and had one or more horizontal construction joints at different positions. The reinforced concrete beams were designed to fail at flexure and tested under two-point loading to ensure flexural failure. The test results indicated that horizontal construction joints on reinforced concrete beams decreased the ultimate load by 83% to 98%, and increased the ultimate deflection by 102% to 133% compared to the reference beam.

Mahdi and Sultan (2023) [25] conducted an experimental study on reinforced concrete beams with horizontal construction joints and the effect of steel fiber, compaction of concrete, and the time interval (1.5, 3, 4.5) hours between the first and second layer of concrete. Three groups of beams were cast the first had four beams; one reference beam while the other three had a horizontal construction joint with a compacted first layer, the second group had three beams with horizontal construction joints with the first layer not compacted, the third group had three beams with a horizontal construction joint with the least load from the first two groups reinforced by steel fiber. Two-point loading was applied to ensure flexural failure. The results of the experimental study concluded that the joint did not affect the cracking load. In contrast, the ultimate load was influenced significantly, and adding steel fiber reinforcement in the joint improved the results considerably.

Kadhum et al. (2024) [3] investigated the effect of horizontal construction joints on the behaviour of reinforced concrete deep beams. Four simply supported reinforced concrete deep beams were cast with similar cross-sections (150x400x1500) mm, concrete properties, and reinforcement ratio. One reinforced concrete deep beam was cast monolithically (reference beam). In contrast, the other beams were cast with one horizontal construction joint positioned below, at or above the mid-height of the beam. The beam was tested under two-point loading until failure occurred. The results concluded that the existence of horizontal construction joint below, at, or above the beam mid-height decreased the ultimate load by 9, 11, and 1%. In contrast, the change in the beam's maximum measured deflection below, at, or above mid-height was 14, 15, and -15%.

AKIN and GÜZ (2024) [9] conducted an experimental study to observe the behaviour of reinforced concrete beams having different angled construction joints in the shear zone. Seven reinforced concrete beams were cast with similar dimensions (150x300x3000) mm, concrete properties, and reinforcement ratio. The first reinforced concrete beam had no construction joints (reference beam), While the other six had a construction joint at different angles (0, 45, 90) degrees in the shear zone in which two reinforced concrete beams were fabricated for each angle, with and without additional reinforcement at the construction joint interface. Two-point loading was applied until failure occurred, and the behaviour of reinforced concrete beams was observed. The experimental findings have shown that construction joints and changes in their angular orientation affect the mechanical performance of reinforced concrete beams. Additionally, increasing the construction joint plane by adding steel reinforcement is a factor that may influence the initiation and propagation of cracks within the construction joint.

Mahdi and Sultan (2024) [24] conducted an experimental study on reinforced concrete beams with a cold joint in different positions, and whether the compaction of concrete affected the flexural capacity of the beam. Five beams were cast with the exact dimensions (100x160x1200) mm and reinforcement ratio. The first beam was cast monolithically (reference beam), the second and third had a horizontal construction joint at (0.3h in the tension fiber and 0.7h in the compression fiber) will the concrete was compacted, the fourth and fifth had the same joint type and position but the concrete was not compacted. Two-point loading was applied to ensure flexural failure. The results concluded that the parameters in this experiment did not affect the cracking load. At the same time, the compaction of concrete affected the results significantly as the beams with the compacted layers of concrete had a flexural capacity decrease of 13.78% to 15.5%. In comparison, the non-compacted beams reduced from 31.35% to 40.91%.

Khalaf et al. (2024) [26] studied the flexural behavior of several construction joints at different concrete ages. Four beams were cast with the exact dimensions. The first was cast monolithically (reference beam), the second, third, and fourth beams had (45 °, 60 °, and L) shaped construction joints. The resulting outcome shows that a construction joint with a 45° angle has the least effect compared to the reference beam.

3. Conclusions

The review has provided a detailed exploration of the effects of construction joints, particularly cold joints, on the structural behavior of reinforced concrete beams. Through the analysis of various studies, several important conclusions were drawn:

1. Reduction in Flexural Strength: Cold joints consistently led to a decrease in the flexural strength of concrete beams. The extent of the reduction was influenced by the orientation and location of the joint, with some joint angles leading to more significant strength loss.
2. Impact of Joint Location and Time Intervals: The time interval between successive concrete pours and the location of the cold joint within the beam were critical factors affecting performance. Cold joints placed in high-stress areas, such as the beam's compression zone, caused more pronounced reductions in load-bearing capacity.
3. Role of Reinforcement: Additional reinforcement, such as stirrups, helped improve beams' load-carrying capacity and crack resistance with cold joints. Proper reinforcement mitigated the adverse effects and strengthened the connection between the old and new concrete layers.
4. Ductility and Energy Dissipation: Beams with cold joints exhibited lower ductility and energy dissipation capacity than those without joints. This finding is particularly important in seismic design, where dynamic load resistance is critical.
5. Surface Preparation: How construction joints were prepared, including cleaning and surface treatments, significantly impacted the bond strength between layers. Surface preparation techniques, such as wire brushing and wet sandblasting, enhanced the bond, improving overall performance.

In conclusion, while cold joints remain a challenge in concrete construction, the findings highlight strategies to minimize their negative impact and improve the overall performance of reinforced concrete beams.

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