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Flexural behavior of Reinforced Concrete Beams with Construction Joints

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Abstract - *The main objective of the work was to study the effect of construction joints (CJs) on flexural behavior of Reinforced Cement Concrete (RCC) beams. Variables investigated in flexural study were both position and grade of concrete. Concrete of grades M20, M40 and M60 were designed and prepared for casting beams. Three reinforced cement concrete (RCC) beams were cast from each mix with joint at different locations. The study concludes that load carrying capacity of beams with joint in middle one third span was slightly higher for M20 and M40 grades compared to beam with joint extending to outer one third span.*

Key Words: **Construction joints, Concrete grades, Flexural behaviour, Load carrying capacity, Reinforced cement concrete**

1. INTRODUCTION

Joints in buildings can be broadly classified into three- contraction joint, isolation or expansion joint and Construction Joint (CJ). Out of these, expansion joints and contraction joints are stress relieving ones while the construction joint is not. For many structures, it is impractical to place concrete in a continuous operation. The amount of concrete that can be placed at one time is governed by batching and mixing capacity, crew size, and the amount of time available. Construction joints are placed at points of ending and beginning of construction for provision of a smooth transition between pours. These joints are formed between successive building element parts during construction work, in which one part is allowed to harden before the next is placed. A construction joint may be defined as 'Joint installed at location where construction stops for any reason and when the location of stoppage does not coincide with the planned location of an expansion joint or contraction joint' [1]. Construction joint introduces vertical or horizontal slip plane which may reduce strength of beams, columns, walls, shear walls etc.

2. LITERATURE REVIEW

In an investigation on the effect of location of construction joints on the performance of reinforced concrete (RC) structural elements, it was concluded that the best location of the construction joint is at the point of minimum shear [2]. It was also concluded that the use of inclined construction joints results in a noticeable reduction in strength of beams relative to the strength of beam without construction joint, reduction in ultimate load capacity is in the range of 8% - 20%. Based on the test results of unreinforced concrete construction joints subjected to in-plane shear forces, it was observed that for members with a properly prepared and moist-cured joint offer the same initial stiffness as that of a member cast monolithically [3]. It is also reported that presence of construction joint reduces the splitting tensile strength of a monolithic specimen by approximately 55% [4]. The literature [5] concluded that presence of a vertical construction joint at mid span reduces the overall flexural strength by approximately 55% when compared to a monolithic section. An analysis of the effect of presence of horizontal construction joints (HCJs) on the behavior of RC beams using nonlinear three-dimensional finite element software – ANSYS [6] was revealed that the presence of one, two and three HCJ in RC beams under flexure gave a decrease in the value of the cracking load such that cracking load (P_{cr}) was 97%, 85% and 80% of beam without any joint (reference beam). The respective ultimate load capacity (P_u) was 96%, 89% and 84% compared to reference beam.

3. RESEARCH SIGNIFICANCE

Based on the literature reviewed in the previous session, it can be concluded that presence of construction joint reduces the split tensile strength, modulus of rupture, cracking load and ultimate load carrying capacity of reinforced beams. It also increases the ultimate deflection of beams. No study on RCC beams having natural slope as inclination for CJ was found. Study on high strength concrete cylinders, PCC beams and RCC beams were limited.

4. EXPERIMENTAL PROGRAMME

4.1 Materials and Mix

Ordinary Portland cement (OPC) (53 Grade) confirming to IS: 12269-1987 [7] having specific gravity of 3.14 and fineness of 6% was used for the experimental work. Manufactured sand having fineness modulus 2.654 and specific gravity 2.59 was used as fine aggregate. Coarse aggregate with maximum size 20 mm and specific gravity 2.77 was used. Super plasticizer used was Ceraplast-300. 8 mm and 10 mm diameter bars were used for casting RCC beams having tensile strength of 614 N/mm^2 and 579 N/mm^2 respectively. Three grades of concrete were designed: M20, M40 and M60. Mix design was done as per IS: 10262-2009 [8] for M20 and M40. ACI 211 method for design of high strength concrete was modified by Aitcin [9]. This modified method was used for designing M60 concrete. Mix details are shown in Table 1. For M20 grade concrete, superplasticizer was not added. For M40 and M60 grade concrete, superplasticizer added was 0.6 % and 1 % by mass of cementitious material.

Table -1: Mix details

Mix	Cement content (kg/m³)	Water cement ratio	Fine aggregate (kg/m³)	Coarse aggregate (kg/m³)
M20	300.00	0.520	746.64	1260.63
M40	312.00	0.448	786.32	1256.90
M60	391.89	0.370	860.59	1049.24

3.2 Test specimens

Cubes of size 100 × 100 × 100 mm were prepared for testing compressive strength. For casting RCC beams, moulds of length 1650 mm and cross section 150 × 200 mm were prepared using timber.

3.3 Design of RCC Beams

The beams were designed as doubly reinforced sections as per IS: 456-2000 [12] stipulations. All the beams have the same dimensions of overall length 1.65 m with effective span of 1.5 m, width 150 mm and depth 200 mm with effective depth of 170 mm. The effective cover provided was 30 mm. Two numbers of 10 mm diameter HYSD bars of 415 grade were provided as tension reinforcement and two numbers of 8 mm diameter HYSD bars of 415 grade were designed as stirrup holders. Two legged 8 mm diameter stirrups at a spacing of 120 mm c/c were provided as shear reinforcement.

3.4 Specimen Preparation

Mixing was done in a laboratory type pan mixer. While preparation of concrete, aggregates and cement were mixed in the revolving pan. After proper mixing, mixture of water and superplasticizer was added. The mixing was continued until a uniform mix was obtained. Concrete beams were cast with dimension 150 × 200 × 1650 mm. Three beams from each mix were cast: first one is monolithic without any joint (denoted as B1), second one with joint at one third position (denoted as B2) and third one with joint at the centre (denoted as B3). Same amount of reinforcement was provided for all the three beams. Reinforcement cage was placed inside the mould by ensuring correct cover using standard cover blocks. For monolithic beam, concreting was done for the full length on the first day itself. In case of B2 beams, first day concreting was done up to one third (of the span) position, that is 575 mm from one end to the full depth and a natural slope of concrete was made to a certain distance after one third point. On second day, cement slurry was applied to the joint prior to casting. Concreting was done for the rest of the length on the second day. In case of B3 beams, first day concreting was done up to the mid span (i.e. 825 mm from one end) and similar procedure was adopted as that of B2 beam on second day of concreting. The curing was started 24 hours after casting by covering all the beams with wet gunny bags. It was ensured that, during the entire period of curing the beams were kept in moist condition. This curing was continued up to 28 days and the testing of beams was carried out on 28th day of casting. Cement slurry application to the joint surface on second day before concreting is illustrated in Fig. 1.

Fig -1: Cement slurry application for joint preparation in RCC beam

4. TEST RESULTS

4.1 Workability

Compacting factor value was obtained for all mixes to determine the workability as per IS: 1199-1959 [13]. The values of compacting factor are given in Table 2.

Table 1-: Compacting factor values

Mix	Compacting factor	Specification (SP:23-1982)
M20	0.824	Stiff
M40	0.819	Stiff
M60	0.890	Stiff plastic

Though it was aimed to prepare all mixes of same workability, the results indicate that the workability of M60 mix was slightly higher. This is probably due to the increased fluidity of the mix owing to the lower ratio of coarse/fine fraction in the mix.

4.2 Compressive Strength

Compressive strengths of the cubes were tested at 3, 7 and 28 days of casting as per IS: 516-1959 [10]. Average of three specimens was reported for 3 and 7 day compressive strength. For 28 day compressive strength, cubes from each batch were cast and tested. That is, a total of 12 specimens were tested from each mix to determine 28th day compressive strength. Hence those results whose variation from average exceeds ±15% were discarded and average of remaining were calculated and reported. Compressive strength variation for different mixes is shown in Chart 1.

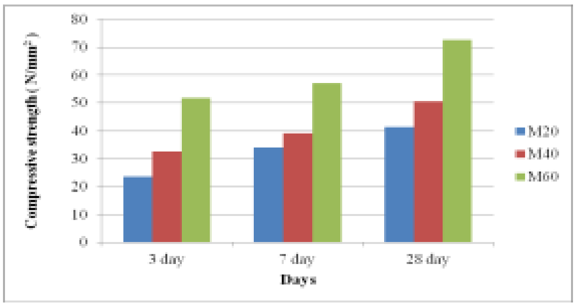

Chart 1-: Compressive strength variation for different mixes

4.3 Flexural behavior of RCC beams

Variables investigated were position of joint and grade of concrete. Same reinforcement and cover was given to all beams.

4.3.1 Experimental Setup and Testing Procedure

Beam specimens were tested as simply supported at two ends, with one end as fixed roller support and other end as a free roller support. One layer of white wash was applied on the surface of the beam in order to make the cracks more visible. The positions of the supports, load points and the midpoint were marked on the beam. Then the beam was placed carefully over the supports in the loading frame along the marking by giving 150 mm beyond the support and a clear distance of 1500 mm between the supports. Level of the beam was checked by a spirit level. Load was applied to the beam using a hydraulic jack of 200 kN capacity. Two point loading was adopted for this study and this was applied at a distance 500 mm from the supports at both ends. Three dial gauges of 0.01 mm accuracy were placed in both load points and midpoint of the bottom portion of the beam to measure the deflection at each load increment. A seating load was given to the beam and the readings of dial gauges were taken corresponding to the zero load. Load was incremented, dial gauge readings were taken and crack width was measured at each increment. The loading was continued up to failure of the beam and the load at failure was noted.

4.3.2 Load Deflection Characteristics

Deflection corresponding to each load increment at mid span and both the load points were noted and the load deflection graphs were plotted. Figs 2 to 16 shows the load deflection graphs for various beams.

M2B1 beam (M20 grade monolithic beam)

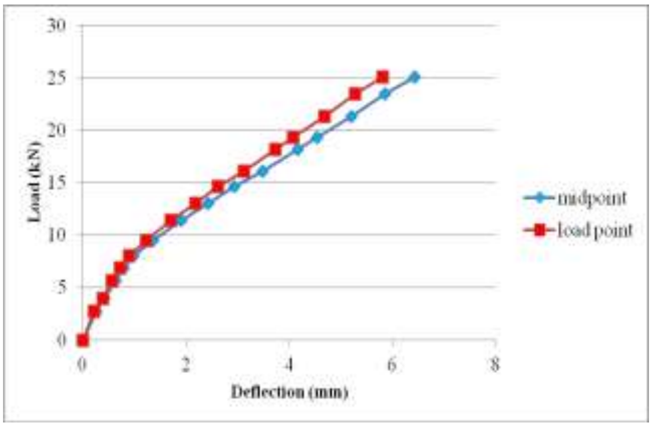

Fig-2: Load vs. deflection graph for M2B1 beam

M2B2 beam (M20 grade beam with joint starting from one third point)

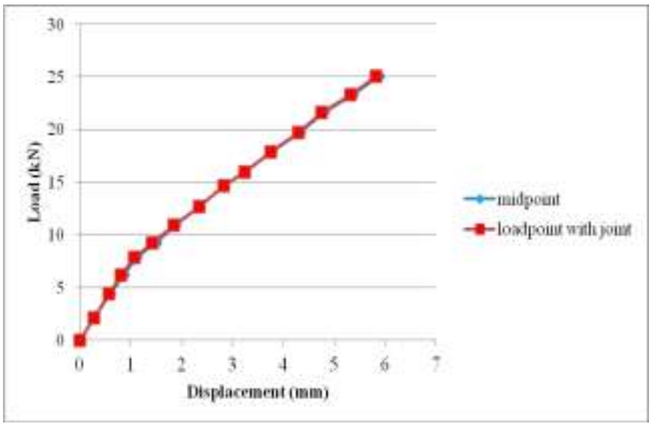

Fig-3: Load vs. deflection graph for M2B2 beam

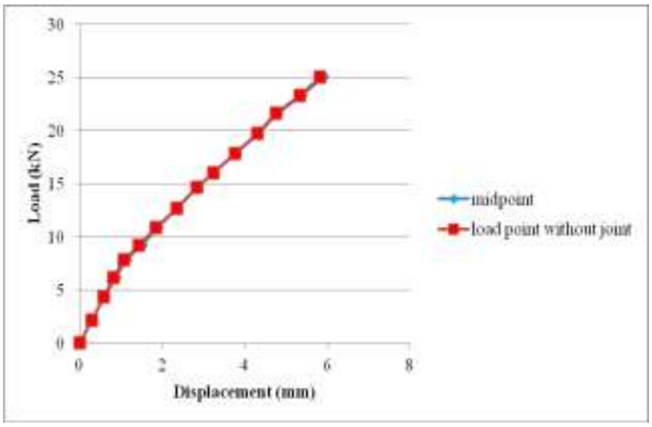

Fig-4: Load vs. deflection plot for M2B2 beam

M2B3 (M20 grade beam with joint starting from mid-point)

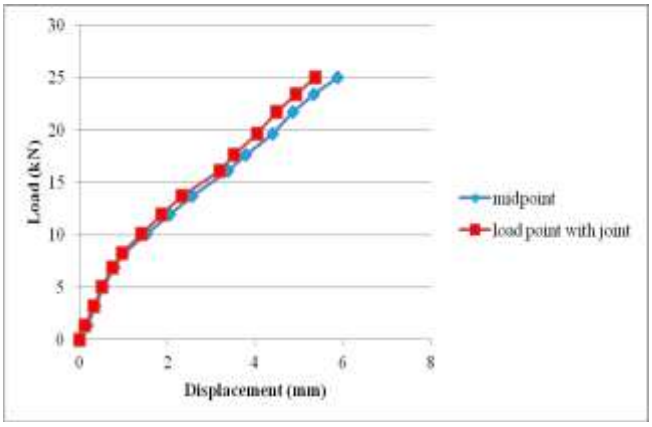

Fig-5: Load vs. deflection plot for M2B3 beam

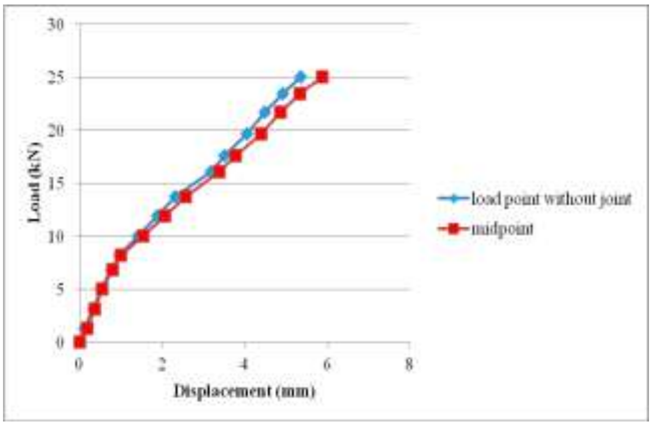

Fig-6: Load vs. deflection plot for M2B3 beam

M4B1 (M40 grade monolithic beam)

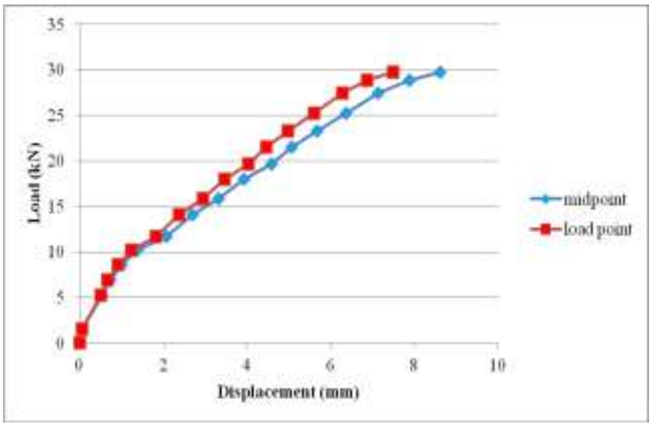

Fig-7: Load vs. deflection plot for M4B1 beam

M4B2 (M40 grade beam with joint starting from one third point)

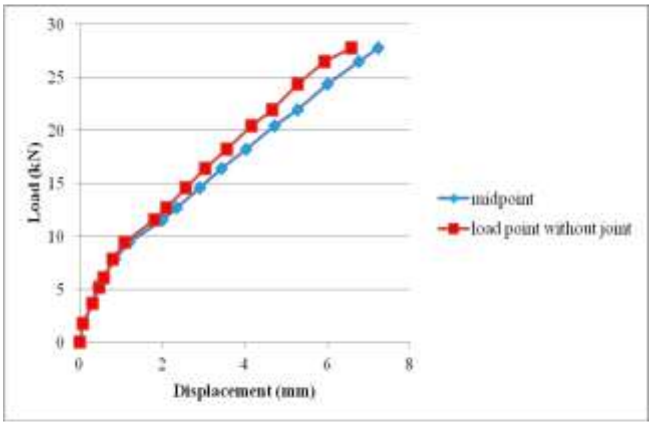

Fig-8: Load vs. deflection plot for M4B2 beam

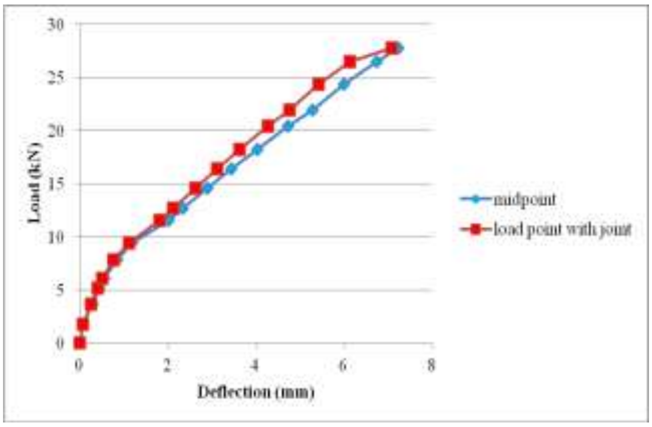

Fig-9: Load vs. deflection plot for M4B2 beam

M4B3 (M40 grade beam with joint starting from mid-point)

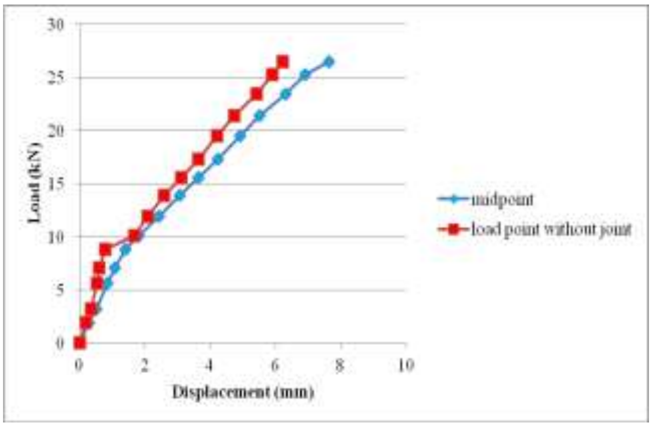

Fig-10: Load vs. deflection plot for M4B3 beam

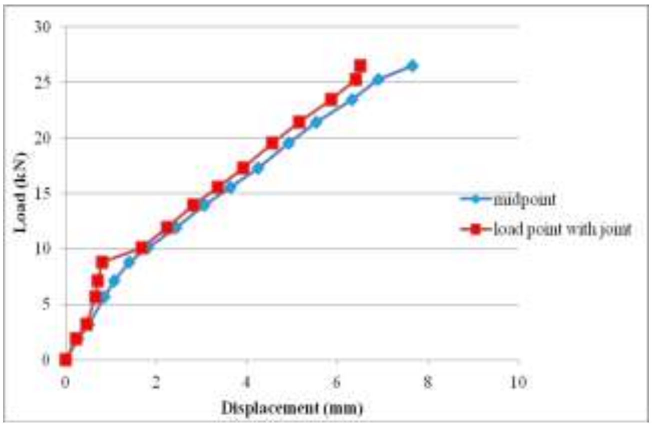

Fig-11: Load vs. deflection plot for M4B3 beam

M6B1 (M60 grade monolithic beam)

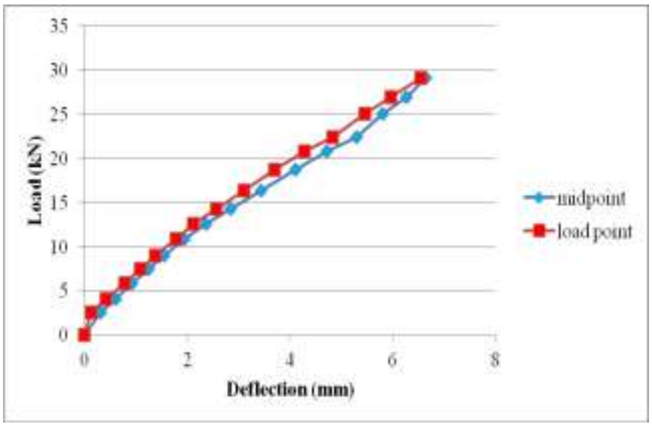

Fig-12: Load vs. deflection plot for M6B1 beam

M6B2 (M60 grade beam with joint starting from one third point)

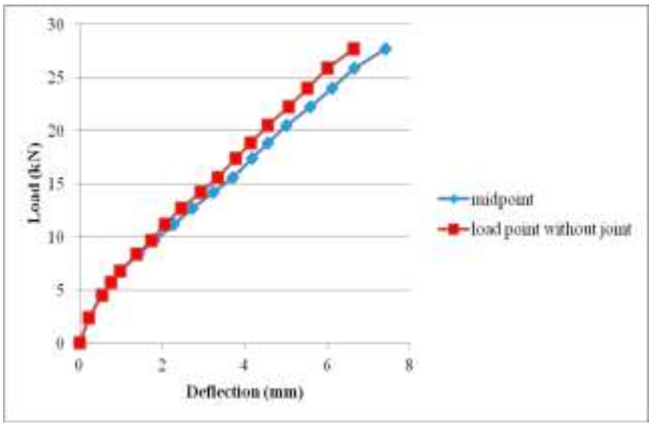

Fig-13: Load vs. deflection plot for M6B2 beam

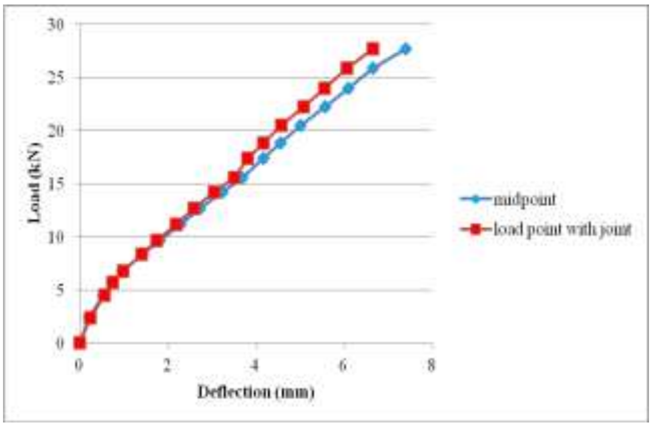

Fig-14: Load vs. deflection plot for M6B2 beam

M6B3 (M60 grade beam with joint starting from mid-point)

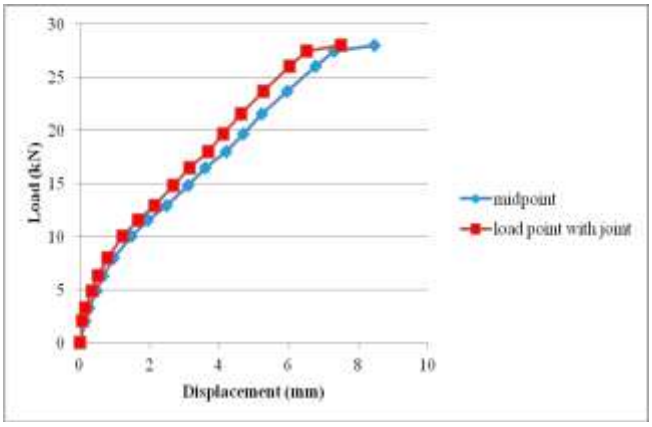

Fig-15: Load vs. deflection plot for M6B3 beam

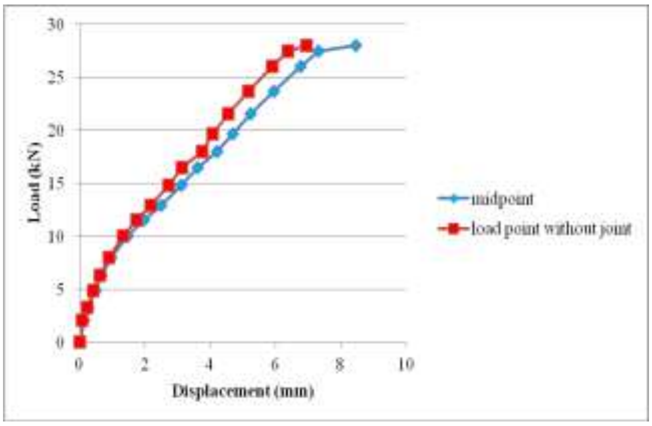

Fig-16: Load vs. deflection plot for M6B3 beam

4.3.3 Ultimate deflection values

Table-3: Ultimate deflection values

Type of beam	Ultimate deflection at one third point with joint (mm)	Ultimate deflection at other one third point (mm)
M2B2	5.88	5.82
M2B3	5.41	5.35
M4B2	7.08	6.57
M4B3	6.50	6.21
M6B2	6.65	6.62
M6B3	7.51	6.96

4.3.4 Pre cracking and post cracking stiffness

Load vs. deflection graph is plotted for loads before the first crack and for that after cracking. Then from the graph, best fit line is drawn and the slope of this line gives the stiffness. Pre cracking stiffness is obtained from the load deflection graph before first crack and post cracking stiffness is obtained from the graph after the first crack. Table 4 shows values of pre cracking and post cracking stiffness of different beams.

Table- 4: Pre cracking and post cracking stiffness

Type of beam	Pre cracking stiffness (kN/mm)	Post cracking stiffness (kN/mm)
M2B1	7.865	3.000
M2B2	6.563	3.702
M2B3	8.544	3.602
M4B1	8.522	2.836
M4B2	8.898	3.088
M4B3	6.637	2.881
M6B1	5.492	3.489
M6B2	7.576	3.415
M6B3	8.304	3.112

4.3.5 First crack load and ultimate load

Table-5: First crack load and ultimate load

Type of beam	First crack load (kN)	Ultimate load (kN)
M2B1	7.6024	25.1024
M2B2	9.2024	25.0624
M2B3	13.7324	25.0324
M4B1	11.7124	29.7024
M4B2	9.3924	27.7524
M4B3	10.1024	26.5024
M6B1	9.0524	29.0824
M6B2	9.6424	27.7224
M6B3	10.0224	27.9724

4.3.6 Ultimate Crack width

The beams were subjected to pure bending failure. The crack-width was taken from the first crack observed till the ultimate load is reached. Micrometer having an accuracy of 0.1mm is used to measure the crack-width for the beam specimens. The crack width for ultimate load for the beams is noted in Table 6.

Table-6: Ultimate crack width

Type of beam	Ultimate load (kN)	Load point 1 (mm)	Midpoint (mm)	Load point 2 (mm)
M2B1	25.1024	0.4	0.6	0.4
M2B2	25.0624	0.2	0.2	0.2
M2B3	25.0324	0.1	0.1	0.1
M4B1	29.7024	0.1	0.4	0.1
M4B2	27.7524	0.6	0.8	0.7
M4B3	26.5024	0.8	0.3	0.8
M6B1	29.0824	0.7	0.8	0.7
M6B2	27.7224	0.6	0.5	0.8
M6B3	27.9724	0.4	0.6	0.8

4.3.7 Moment Carrying Capacity

Moment carrying capacities of beams based on experimental results are shown in Chart 2. M4B1 beam showed the highest moment carrying capacity. But the values obtained for all the beams were nearly same.

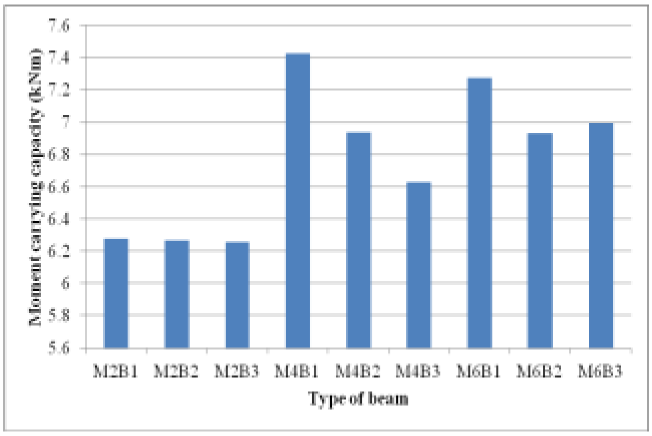

Chart-2: Moment carrying capacity of beams based on experimental results

4.3.8 Energy Absorption Capacity

In the case of designing the beams ductility plays an important role. Energy absorbed by the specimen is determined from the area under the load deflection curve. Energy absorption values of different beams are shown in Table 7.

Table-7: Energy absorption capacities of different beams

Type of beam	Energy absorption capacity (Nm)
M2B1	93.312
M2B2	89.340
M2B3	81.158
M4B1	149.384

M4B2	114.300
M4B3	116.077
M6B1	105.734
M6B2	115.000
M6B3	135.299

4.3.9 Crack Pattern

The formation of crack occurs when the stress exceeds the tensile strength of concrete. The cracks in both flexural and shear area were noted and carefully analyzed. Crack patterns of B1, B2 and B3 type beams are shown in Fig. 17, Fig. 18 and Fig. 19 respectively.

Fig-17: Crack pattern of B1 type beam

Fig-18: Crack pattern of B2 type beam

Fig-19: Crack pattern of B3 type beam

In case of B1 type of beams (monolithic), first crack (flexural crack) developed at middle one third span near to load points at both sides. Later, cracks near to centre developed. Also cracks that developed earlier got extended. On further increment of load, flexural cracks were developed at outer one third span. More cracks were formed at centre and supports. At higher loads, shear cracks were formed near to supports. After the formation of shear cracks, the widening of cracks was in a faster rate. In B2 type of beams (beams with joint starting from one third point and remaining in middle one third region), first crack was developed in middle one third span near to load point at both sides. Later, cracks near to centre developed. Also cracks that developed earlier got extended. On further load increments, more cracks were formed in middle one third span along joint. Later flexural cracks were developed at outer one third span and near to support region. At higher loads, shear cracks were formed near to supports. After the formation of shear cracks, the widening of cracks was in a faster rate. After ultimate load is reached, more crack concentration was found in middle one third span. In contrast to B1 and B2 type of beams, first crack in B3 type of beams (beams with joint starting from mid span and extending to outer one third region) developed outside the middle one third portion were joint is present. Further increase in load resulted in development of flexural cracks in middle one third region near load points as well as outer one third regions. Later crack at centre was formed. Near to ultimate load, shear crack got developed. Analysis of crack pattern of B3 type beams revealed that more cracks were developed in the region where joint was present.

5. CONCLUSIONS

Experimental investigations are carried out to study the effect of construction joints on strength performance of concrete. Compressive strength of each mix was examined. Nine beams were also cast. Flexural testing of beams was done by two point loading. Load-deflection characteristics, pre cracking and post cracking stiffness, energy absorption, moment carrying capacity, ultimate failure load, crack width and crack pattern are the parameters considered for flexural studies. The major conclusions drawn from this research are presented below:

- From flexure study of RCC beams, it was found that deflection at load point where joint was present was higher compared to load point where no joint was present.
- Load carrying capacity of beams with joint in middle one third span was slightly higher for M20 and M40 grades compared to beam with joint extending to outer one third span.

REFERENCES

[1] IS 3414:1968, *Code of Practice for Design and Installation of Joints in Buildings*, Bureau of Indian Standards, New Delhi.
[2] Z. W. Abass, Effect of Construction Joints on Performance of Reinforced Concrete Beams, *Al-Khwarizmi Engineering Journal,* 8, 48- 64, (2012).
[3] B. Djazmati, and J. A. Pincheira, Shear Stiffness and Strength of Horizontal Construction Joints, *ACI Structural Journal,* 101, 484-493, (2004).
[4] N. N. Gerges, C. A. Issa and S. Fawaz, Effect of construction joints on the splitting tensile strength of concrete, *Case Studies in Construction Materials*, 3, 83-91, (2015).
[5] C. A. Issa, N. N. Gerges and S. Fawaz, The effect of concrete vertical construction joints on the modulus of rupture, *Case Studies in Construction Materials*, 1, 25-32, (2014).
[6] Q. A. Majeed, L. A. Ghaleb and M. G. Ghaleb, Effect of the number of horizontal construction joints in reinforced concrete beams, *Engineering and Technical Journal*, 28, 1-19, (2010).
[7] IS 12269:1987, *Specification for 53 Grade Ordinary Portland Cement,* Bureau of Indian Standards, New Delhi, 2000.
[8] IS 10262:2009, *Recommended Guidelines for Concrete Mix Design,* Bureau of Indian Standards, New Delhi.
[9] P. C. Aitcin, High Performance Concrete, E and FN Spon, New York, (1998).

[10] IS 516:1959, *Methods of Test for Strength of Concrete*, Bureau of Indian Standards, New Delhi.
[11] IS 5816:1999, *Splitting Tensile Strength of Concrete-Method of Test*, Bureau of Indian Standards, New Delhi.
[12] IS 456:2000, *Plain and Reinforced Concrete – Code of Practice*, Bureau of Indian Standards, New Delhi, 2000.
[13] IS 1199:1959, *Methods of Sampling and Analysis of Concrete*, Bureau of Indian Standards, New Delhi.