Case Studies in Construction Materials 5 (2016) 112–123

Contents lists available at ScienceDirect

Case Studies in Construction Materials

journal homepage: www.elsevier.com/locate/cscm

Case study

The effect of construction joints on the flexural bending capacity of singly reinforced beams

Nagib N. Gerges[a], Camille A. Issa[b,*], Samer Fawaz[a]

[a] *Department of Civil Engineering, University of Balamand, Lebanon*
[b] *Department of Civil Engineering, Lebanese American University, Lebanon*

ARTICLE INFO

Article history:
Received 29 June 2016
Accepted 14 September 2016
Available online 23 September 2016

Keywords:
Construction joints
Concrete beams
Singly reinforced
Flexural capacity

ABSTRACT

The main purpose of conducting this study is to determine the difference in the bending capacity between a singly reinforced monolithic beam and a singly reinforced beam with a construction joint at the beam center, for a range of different compressive strength (f'c) of concrete. Testing was conducted according to applicable ASTM standards. During humongous construction projects, it is very rare to build a concrete structure without instigating the use of construction joints, whether by design or by de facto forces. On site, the construction supervisor would contemplate whether one could relate the bending capacity of the concrete beam with the use of accidently imposed construction joint. Thus it is very essential to determine the effect the construction joint has on the flexural bending capacity of the concrete. Provided are charts to account for the loss in the bending capacity of singly reinforced beam in the existence of a construction joint for a specific concrete compressive strength.

1. Introduction

It is often not possible to complete a job at one go, for example because of the size or complexity of the structure or because of limited materials or manpower. When work resumes it will be necessary to place fresh concrete on or against the previous pour that will have already hardened. The resultant contact surface is known as a construction joint or day work joint [1]. Waters [2] was a pioneer in addressing the issue of concrete tensile strength across construction joints and had mainly investigated the topic of bonding surfaces.

Construction joints [3,4] is the most commonly experienced joint in most concreting work in spite of the fact that this type of joint is actually not a must in concrete structures unlike the other types joints. A construction joint is provided when concrete pouring needs to be stopped due to some reason and then is continued again later. This is done to retain the monolithic nature of the structure which otherwise would be broken due to the break in the continuity.

In other words, the joint could have been avoided if the entire concreting were completed without any stopping in between so that no part of the structure needs to be continued (by concreting) at a later date. Practically that is often not possible, especially for larger structures. Interruptions can happen due to varieties of reasons such as sudden breakdown of machinery, stopping of work at the end of the day, sudden heavy rain, installation of formwork for next lift (for wall, column etc.) and so on.

* Corresponding author.
E-mail address: cissa@lau.edu.lb (C.A. Issa).

http://dx.doi.org/10.1016/j.cscm.2016.09.004
2214-5095/

Sometimes provisions for future extension of a building or a structure are required to be kept. Construction joints are often required at the ends of beams, slabs, tie beams etc., in such cases, for the purpose of future extension.

Since, construction joints are practical requirements for most concrete structures they should preferably be planned beforehand, wherever possible, and shown in the construction drawings. That would help in planning the concrete pour-plan accordingly and also in preparing the joints properly. Construction joints resulting from unforeseen events like rain, machinery breakdown etc., however, can arise at any moment and one should just stay prepared for such cases.

A construction joint can be avoided if it can be coincided with an expansion joint as monolithic nature of structure is always broken at expansion joints. Where contraction joints are required to be provided, it is always better to plan construction joints to coincide with contraction joints so as to minimize the number of joints in a structure.

Concrete's capacity to take bending stresses is negligible. In reinforced concrete the steel bars take the stresses due to bending moment (BM) while the concrete has to endure primarily the shear stresses. Hence, planes of minimum shear force (SF) in structures are the ideal locations for providing construction joints. One need not worry about BM stresses as there always is enough reinforcement to take care of it and concrete does not have to bear stresses due to BM. So, in case of a beam or a slab the middle third span is the zone for providing construction joints where shear stresses are the minimum. For a column, a construction joint may be provided 3 to 4 inches below the lowermost soffit of the adjoining beams.

The plane of a construction joint should be perpendicular to the steel reinforcement of the concrete member. The formwork for construction joints should have shear key blocks. Shear keys provide better interlocking and thus more efficient transfer of SF between the old and new concrete.

Forms should also have well located perforations to allow the reinforcement or dowel bars to pass through. Dowel bars are usually provided when a slab, pavement etc. would be subjected to heavy loads or vehicular traffic. They may as well have to be provided when concreting has to be stopped at high SF zone due to sudden unforeseen reasons as mentioned above. Shear keys are not necessary where dowel bars are provided.

Before continuing concreting the formwork and shear key blocks are stripped. If concreting is continued within a day or two of stopping the work, the construction joint is thoroughly water cleaned and then a layer of rich mortar is applied onto it before proceeding with the concreting. For an older joint its surface is roughened first and then water cleaned well to get rid of all dirt, loose materials etc. Thereafter, a layer of rich mortar is applied and concreting is resumed.

The flexural bending capacity [5] of concrete is one of the most important parameters that affect the design of a concrete structure. By definition, the bending capacity is the ability of reinforced concrete beam to resist bending moment due to different type of applied loads. The compressive strength is another important factor that affects the ability of the beam to resist bending moment. The standard for performing the four point loading is the ASTM D6272 [6], it details the procedure to break a beam (750 mm × 150 mm × 150 mm) using the four point loading and determines the maximum load carrying capacity of the beam.

2. The experimental study

Seven different mix designs were utilized to obtain a reasonable set of data points with different values of concrete compressive strengths (f'_c) and nominal bending capacity (M_n). The identification of each concrete mix design is designated in the following order: Mix 1, Mix 2, Mix 3, Mix 4, Mix 5, Mix6 and Mix 7. In total six singly reinforced beams were poured for each mix design in which three are monolithic and the other three contain a construction joint in the center. In addition, one test cylinders were poured for each beam. In total, 42 beams and 42 cylinders were casted for this experimental study. The

Fig. 1. Mold Form Preparation.

Corresponding test cylinders were tested using the compression cylinder machine to obtain compressive strength of concrete for each beam. The maximum loading that the beam can resist was obtained using the four point loading machine. ASTM C192 [7], ASTM C39 [8], ASTM C33 [9] and ASTM C617 [10] are the standards used for concrete pouring, compressive strength cylinder testing, testing aggregates, testing for flexural strength of concrete and cylinder capping respectively.

3. Preparation of experimental specimens

According to ASTM C39 [8], ASTM C78 [6] and ASTM C617 [10] we have tested our concrete beams and cylinders. As for the concrete mixing, pouring, finishing and curing, ASTM C192 [7] standards were used. The following steps of the work schedule were performed to prepare one full set of beams and cylinders for each mix. Three phases were performed in the process one on daily basis.

During the first day, 3 monolithic beams and 3 half beams with construction joint were poured (Fig. 1). In addition to that, 3 test cylinders were casted. Beam and cylinder molds were prepared according to C192 [7] (Section 4). They were cleaned and oiled in the inside faces of the molds. It is important that the molds have a smooth and clean contact surface with the freshly poured concrete. A piece of wooden bulkhead was used as a construction joint for the three halves of beams. The construction joint was placed perpendicular to the beam in the exact center of the beam mold, which is the location of the maximum bending moment and where the shear is zero.

The preparation of the materials was done according to ASTM C192 (Section 6). The total concrete quantity required was 0.09631 m^3 (10% waste). Table 1 displays the seven concrete design mixes.

No admixtures were used in this experiment. The buckets were weighed on the scale before filling them with the necessary materials in order to be precise. The materials were filled in the buckets and weighed on the electronic balance using the scoops.

The concrete mixing was performed according to ASTM C192 [6] (Section 7). The power-driven concrete mixer was located in a convenient way next to the molds and a wetted wheelbarrow, using a damp sponge, was placed beneath the sliding door of the mixer, where the concrete is poured out from.

First, half the quantities of the course aggregates were dumped into the mixer. Second, a very small quantity of the water was added and the mixer was turned on for 3 s just to make the aggregates wet. Third, all the sand (fine aggregates) were dumped into the mixer evenly. Fourth, all the cement was evenly distributed in the mixer. Fifth, the remaining of the course aggregates was dumped inside the mixer. Finally, the mixer was turned on and the batch was mixed for 3 min while adding the remaining quantity of water at a constant rate, then turned off for another 3 min (resting period) and then turned back on for another 2 min. Once the eight minutes were done, the sliding door of the mixer was opened and the concrete flowed into the wheelbarrow. A stop-watch was used for timing.

According to ASTM C192 [7] (Section 7), and using the scoops, three beams were fully filled with concrete (monolithic beams) and the remaining three were half-way filled to the construction joint. As one was filling up the beams with the fresh concrete, another was using the electric concrete vibrator to compact the concrete. The concrete vibrator was used according to ASTM C192 [6] (7.4.3).

After finishing the vibration, a mallet was used 10 times to tap the sides of the mold sharply, (it helps to release any entrapped air voids). After the consolidation was done, the surface of the concrete was smoothed using the finishing trowel (Figs. 2 and 3).

According to ASTM C192 (Section 7), the concrete is placed in the cylindrical mold in 3 equal layers, each 1/3 of the volume of the mold. For the final layer, sufficient concrete was placed to just fill mold after compaction. Each layer is rodded with 25 strokes distributed uniformly across the cross section of the mold. After rodding each layer, the outside of the mold was tapped 15 times with the mallet and the top surface was toweled off. According to ASTM C192 [7] (Section 8), the samples were covered with impervious plastic sheeting to avoid excessive loss of water due to evaporation.

On the second day, the other halves of the beams with construction joints were poured along with another 3 test cylinders. The construction joint were removed on this day according to ASTM C192 [7] (Section 4). After the removal of the wooden bulk heads, the surface of the concrete stopped by the construction joint was roughened lightly until the course aggregates were exposed (refer to Picture 10 in Appendix B). The inside of the molds were cleaned again.

Table 1
Concrete Mix Proportions 1.

f'_c (Mpa)	w/c	Water	Cement	Gravel	Sand
18	0.621	19.01	30.61	109.00	72.00
21	0.674	18.94	28.21	109.00	72.00
24	0.650	20.00	30.77	109.00	72.00
27	0.575	21.00	36.10	109.00	72.00
30	0.540	20.26	37.52	109.00	72.00
33	0.498	20.23	40.64	109.00	72.00
35	0.470	21.00	44.68	109.00	72.00

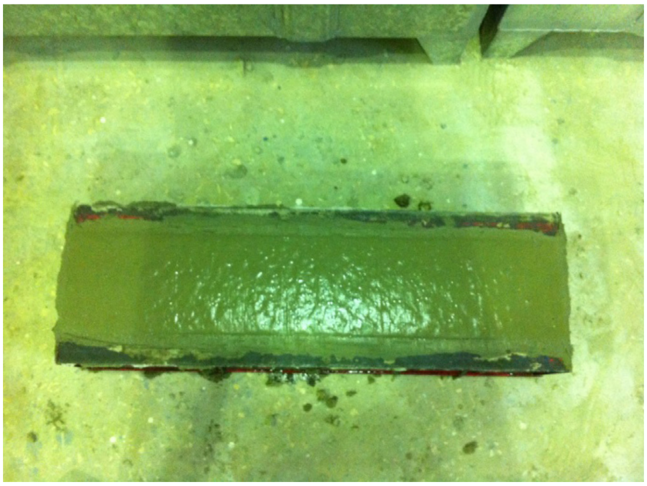

Fig. 2. Monolithic Beam.

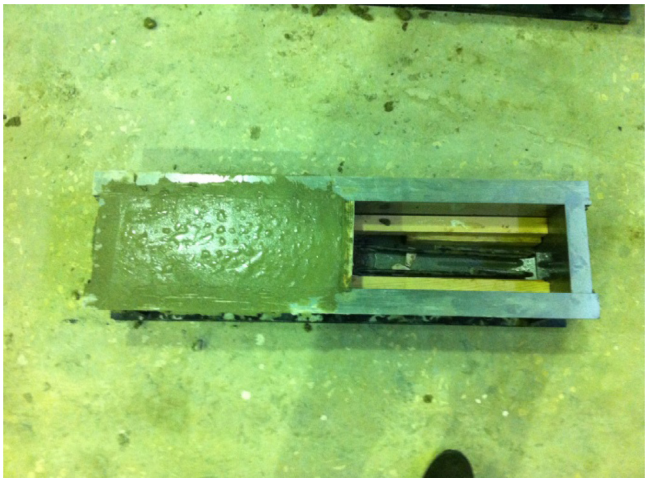

Fig. 3. Beam with a Construction Joint.

The aggregate quantities needed to be poured for the remaining portion of the beams are less than what was required the previous day. For this experiment, the required volume of concrete was 0.04 m_3 (includes 10% waste). Table 2 displays the seven concrete mixes used for the second pouring for beams with construction joints.

The procedure mentioned in the second step was applied here:

- Concrete mixing: The same procedure mentioned in step 3 was applied here.

Table 2
Concrete Mix Proportions 2.

f'_c (Mpa)	w/c	Water	Cement	Gravel	Sand
18	0.621	9.50	15.30	49.06	32.4
21	0.674	8.70	13.00	49.06	32.4
24	0.650	9.18	14.15	49.06	32.4
27	0.575	9.45	16.25	49.06	32.4
30	0.540	9.11	16.90	49.06	32.4
33	0.498	9.10	18.23	49.06	32.4
35	0.470	9.20	19.57	49.06	32.4

- Pouring beams: The same procedure mentioned in step 4 was applied here.
- Pouring test cylinders: The same procedure mentioned in step 5 was applied here.
- Curing: The same procedure mentioned in step 6 was applied here.

On the third day, the molds were removed according to ASTM C192 [7] (Section 8) bolts of the molds were unscrewed and the concrete beams and cylinders were removed (Figs. 4 and 5).

Before curing the concrete, labels were written on the beams and cylinders and the date of pour were written in the data sheet for identification purposes. For example, the labeling system used for the Mix 1 beams was: 1, 2, 3, 1′, 2′, and 3′. Simple labels were used in order to simplify this identification system in the data-log sheets.

ASTM C192 [7] (Section 8) requires for curing purposes that cylinders and beams be immerged in the water storage tank saturated with calcium hydroxide having a temperature of 23 °C for a minimum of 28 days before testing (Fig. 6).

According to ASTM C39 [8] cylinder corresponding to the beam that was poured before 28 days was removed from the water tank. Using a steel tape, the diameter of each cylinder was measured at the middle. The capping was performed according to ASTM C617 [10] which recommends to cape the both sides of the cylinder for more accurate results. First, the end surface of the test cylinder should be dry using a blow-dryer. At that time, the capping compound should be in the warming pot. It takes about 30 min to make the capping materials ready. The mold plate was oiled and the capping materials were poured into the plate. Now the cylinder should be immediately placed in the mold. After the setting of the sulfur mortar, the cylinder was twisted in its place and pulled out to remove it from the mold. The same procedure was done for the opposite end of the cylinder.

The cylinders were tested according to ASTMC39 [8]. Compression test is performed by entering the specimen on the lower plate of the testing machine. Adjusting the loading rate of the machine for cylinders at 4.4 KN/s. Apply the load until the specimen fails. Register the maximum load recorded by the machine. The compressive strength is then calculated using load and the determined cylinder area based on the measured diameter (Fig. 7).

Beams were prepared according to ASTMC78 [6]. Once the beam is removed from water, the beam dimensions were recorded (length, depth and width). Reference lines were drawn displaying centerline, 75 mm from both sides of the centerline and 225 mm from both sides of the centerline. The 75 mm from both ends represents the limit of cracking and the 450 mm spacing represents the lower support of the testing machine. The beam is loaded at a rate of 0.1 KN/s. The maximum load was recorded when the yielding of the steel began. Shear and moment diagram were drawn and the maximum bending capacity was calculated. All the cracks fell within the 75 mm range (Figs. 8–10).

4. Data collection

Data was directly recorded at the conclusion of each testing. Table 3 displays the results of the compressive strength test of the cylinders:

Table 4 displays the results of the crushing of the beams. For each beam, the ultimate load at which the beam failed was recorded in addition to its height and concrete cover.

To eliminate the cover effect, the actual moment sustained by the beam (before failure) was computed and divided by the effective depth in order to eliminate the effect of this parameter. For each mix the values of the compressive strength and the bending capacity for monolithic beams and beams with construction joints were averaged. The ratio $M_{ConstructionJoint}/M_{Monolithic}$ was computed for each Concrete Mix Design Adjusted data results are displayed in Table 5.

Fig. 4. Test Cylinder.

Fig. 5. Monolithic Beams.

5. Results

In order to perform the analysis, data was entered to SPSS [11] which is a software used for statistical analysis. This software is able to perform regressions in order to determine the equation of the best fit curve and its correlation factor. Table 6 displays the model summary and the values of the correlation factors obtained for each type of best fit curve:

The highest correlation factor (0.93) was obtained for a cubic equation of the best fit curve. Therefore, that model was the one adopted.

Fig. 11 displays the best fit curves obtained from SPSS using various curve fitting techniques.

In the figure Wolfram Mathematica [12] software programmed using the same data to determine the equation of this best fit curve according to a cubic pattern.

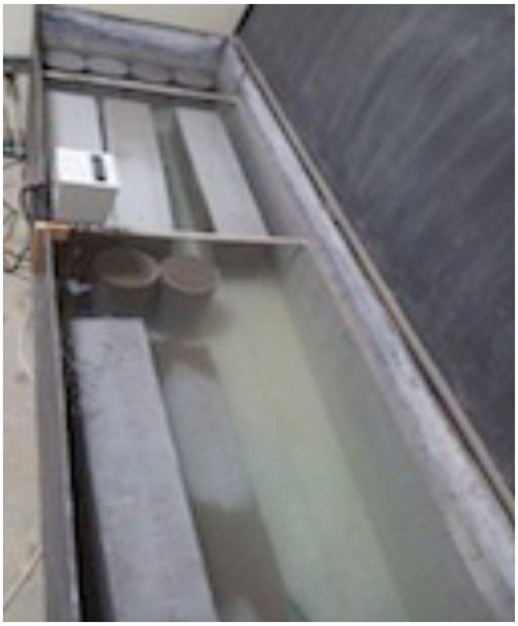

Fig. 6. Curing in the Water Storage Tank for 28 Days.

Fig. 7. Concrete Cylinder Testing Machine.

In the Fig. 12, the variable "x" represents the 28 days compressive strength of concrete in MPa.

From Fig. 12 x and y, one can observe that when the compressive strength of the beam increases, the effect of construction joint increases by reducing the bending capacity of the beam. This augmentation has a logical explanation from a concrete technology point of view, because as concrete compressive strength increases, water cement ratio decreases, the quantity of cement paste used in the mix increases, thus the rate of increase in strength increases. Hence, after 24 h, when the second part of the beam is casted, the hardened part would have gained a higher percentage of its 28 days strength compared to the newly placed concrete. This difference in strength is responsible of the reduction in the bending capacity of the beam. While vice versa, as concrete compressive strength decreases, water cement ratio increases, the quantity of cement paste used in

Fig. 8. Four Points Beam Testing Setup.

Fig. 9. Failure of a Monolithic Beam with a Construction Joint.

the mix decreases, thus the rate of increase in strength decreases. Thus, after 24 h, at the time when the second part of the beam is casted, the difference in strength between the two parts will be lower, and closer to a monolithic beam behavior.

As an example to display how figures x and y can be used in a practical application, suppose a 600 by 300 mm^2 singly reinforced beam is to be designed according to the following criteria:

- $M_{Applied}$ (KN m) = 240 KN m
- Concrete Cover = 25 mm
- single loop ϕ8 mm stirrups
- Concrete Compressive Strength (f'_c) of 19 MPa
- Reinforcing Steel Yield Strength (f_y) of 314 MPa

Fig. 10. Failure of a Beam with a Construction Joint.

Table 3
Testing Cylinders Data Sheet.

Mix 1	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	149.60	286.90	16.32	150.20	290.00	16.37
2	149.10	300.30	17.20	150.20	305.00	17.21
3	150.10	270.10	15.26	150.20	260.00	14.67
18 MPa	Average		16.30	Average		16.10
Mix 2	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	151.90	346.80	19.14	149.10	334.20	19.14
2	151.70	346.70	19.18	149.50	336.80	19.19
3	151.80	376.50	20.80	150.30	356.30	20.08
20 MPa	Average		19.47	Average		19.50
Mix 3	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	151.00	417.80	23.33	150.00	408.30	23.11
2	150.00	429.80	24.32	151.00	410.70	22.93
3	151.00	420.30	23.47	150.00	405.90	22.97
24 MPa	Average		23.71	Average		23.10
Mix 4	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	151.00	565.50	31.58	150.00	570.00	32.26
2	150.00	580.80	32.87	150.00	590.00	33.39
3	151.00	638.60	35.66	150.00	635.00	35.93
35 MPa	Average		33.37	Average		33.90
Mix 5	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	150.00	756.00	42.78	150.00	710.00	40.18
2	150.00	709.80	40.17	150.00	715.00	40.46
3				150.50	705.00	39.63
40 MPa	Average		41.48	Average		40.10
Mix 6	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	150.60	611.70	34.34	151.00	645.00	36.02
2	150.00	638.00	36.10	150.50	650.00	36.54
3				150.00	661.00	37.40
35 MPa	Average		35.22	Average		36.7
Mix 7	First Cast			Second Cast		
Cylinder	Diameter (mm)	Load (KN)	f'_c (Mpa)	Diameter (mm)	Load (KN)	f'_c (Mpa)
1	151.00	688.40	38.44	151.00	700.00	39.09
2	150.00	683.80	38.70	150.50	695.00	39.07
3	150.00	691.00	39.10	150.00	710.70	40.22
40 MPa	Average		38.80	Average		39.5

The beam has a construction joint at midspan, affecting its bending capacity. The reduction of the bending capacity can be determined by using the graph provided by Mathematica (Fig. 13 y) and utilizing the following procedure.

a Enter the chart with value of F'c = 19 MPa
b Draw a vertical line (AB)
c Draw a horizontal line (BC)
d Read the value of $M_{ConstructionJoint}/M_{Monolithic}$, which is 0.94

Thus according to Fig. 14 y, a beam built with a construction joint, poured with concrete strength of 19 MPa, is expected to suffer a loss of 6% of its bending capacity. A comparison between the amounts of steel required to resist bending in two cases:

Table 4
Beams Crushing Results.

Mix 1	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.10	3.50	11.20	63.90	4.79	15.00	1.50	13.10	74.00	5.55
2	15.00	1.25	13.35	75.40	5.66	15.00	1.50	13.10	70.00	5.25
3	15.30	4.50	10.40	55.30	4.15	15.00	0.80	13.80	68.10	5.11
Mix 2	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.30	1.20	13.70	72.30	5.42	15.00	0.90	13.70	71.80	5.39
2	15.20	1.00	13.80	77.40	5.81	15.10	0.80	13.90	74.50	5.59
3	15.30	1.10	13.80	73.50	5.51	15.10	1.00	13.70	69.50	5.21
Mix 3	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.20	1.35	13.45	76.30	5.72	15.00	0.90	13.70	74.00	5.55
2	15.40	0.85	14.15	77.00	5.78	15.00	0.75	13.85	71.30	5.35
3	15.50	1.50	13.60	75.30	5.65	15.10	0.75	13.95	73.00	5.48
Mix 4	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.20	1.10	13.70	75.20	5.64	15.10	0.50	14.20	71.30	5.35
2	15.60	1.25	13.95	72.30	5.42	15.20	0.60	14.20	68.70	5.15
3	15.60	1.20	14.00	74.50	5.59	15.20	0.70	14.10	67.30	5.05
Mix 5	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.40	2.20	12.80	64.00	4.80	15.00	1.70	12.90	52.50	3.94
2	15.25	2.10	12.75	71.50	5.36	15.00	1.05	13.55	63.30	4.75
Mix 6	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.40	2.10	12.90	67.50	5.06	15.00	2.15	12.45	60.80	4.56
2	15.20	2.15	12.65	63.40	4.76	15.00	2.05	12.55	57.20	4.29
3	15.20	2.00	12.80	62.70	4.70					
Mix 7	Monolithic					Construction joint				
Beam	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)	H (cm)	CC (cm)	d (cm)	Load (KN)	Actual Moment (KN m)
1	15.40	2.25	12.75	62.90	4.72	15.00	2.25	12.35	51.40	3.86
2	15.40	1.90	13.10	65.40	4.91	15.20	2.00	12.80	57.90	4.34
3	15.50	2.00	13.10	66.90	5.02	15.20	2.10	12.70	57.80	4.34

when the effect of the construction joint is not taken into consideration and, when the applied moment is modified in order to take into consideration the effect of the construction joint.

According to ACI Code [5] requirements to handle the required moment capacity of 200 KN-m, the steel reinforcement obtained is 2990 mm^2. In order to compensate for the loss in the moment capacity due to the construction joint, the applied

Table 5
Adjusted Data.

f'_c	$M_{CJ}/M_{Monolithic}$
16.26	0.986733333
19.4667	0.946733333
23.7067	0.897333333
32.225	0.869
35.3667	0.864733333
38.7533	0.834666667
41.475	0.7795

Table 6
Correlation Factors obtained by SPSS.

Equation[a]	Model Summary					Parameter Estimates			
	R Square	F	df1	df2	Sig.	Constant	b1	b2	b3
Linear	0.929	65.720	1	5	0.000	1.083	−0.007		
Logarithmic	0.925	61.674	1	5	0.001	1.493	−0.183		
Inverse	0.906	47.992	1	5	0.001	0.710	4.584		
Quadratic	0.929	26.324	2	4	0.005	1.075	−0.006	−1.086E-5	
Cubic	0.930	26.669	2	4	0.005	1.065	−0.006	0.000	−4.008E-7
Compound	0.924	60.458	1	5	0.001	1.104	0.992		
Power	0.912	51.581	1	5	0.001	1.751	−0.206		
S	0.885	38.570	1	5	0.002	−0.321	5.140		
Growth	0.924	60.458	1	5	0.001	0.099	−0.008		
Exponential	0.924	60.458	1	5	0.001	1.104	−0.008		
Logistic	0.924	60.458	1	5	0.001	0.906	1.008		

[a] Dependent variable is $M_{CJ}/M_{Monolithic}$ and the independent variable is f′c.

moment was magnified respectively. Hence, thus the new design moment capacity is calculated as 212.7 KN-m. Thus, in the existence of the construction joint, the steel reinforcement obtained is 3240 mm^2.

Hence, an additional area of steel reinforcement of 250 mm^2 is required in order to account for the loss due to the construction joint.

6. Conclusions

In the construction world, the presence of construction joints is inexorable. It is unfeasible to execute any concrete construction project without using a construction joint. Therefore, it is important to assess and carefully study all the aspects of this new parameter, especially the structural effect. This study dealt with the effect of the construction joint on the bending capacity of singly reinforced concrete beams. It was proven that as the concrete compressive strength increases, the effect of the construction increases and causes more loss in the bending capacity of the structural element. A procedure to compensate for the reduction in the moment capacity due to the existence of a construction joint is presented.

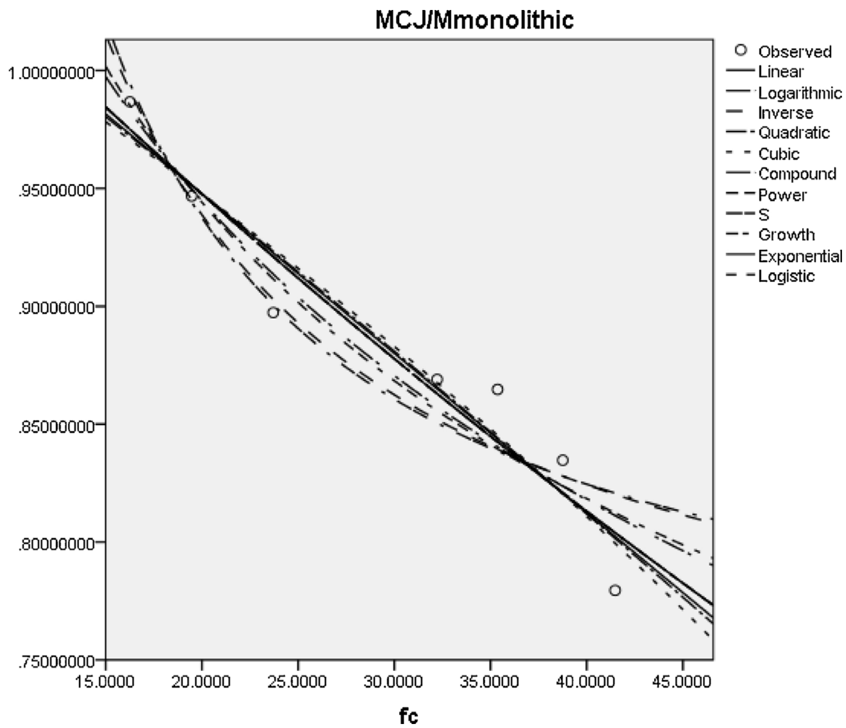

Fig. 11. Best Fit Curves According to SPSS.

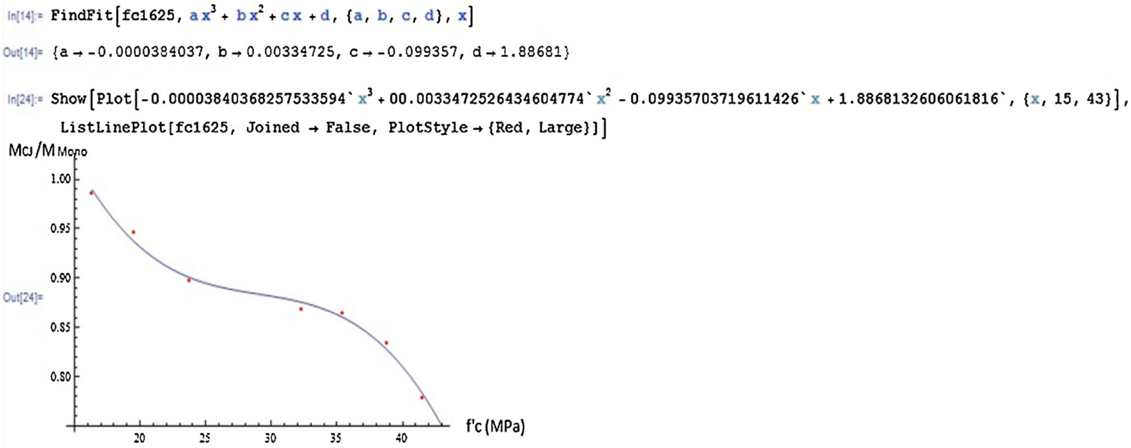

Fig. 12. Results Obtained from Mathematica.

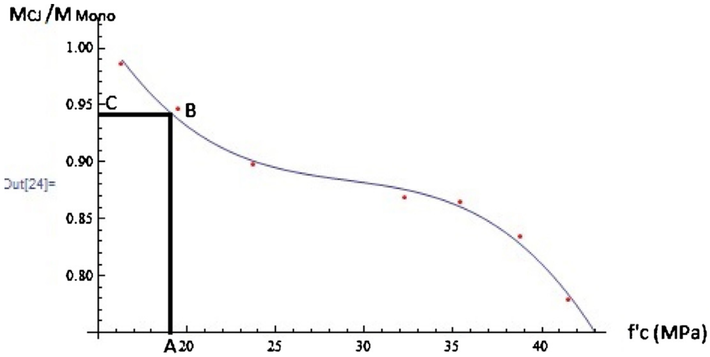

Fig. 13. M $_{CJ}$/M $_{Mono}$ vs f'c chart.

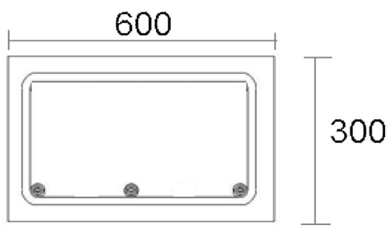

Fig. 14. Beam Cross Section (mm).

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