



## Effect of Construction Joints on Performance of Reinforced Concrete Beams

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### Abstract

Construction joints are stopping places in the process of placing concrete, and they are required because in many structures it is impractical to place concrete in one continuous operation. The amount of concrete that can be placed at one time is governed by the batching and mixing capacity and by the strength of the formwork. A good construction joint should provide adequate flexural and shear continuity through the interface.

In this study, the effect of location of construction joints on the performance of reinforced concrete structural elements is experimentally investigated.

Nineteen beam specimens with dimensions of 200×200×950 mm were tested. The variables investigated are the location of the construction joints (at midspan or at third point of the specimens), type of construction joints (vertical, inclined, and key construction joints), and presence of stirrups at these joints. The specimens were tested using 1000 kN computer controlled versatile electronic testing machine. The specimens were positioned in the machine so that the deflection at center and/or at the location of construction joint was measured at each load step.

The results of the experimental program indicated that the best location of the construction joint is at the point of minimum shear. It was found that the use of vertical construction joint has little effect on the overall behavior of beam specimens (the percentage of reduction in ultimate load capacity is in the range of 0% - 5%).

While inclined construction joints results in a noticeable reduction in strength of beams relative to the strength of beam without construction joint the percentage of reduction in ultimate load capacity is in range of 8% - 20%. The presence of stirrups at the construction joints is an important variable, which affect the type of failure and load carrying capacity. It is found that adding of stirrups across the joint results in an increase in capacity in the range of (7% - 15%) and a decrease in deflection in the range of (20% - 48%).

**Keyword:** Construction joint, reinforced concrete, beams, cracks in concrete.

### 1. Introduction

Joints are necessary in concrete structures for variety of reasons. Not all concrete in a given structure can be placed continuously, so there are construction joints that allow for work to be resumed after a period of time. Since concrete undergoes volume changes, it can be desirable to provide joints and thus relieve tensile or compressive stresses that would be included in the structure. It is necessary then to provide various types of joints in most concrete structures, and in order that these joints adequately perform the

functions for which they are intended, it is essential that they be installed and located correctly<sup>(1)</sup>.

#### 1.1. Joints in Concrete Structures

When joints are installed in a concrete structure, it is essential that they do not impair the normal functions of the structure and usually it is desirable that they should blend with the general appearance. In general, it is convenient to classify the various types of joints in two groups<sup>(2)</sup>:

## A. Functional joints

These joints are installed to accommodate movement (volume change) due to temperature, shrinkage during setting, expansion, sliding, warping ... etc.

## B. Construction joints

These joints are made when there is a break stoppage in the construction program. Construction joints are stopping places in the process of placing concrete and they are provided to simplify construction of a structure. The location of construction joints depends on the type of work, the site condition and the production capacity of the plant or labor employed. It frequently happens; when large volume of concrete are being placed that there is a break in the construction work. Pure construction joints are not intended to accommodate movement but they are merely separation between consecutive concreting operations and in fact, every effort is directed towards preventing movement from occurring at these joints. Construction joints should not be confused with expansion joints. Expansion joints are usually used to allow for free movement of parts of a structure and which are normally designed for complete separation. Construction joints are nearly always the weakest points in a structure. The main problem that remains therefore in the formation of a good construction joint is the capability of providing a

well bonded medium between the hardened and the fresh concrete . Thus construction joints in concrete structure should be placed where shear forces are expected to be low. Both the location and the size of joint should in general be chosen according to the type of structure to ensure good performance of the structure and to provide acceptable appearance.

In the case of reinforced concrete beams, construction joints may run horizontally, vertically, inclined or key joints; depending on the placing sequence prescribed by the design of the beam, Fig.(1).

The main concern in joint construction is in providing adequate shear transfer and flexural continuity through the joint. Flexural continuity is achieved by continuing the reinforcement through the joint, while shear transverse is provided by shear friction between old and new concrete, and dowel action in reinforcement through the joint. Construction joints may result in less than 100 % of shear capacity. The Construction joints should be made in the following manner<sup>(3,4)</sup>:

- 1- The surface of hardened concrete along the joint should be thoroughly roughened.
- 2- The surface of the concrete should then be cleaned thoroughly to remove all foreign and attached matter such as waste.
- 3- Hardened concrete should be moistened thoroughly before new concrete is placed on it.
- 4- No pool of water should be left standing on the wetted surface when new concrete is placed.

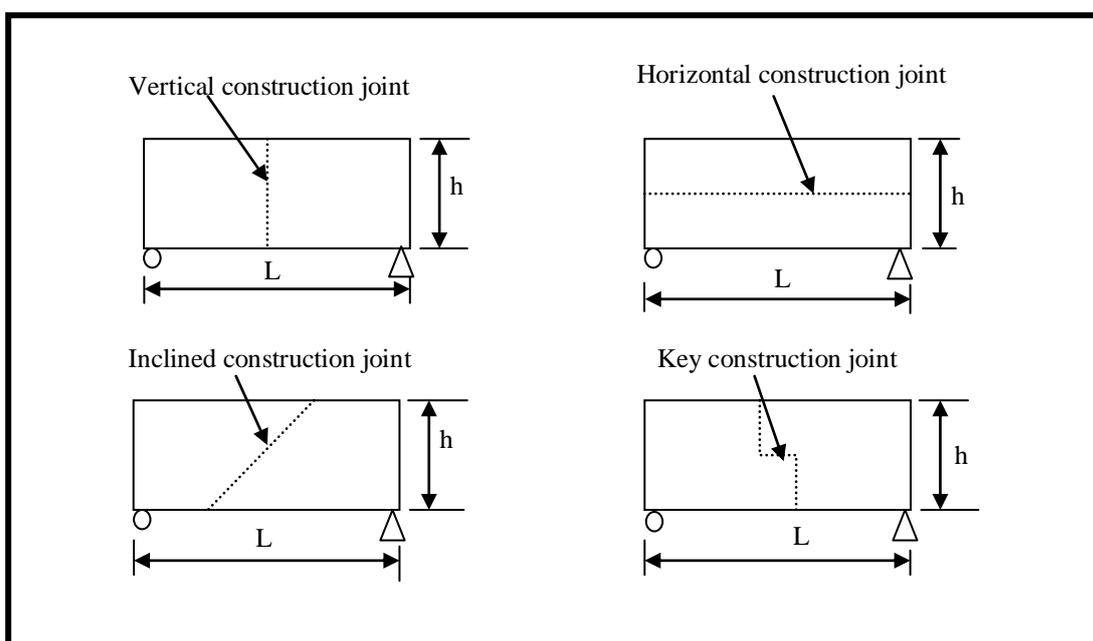


Fig. 1. Types of Construction Joints.

## 1.2. Location of Construction Joint

Location of construction joints is usually predetermined by agreement between the architectural engineer and the contractor, so as to limit the work that can be done at one time to a convenient size, with the least impairment of the strength of the finished structure. Generally, it is impractical to place concrete in lifts higher than one story. Designer should recognize this when locating horizontal construction joints. For building in which the concrete walls are to be exposed, joints may be located at bends of ornamentation, ledge, rustications, or other architectural details. It is convenient to locate horizontal joints at the floor line in line with window sills. In the design of hydraulic structures, construction joints usually are spaced at shorter intervals than in non-hydraulic structures to reduce shrinkage and temperature stresses. Construction joints should be located by the designer to provide logical separation between segments of the structure. As a rule, construction joints are allowed only where shown on the drawings.

If the placing of concrete is involuntarily stopped for a time longer than the initial setting time of the concrete used, the old surface is to be considered as a construction joint, and treated as such before casting is resumed. The appearance of a structure can be influenced by the location of the construction joint, and the aim should be to install them in apposition that renders them as inconspicuous as possible; the alternative is to make them clearly visible as a feature of the structure. The joint should fit into the architectural design, and their location should facilitate the

construction of forms and placing of concrete. However, from a point of view of strength of the structure, it is desirable to position construction joint at point of minimum shear. For slabs and beams it is, therefore, usual to have construction joint at mid span or in the middle third of the span. These rules are based on the assumption that a construction joint may result in less than 100% of shear capacity in the interface. If there were practicable to have such joints at the supports for slabs and beams, it improves appearance and result in a considerable saving in the cost of the formwork<sup>(5)</sup>.

## 2. Variables of the Test Program

The variables affecting the location of construction joints of reinforced concrete structure elements are studied experimentally. These variables include the location and type of the construction joint and whether or not stirrups are present at the joint.

### A. Location of Construction Joint

The effect of location of the joint is the main variable in this study. Two different locations are considered: at the middle of the beam specimen and at the third point as shown in Fig.( 2 ). The reason for choosing the two locations is to investigate the behavior of the reinforced concrete beams when the construction joint is at zero shear and maximum moment and at the zone of small shear and small moment.

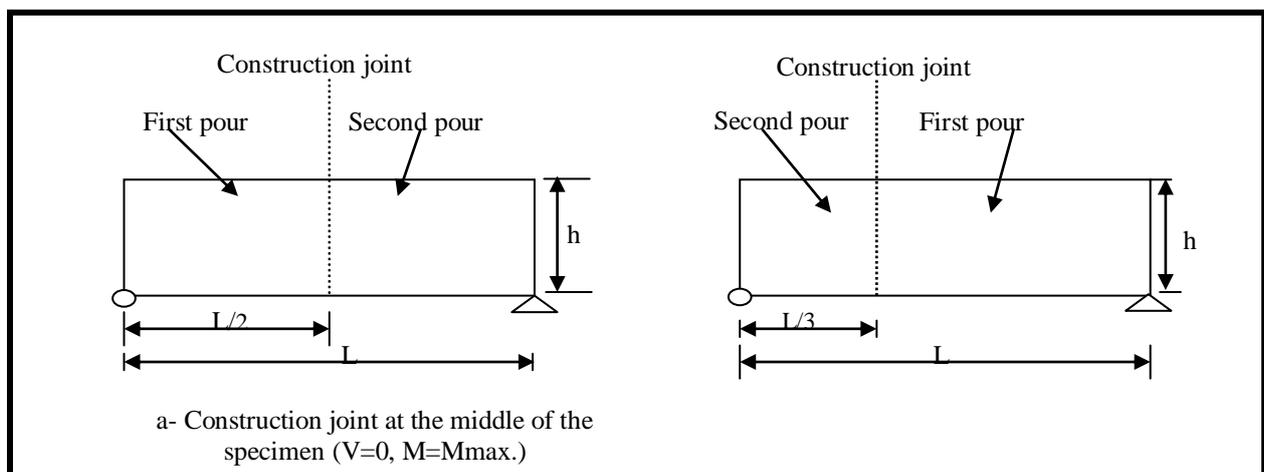


Fig. 2. Location of Construction Joints.

**B. Types of construction joint**

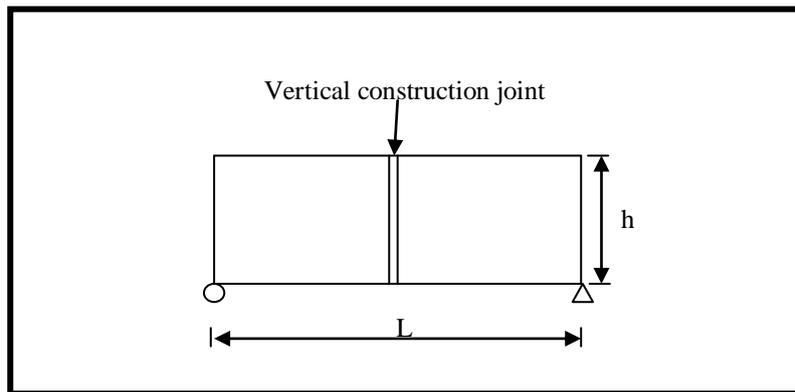
Three types of construction joints were investigated in this study:

**B.1. Vertical construction joint**

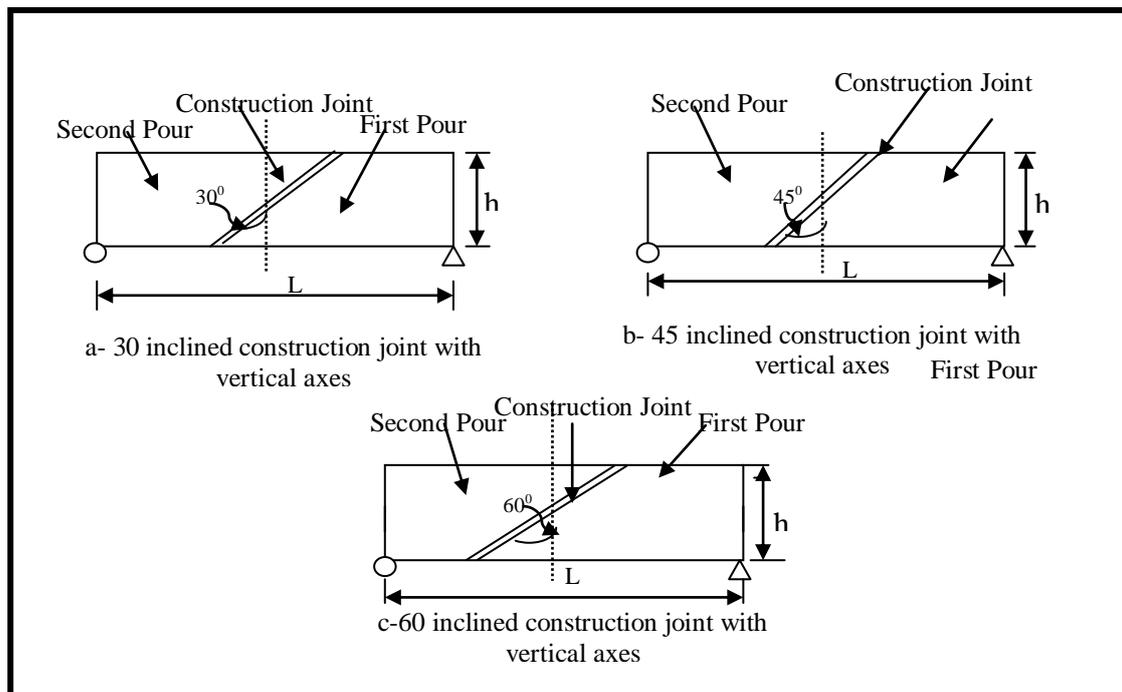
This type of construction joint is made by using stop-board of wood placed vertically after casting the first part of the beam. The stop-board has to be scatted to all longitudinal reinforcement to extend from the old concrete to new one, as shown in Fig. ( 3 ).

**B.2. Inclined construction joints**

In this type of construction joints, the stop-board is cut so that various inclinations of the construction joints can be maintained. Three inclinations were used, 30°, 45° and 60° with the vertical axes, as shown in Fig. (4). The reason for choosing these three inclinations is to investigate the effect of such inclinations on the performance of the beam.



**Fig. 3. Vertical Construction Joint.**



**Fig. 4. Types of Inclined Construction Joints.**

**B.3. Key construction joints**

The key is normally formed by fixing beveled edge strip of wood to a stop board. The stop-board

has to be scatted to all reinforcement to extend from the old concrete to the new one. The details of key construction joints used in this investigation are shown in Fig. (5).

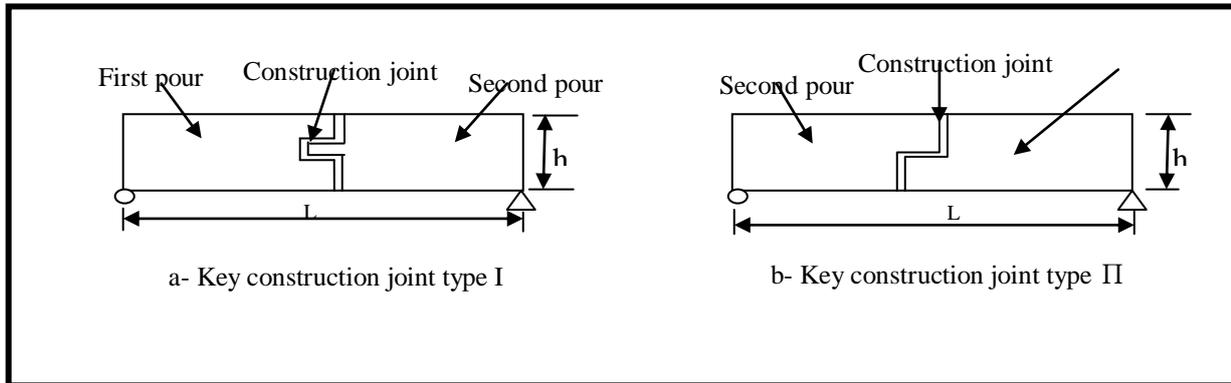


Fig. 5. Types of Key Construction Joints .

**C. Presence of stirrups at the construction joint**

One of the groups contains stirrups at the construction joint located at third point of the

beam it is used to compare the efficiency of such joint with other groups having joint at third point of the beam but without stirrups at that joint, see Table (1).(Note that in key joint , (L) Shape stirrups was used throughout the joint).

Table1, Test Parameters of Beam Specimens.

Series No.	Specimen No.	Location of the joint	Stirrups at joint	Types of Construction joint
Reference beam	19	-	-	Without Construction joint
	1			Vertical
	2			Inclined by 30 <sup>0</sup>
Series one	3	At the middle of the specimen	Without stirrups at the joint	Inclined by 45 <sup>0</sup>
	4			Inclined by 60 <sup>0</sup>
	5			Key joint I
	6			Key joint II
	7			Vertical
Series two	8	At the third point of the specimen	Without stirrups at the joint	Inclined by 30 <sup>0</sup>
	9			Inclined by 45 <sup>0</sup>
	10			Inclined by 60 <sup>0</sup>
	11			Key joint I
	12			Key joint II
	13			Vertical
	14			Inclined by 30 <sup>0</sup>
Series three	15	At the third point of the specimen	Having $\varnothing$ 10 mm stirrups at the joint	Inclined by 45 <sup>0</sup>
	16			Inclined by 60 <sup>0</sup>
	17			Key joint I
	18			Key joint II

\* Note:The concrete compressive strength for all beam specimens was 20 Mpa (using cylinder mold).

### 3. Experimental Work

The experimental work includes 19 simply supported reinforced concrete beams with dimensions of ( 200x 200x950mm), as shown in Fig. (6) and plate(1A,1B). The specimens were reinforced with four longitudinal bars ( 2- $\varnothing$ 12 mm bars at bottom and 2- $\varnothing$ 10 mm bars at top ), and ( $\varnothing$ 10mm ) closed stirrups located at 80mm/c along the beam. Table (2) shows the properties of the reinforcement bars used.

In all mixes, the cement was Ordinary Portland cement, Type I, which was manufactured by the United Company Cement factory/Iraq. Al-Ukhaider natural sand of (4.75mm) maximum size was used as fine aggregate. while the coarse aggregate was crushed gravel with max size of (19mm).Table (3) shows the quantities of concrete mix used in beam specimens.

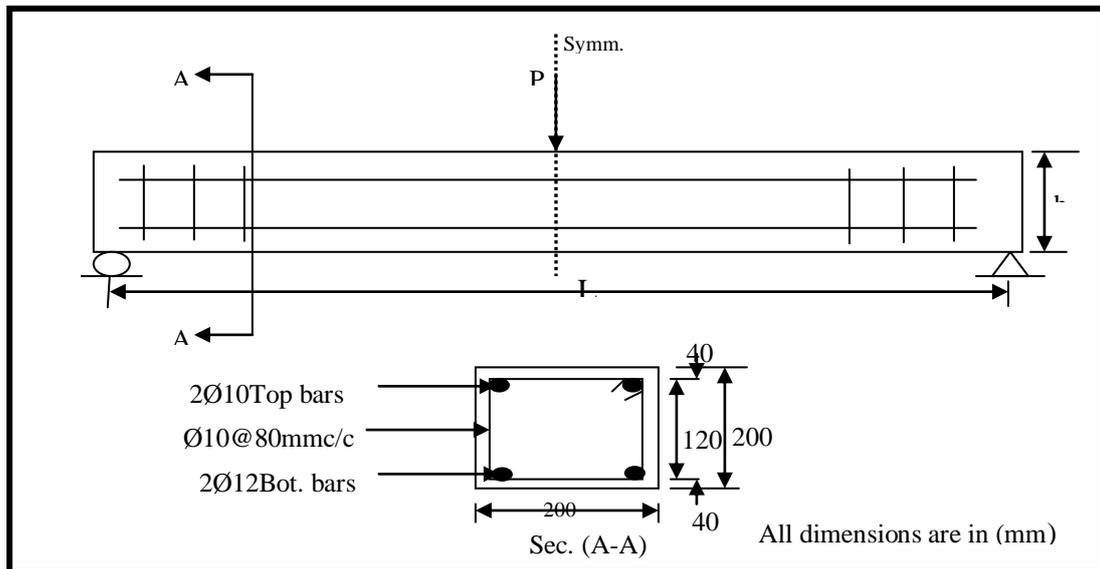


Fig. 6. Dimensions and Reinforcement Details of Beam Specimens.



1A



1B

Plate1: Beam Specimens before Testing (A) and (B).

**Table 2,  
Properties of Reinforcement Bars.**

Bar size(mm)	Area Ab in (mm <sup>2</sup> )	Yield strength in (MPa)	Tensile strength in (MPa)
10	78.5	513	601
12	113	572	666

**Table 3,  
Quantities of Concrete Mix.**

Concrete compressive strength (MPa)	W/C ratio	Cement content (kg/m <sup>3</sup> )	Aggregate content (kg/m <sup>3</sup> )	Sand content (kg/m <sup>3</sup> )
20	0.6	215	1057	641.5

Two slandered cylinders 150x300mm were cast from each batch of concrete during the casting of the first part of the specimen . Another two cylinders were cast with second part of the specimen for each casting operation. Thus, four cylinders for each specimen were made. The

cylinders stored and cured under the same condition as the beam specimens and their compressive strength were measured at the time of testing . Table (4) shows the concrete compressive strength for the beam specimens.

**Table 4,  
Actual Concrete Compressive Strength for the Beam Specimens.**

Series No.	Cylinder No.	Part 1		Part 2	
		Load (kN)	Compressive Strength (MPa)	Load (kN)	Compressive Strength (MPa)
Series one	1	342.8	19.4	349.9	19.8
	2	355.2	20.1	335.7	19
		Average	19.7	Average	19.4
Series two	1	332.2	18.8	326.9	18.5
	2	339.3	19.2	335.7	19
		Average	19	Average	18.7
Series three	1	351.6	19.9	342.8	19.4
	2	360.5	20.4	346.6	19.6
		Average	20.2	Average	19.5

The beam specimens with a construction joint were manufactured by casting one part of the specimen in an oiled plywood forms, and after 7 days the second part was cast to make the beam specimen as a one unit with construction joint between them. No attempt was made to improve the bond at the joint by degreasing or roughening the old face of concrete. Electrical vibrator was used to vibrate the specimens. Vibration process continued for 60 sec. The test specimens were removed from the mould after 10 days. All the specimens were cured for 14 days by sprinkling.

Each specimen was loaded to failure in 1000 kN computer controlled VERSTILE ELECTRONIC TEST MACHINE. The beam specimen is seated on the bending testing table for the machine. The concentrated load was applied at the center of the specimen gradually and the deformation was measured with 0.01 mm dial gauges located at the center of specimen, and at the construction joint when its location is at third point of the specimen. The displacement was recorded by the dial gauge groups at each 10 kN of load until failure occur either by cracking through the construction joint or through the concrete.

4. Results, Discussion and Conclusions

The load deflection curves for beams having construction joints are compared with load

deflection curves for beams without construction joints , as shown in Fig.(7) to Fig.(24). Deflections at center and / or at location of the construction joint are listed in table (5).

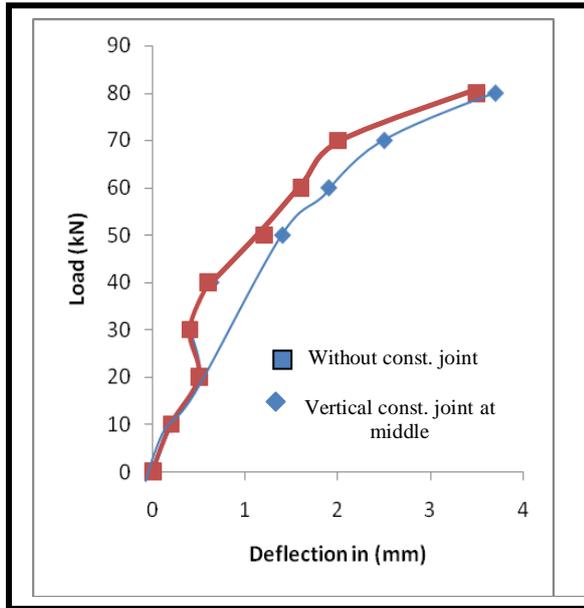


Fig. 7. Load Deflection Behavior of Beam No. (1) (Series one).

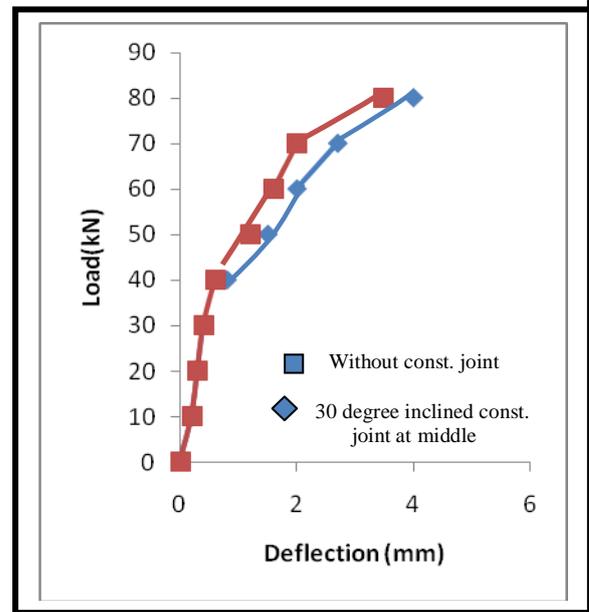


Fig. 8 Load Deflection Behavior of Beam No. (2) (Series one).

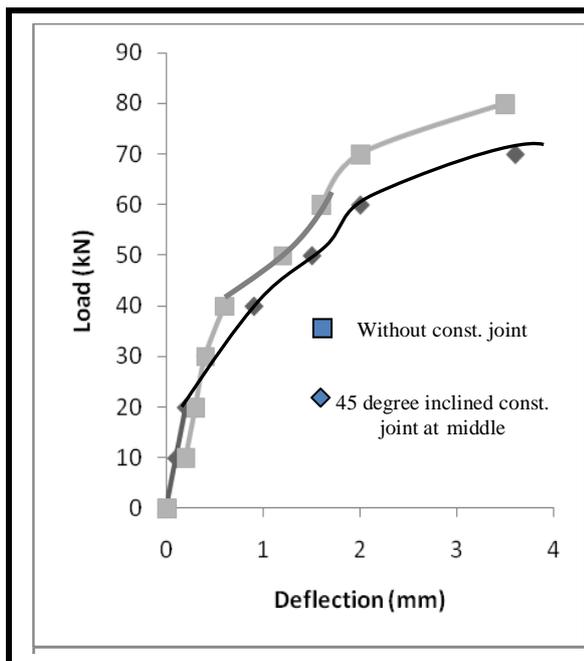


Fig. 9. Load Deflection Behavior of Beam No. (3) (Series one).

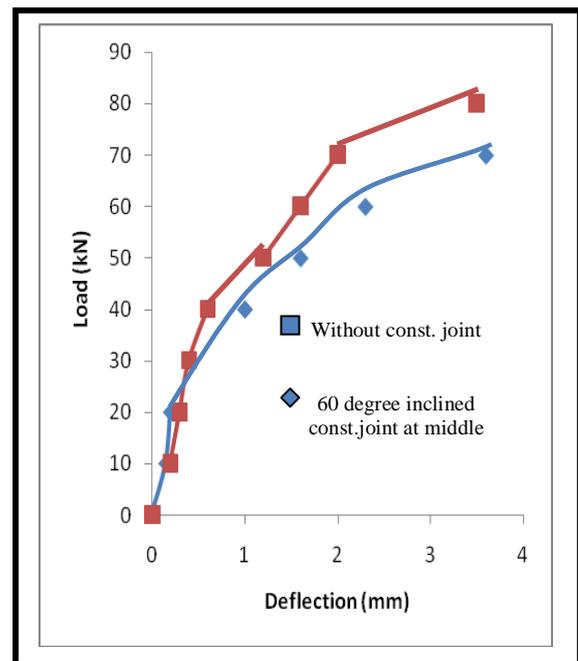


Fig. 10. Load Deflection Behavior of Beam No. (4) (Series one).

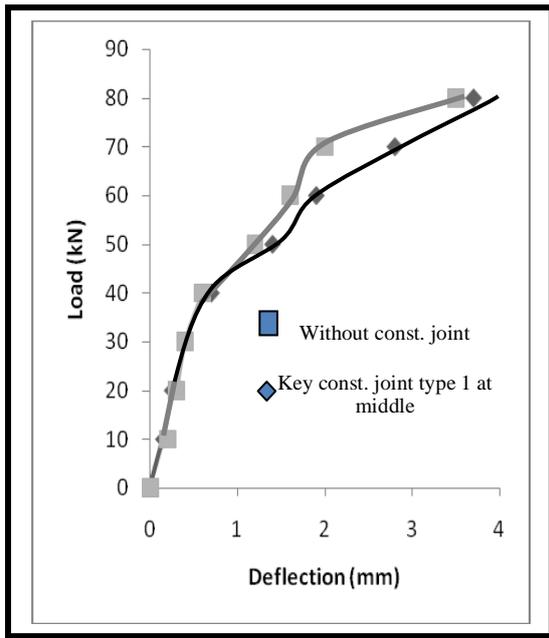


Fig.11. Load Deflection Behavior of Beam No. (5) (Series one).

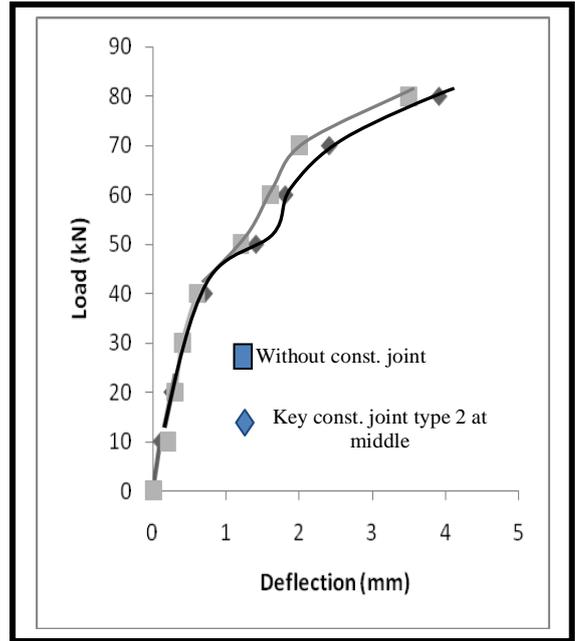


Fig.12. Load Deflection Behavior of Beam No. (6) (Series one).

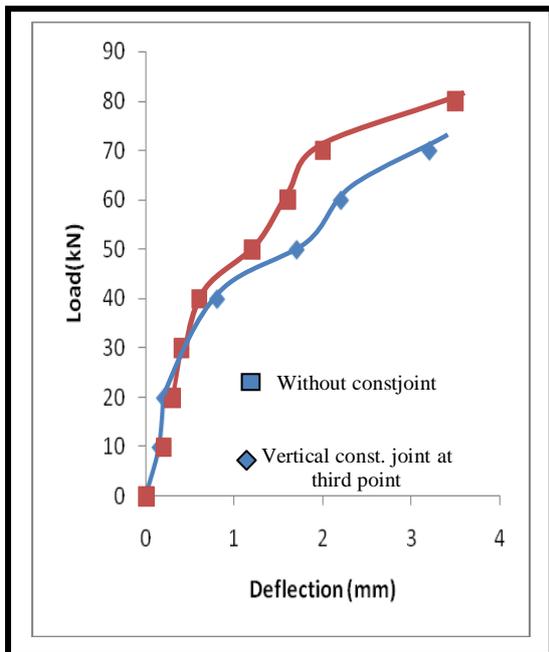


Fig. 13. Load Deflection Behavior of Beam No. (7) (Series two).

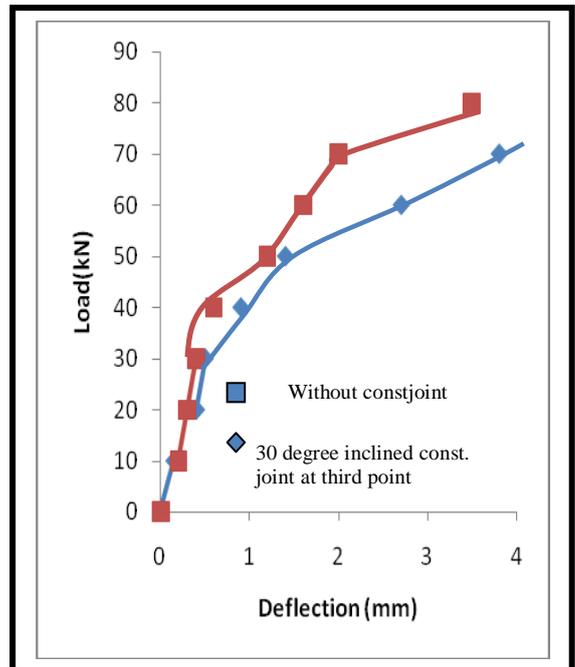


Fig. 14. Load Deflection Behavior of Beam No. (8) (Series two).

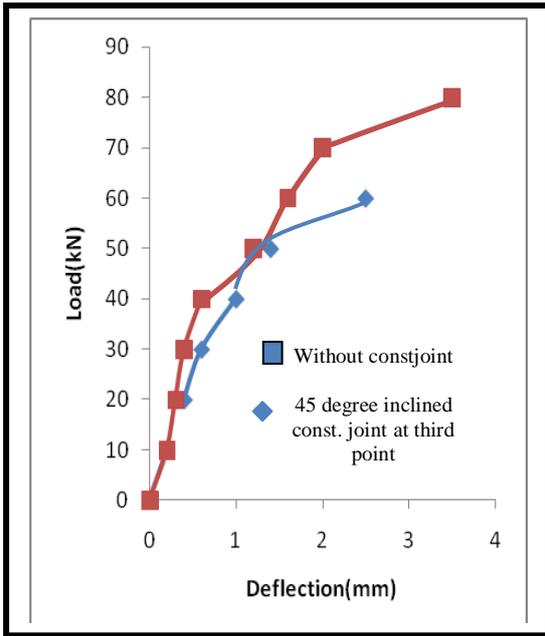


Fig.15. Load Deflection Behavior of Beam No. (9) (Series two).

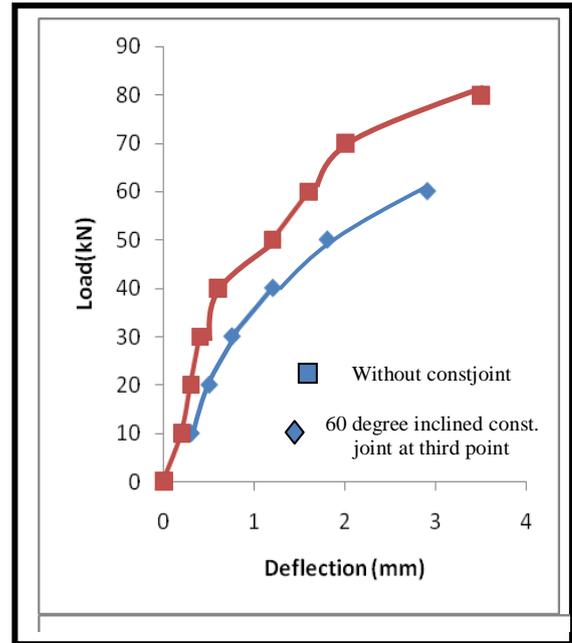


Fig.16. Load Deflection Behavior of Beam No. (10) (Series two).

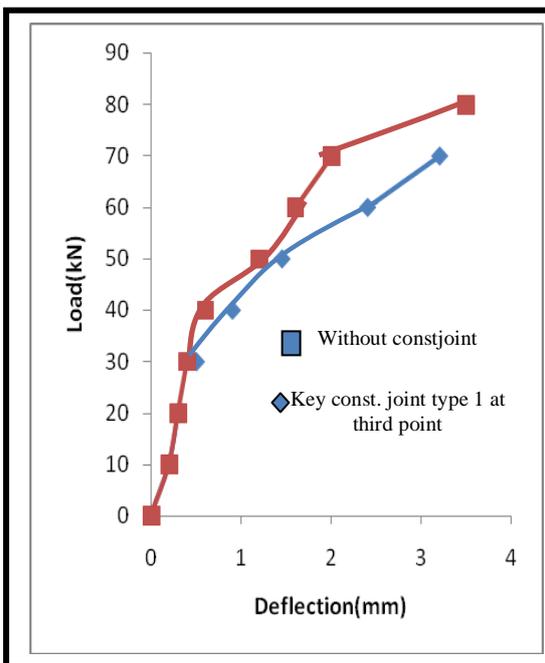


Fig. 17. Load Deflection Behavior of Beam No. (11) (Series two).

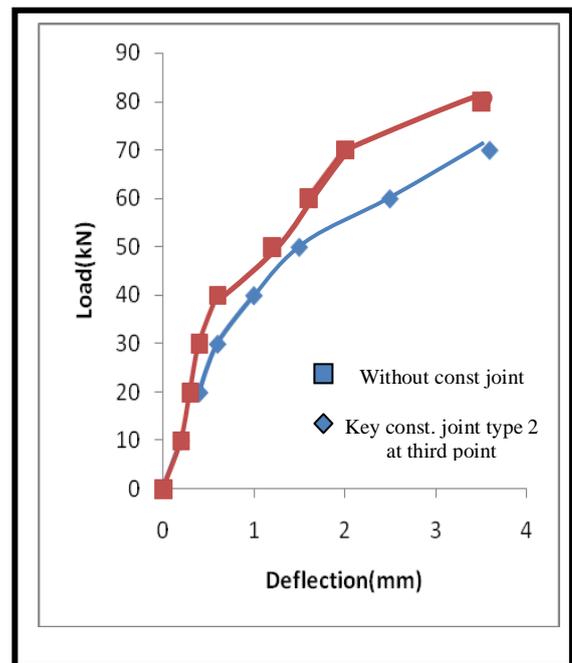


Fig. 18. Load Deflection Behavior of Beam No. (12) (Series two).

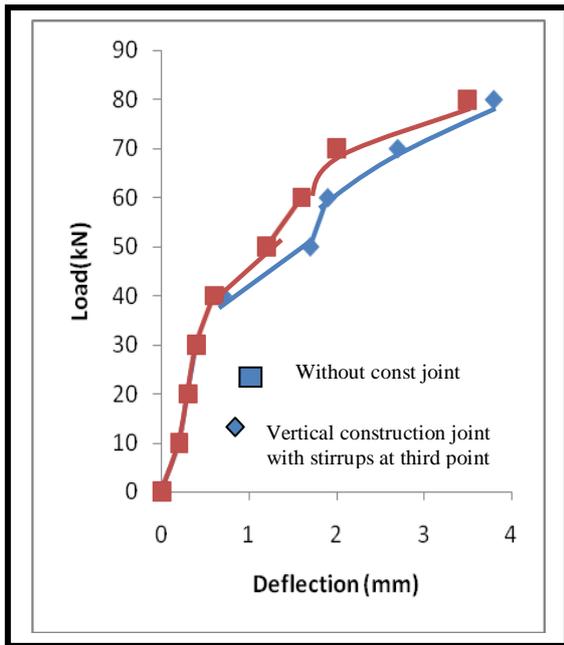


Fig. 19. Load Deflection Behavior of Beam No. (13) (Series three).

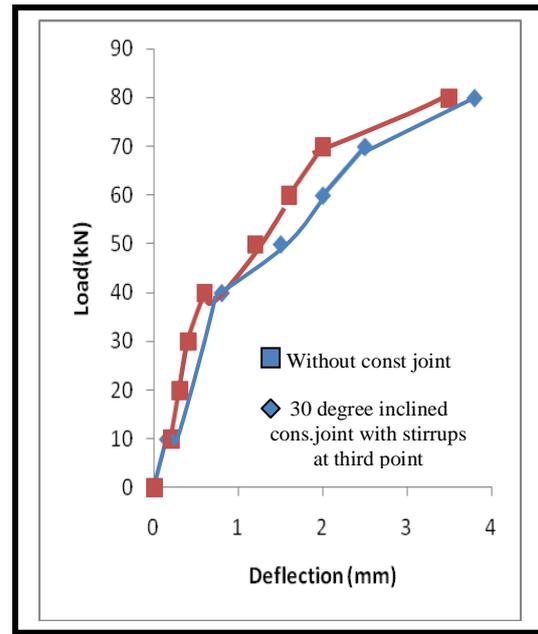


Fig. 20. Load Deflection Behavior Of Beam No. (14) (Series Three).

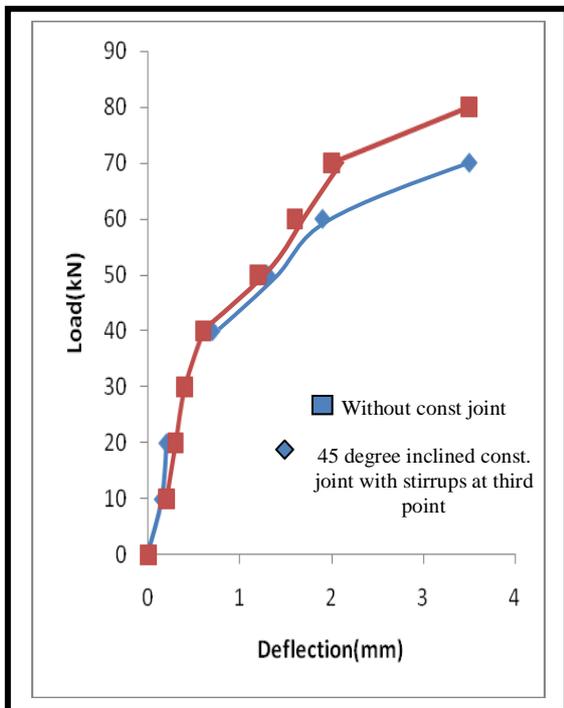


Fig. 21. Load Deflection Behavior of Beam No. (15) (Series three).

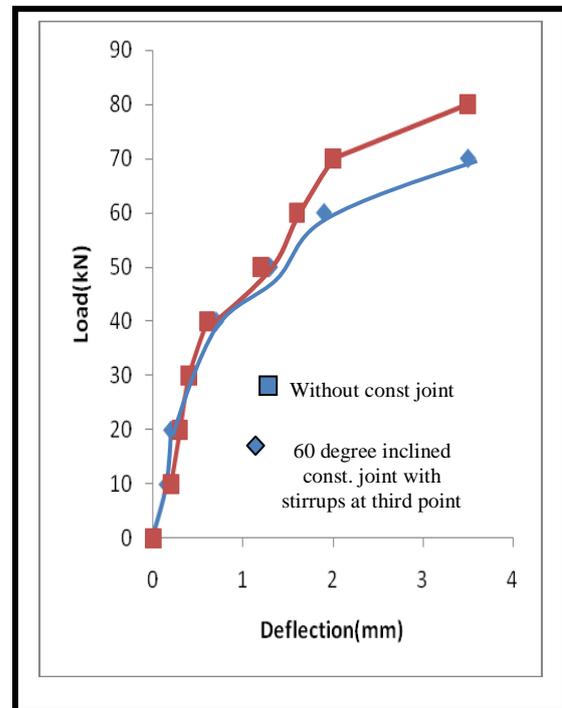


Fig. 22. Load Deflection Behavior of Beam No. (16) (Series three).

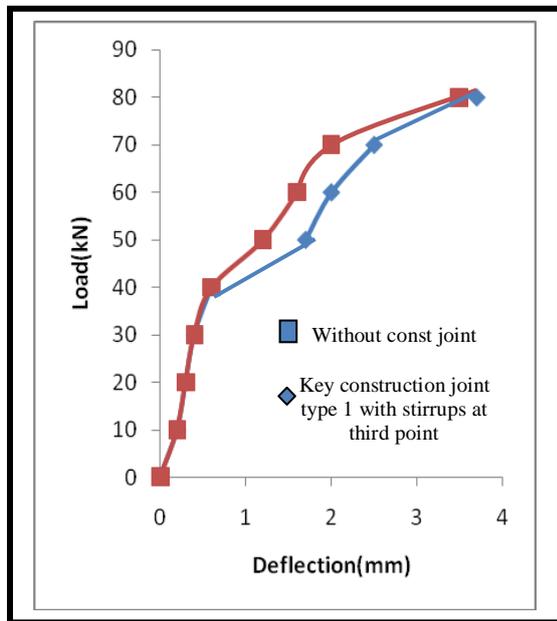


Fig. 23. Load Deflection Behavior of Beam No. (17) (Series three).

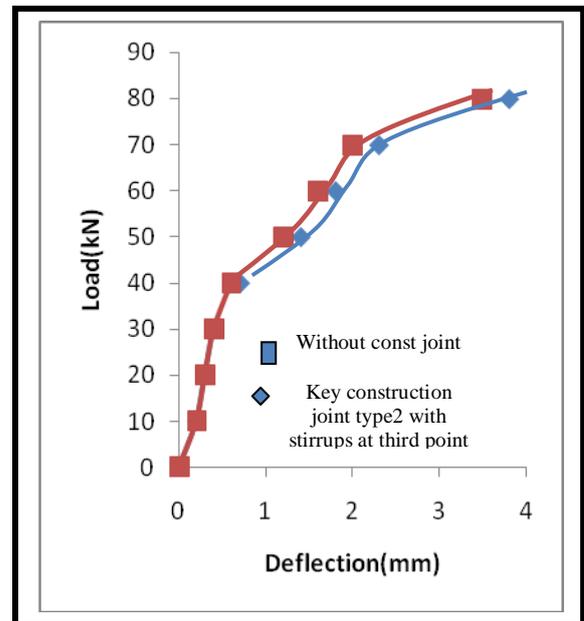


Fig. 24. Load Deflection Behavior of Beam No. (18) (Series three).

Table 5, Load, Type of Failure and Ultimate Deflection of the Tested Beam Specimens.

Series No.	Specimens No.	Type of failure	Ultimate deflection at center (mm)	Failure Load (kN)
Reference beam	19	Flexural failure	3.6	80
Series One	1	Flexural failure	3.7	80
	2	Flexural failure	4	80
	3	Joint failure	3.6	70
	4	Joint failure	3.6	70
	5	Flexural failure	3.7	80
	6	Flexural failure	3.9	80
Series Two	7	Joint failure	3.2	70
	8	Joint failure	3.8	70
	9	Joint failure	2.5	60
	10	Joint failure	2.9	6
	11	Joint failure	3.2	70
	12	Joint failure	3.6	70
T Series Three	13	Flexural failure	3.8	80
	14	Flexural failure	3.8	80
	15	Joint failure	3.5	70
	16	Joint failure	3.7	70
	17	Flexural failure	3.7	80
	18	Flexural failure	3.8	80

The load was applied to the beam specimens until failure occurred through the construction joints or flexural failure developed. Close to failure, the flexural cracks change into inclined shear cracks pointing toward the compression zone. During tests, specimens were examined for cracks. The load at which each crack becomes

visible was marked. The behavior of the reference beam (beam without construction joint) as shown in plate (2) and (3) is similar to ordinary reinforced concrete beams failing in flexure. The first crack develops at the beam center at stress which is close to flexural strength of concrete. As the load increased, several other flexural cracks on

both sides of the central region developed. Near failure which occurs at about 80 kN, these flexural cracks change direction toward the load location. The measured ultimate deflection was 3.6 mm.



**Plate (2) Testing Machine.**



**Plate (3) Beam without Construction Joint (Reference Beam) After Testing .**

For beam specimens with construction joint at middle section of the specimens (series one) the primary type of failure depends on the type of construction joint. The joint failure (crack through the joint) occurs when the construction joint is inclined at an angle greater than or equal  $45^\circ$  with vertical axis, as shown in plate (4).

Flexural crack failure similar to the failure of the reference beam was observed to occur when the inclination angle is less than  $45^\circ$  with vertical axis. The primary type of failure for series two (specimens with construction joints at third point) was by cracking through the construction joint (joint failure). No cracks outside the joint location were observed in these specimens during the test. The load-deflection curves indicate that the deflection at all load levels is greater than the deflection of the reference beam. For series three it is obvious that the presence of stirrups at the construction joints improves the performance of these beams relative to similar beams with construction joints but without stirrups.



**Plate(4) Beam With  $60^\circ$  Inclined Construction Joint at Midspan After Testing.**

The beams with stirrups at the construction joint failed by flexural cracking at higher load level when compared with beam specimens with construction joints but without stirrups at these joints . Specimens with construction joints at third point failed by cracking through the joints as shown in plate (5) at lower load levels of comparable specimens with construction joint at middle of the beam specimens . As shown in Table (5), and Figs. ( 25 ) and ( 26 ).



Plate (5) Beam with Vertical Construction Joint at Third Point without Stirrups after Testing .

The reason for failure through the construction joints located at third points may be explained on the basis of presence of greater tension in concrete at these locations as compared to no tension at mid span. The presence of such tension reduces the shear capacity possibly because adhesion and friction at the interface between new and old concrete may be affected. For beams and slabs it is usual to have construction joints at mid span or in the middle third of the span. These rules are based on the assumption that a construction joint may result in less than 100% of shear capacity at the interface.

The type of construction joints was found to be an important factor affecting the behavior of the tested beams. The vertical and key construction joints have similar performance and the capacity and deflection of these beams are close to that of the reference beam. The effect of inclined construction joints depends primarily on the degree of inclination of the surface of concrete; lower inclination with vertical axis gives higher strength joints. As shown in Table (5) and Figs. (27) and (28).

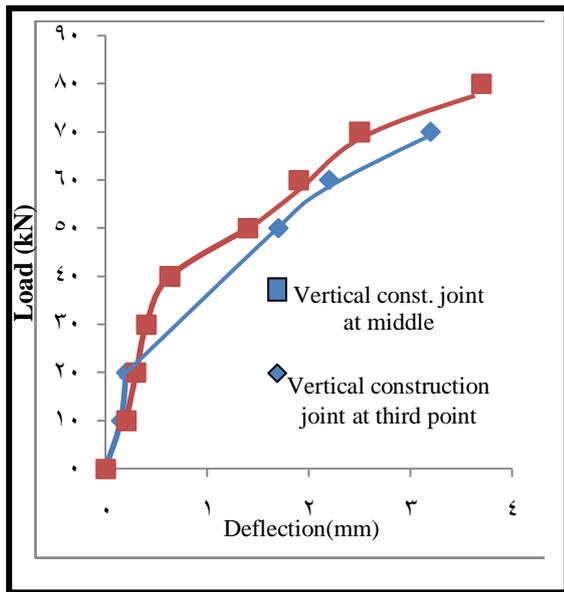


Fig. 25. Effect of Location of Vertical Construction Joint.

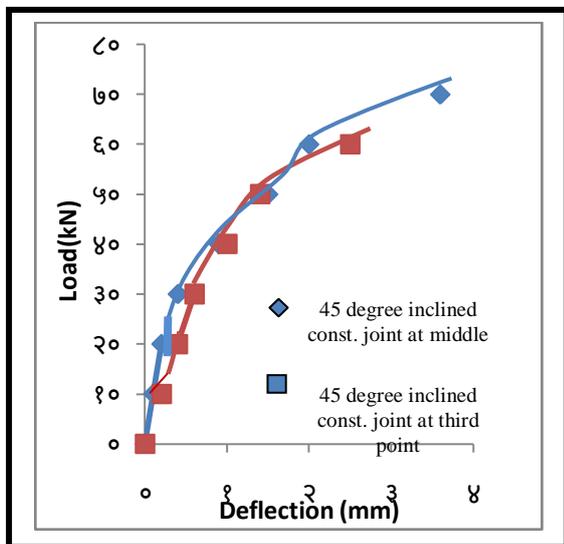


Fig. 26. Effect of Location of 45° Inclined Construction Joint.

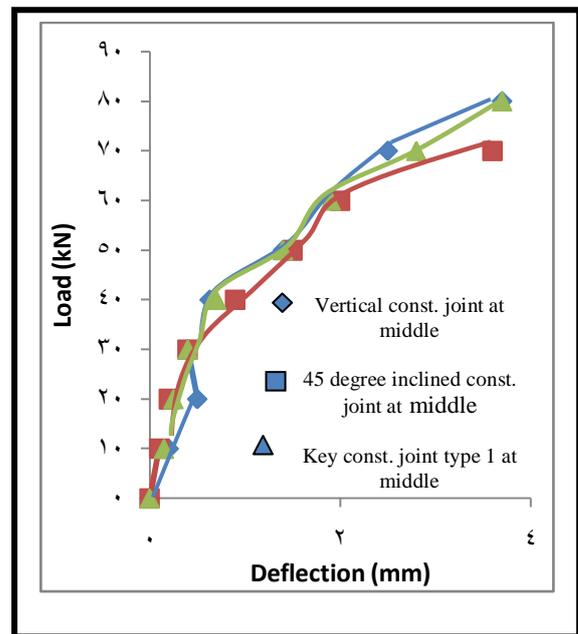


Fig. 27. Effect of Type of Construction Joint at Middle.

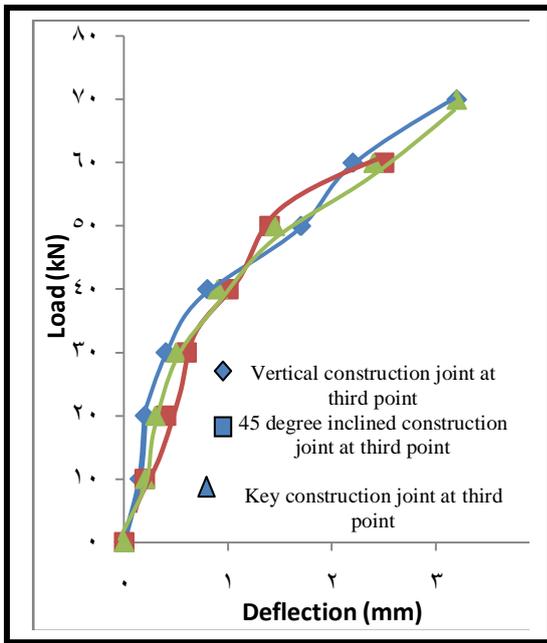


Fig. 28. Effect of Type of Construction Joint at Third Point .

When stirrups were added at the construction joints, the strength of beams increases with the increase in percentage of steel across the construction joint . The behavior of these beam specimens during tests was similar to the behavior of beam specimens of series one where the construction joints at midspan. Table (5) shows that these specimens fail at higher levels of loads when compared with beam specimens with construction joints at third point without stirrups.

Table (5) shows that the type of failure of vertical, 45° inclined construction joint and less with vertical axis, and key construction joints for series three specimens failed by flexural failure which is different from the type of failure of beam specimens of series two which failed by joint failure. It can be concluded that the presence of stirrups at the construction joint have improved the behavior of beam specimens. Figs. (29 ) and (30 ) shows the effect of the presence of stirrups at the construction joints with similar beams having no stirrups at the construction joints.

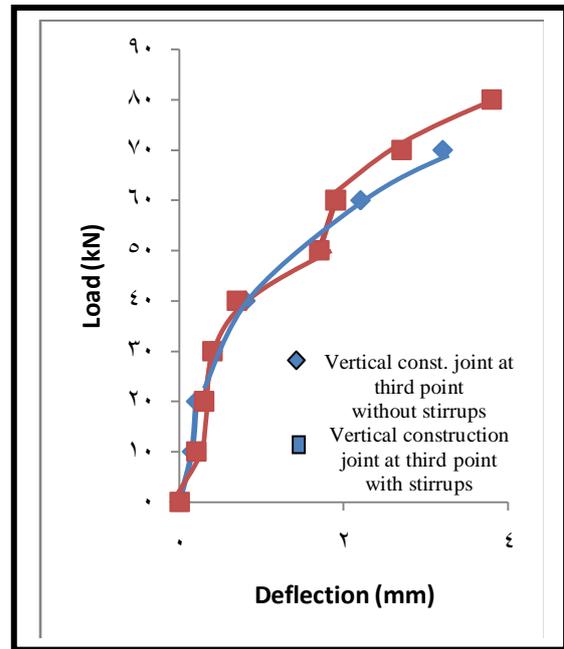


Fig. 29. Effect of Presence of Stirrups at Vertical Construction Joint .

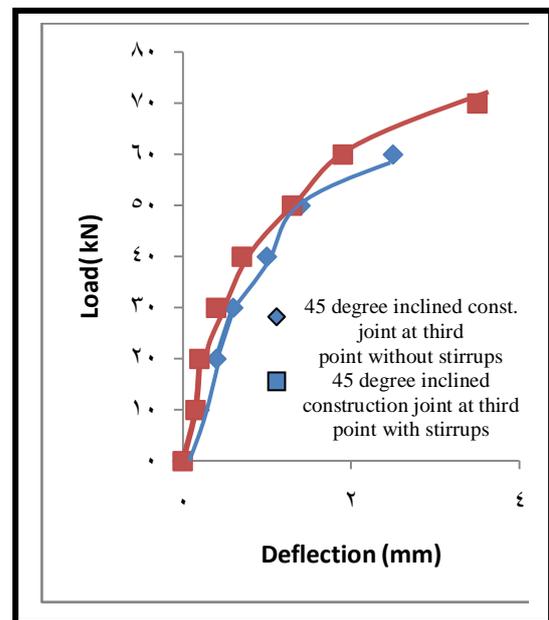


Fig. 30. Effect of Presence of Stirrups at 45° Inclined Construction Joint .

From the experimental results the following conclusions can be drawn:

- 1- It is preferable to locate the construction joint at the point of zero shear perpendicular to the main reinforcement. In this investigation it is found that beams with construction joints at zero shears perform better than beams with construction joint at the third points of specimens (the percentage of reduction in ultimate load capacity is in range of 2% -15%).
- 2- Vertical construction joints have a slight effect on the overall behavior of reinforced concrete beams under flexural mode when they are placed at the middle of the beam span (zero shears). The load carrying capacity for the tested beam with vertical construction joints is about 95% of the capacity of the reference beam without construction joint.
- 3- The effects of inclined construction joints depend primarily on the degree of inclination of the surface of concrete, lower inclination with vertical axis gives higher strength joints. The load carrying capacity of beam with construction joints inclined by  $45^\circ$  is in the range between (8%- 20%) lower than that of beam without construction joint.
- 4- The percentage of steel across the joint (i.e. amount of stirrups at the construction joints) affects the overall load-deflection behavior of reinforced concrete beams having construction joint. As the amount of such steel is increased, the ultimate load-carrying capacity increased. For the studied cases, it is found that increasing the amount of steel across the joint in the range of (50%- 100%) causes an increase in capacity in the range of (7% - 15%) and a decrease in the ultimate deflection in the range of (20% - 48%).
- 5- The performance of beam with vertical or key construction joints is similar to the performance of beams without construction joints.

## 5. References

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## تأثير المفصل الإنشائي على تصرف العتبات الكونكريتية المسلحة

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### الخلاصة

إن المفاصل الإنشائية هي عبارة عن مناطق التوقف في عملية صب الخرسانة و هي ضرورية في عديد من المنشآت التي لا يمكن فيها صب الخرسانة على مرحلة واحدة. إن مقدار الخرسانة التي يمكن صبها يعتمد على السعة الإنتاجية و سعة الخلط في المواقع و على نوعية القوالب المستخدمة. المفصل الإنشائي الجيد يوفر استمرارية للقصر و الانحناء خلال السطح البيئي. في هذا البحث تم دراسة تأثير أنواع و مواقع المفاصل الإنشائية على أداء الأجزاء الخرسائية عن طريق فحص نماذج عمليا في المختبر.

تم فحص 19 نموذج بالأبعاد  $200*200*950$  (ملم). إن المتغيرات التي تم اعتمادها هي موقع المفصل الإنشائي (في منتصف أو ثلث النموذج) ، نوع المفصل الإنشائي (عمودي، مائل بزواوية مع المحور العمودي ، قفل و مفتاح)، و إضافة أطواق في المفصل الإنشائي. تم فحص النماذج بواسطة ماكينة فحص ذات سعة 1000 كيلو نيوتن. وضعت النماذج بشكل يسمح بقياس مقدار الانحراف في منتصف أو تحت المفصل لكل مرحلة حمل. تشير النتائج العملية إلى أن أفضل موقع للمفصل الإنشائي هو في المناطق التي فيها قوى قص قليلة ، و تشير أيضا إلى إن المفصل العمودي ذو تأثير بسيط على قوة النماذج (نسبة الانخفاض جاءت بين 5%-0%) و لكن ، يوجد نقصان ذا تأثير ملحوظ على قوة النماذج مع زيادة درجة ميل المفصل الإنشائي مع المحور العمودي نسبة الانخفاض كانت بين 8%-20%). ووجد في هذه الدراسة أيضا إن إضافة حديد التسليح على شكل أطواق في منطقة المفصل الإنشائي متغير مهم له تأثير على نوع الفشل الحاصل و مقاومة التحمل القصوى ، ووجد إن زيادة كمية الحديد في منطقة المفصل يؤدي إلى زيادة في مقاومة التحمل النهائية ما بين 7%-15%) و نقصان في مقدار الانحراف ما بين 20%-48% .