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EFFECT OF PRESTRESSING STRANDS ON THE LOAD DEFLECTION BEHAVIOR OF STEEL BEAMS

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Abstract: Seven simply supported steel beams were tested to explain the effect of strengthening by external prestressing strands. All of these beams have the same steel section, clear span length and the strengthening samples implemented by two external prestressing strands. The tested beams are divided into two categories according to existing of external prestressing strands, the first category consists of one steel beam as a reference, while, the second group deals with steel beams strengthening by external prestressing strands and consists of six steel beams divided according to the eccentricity location of prestressing strand with jacking stress (814.589 MPa). During the teste, it was found that the load deflection curves for tested beams strengthening with external prestressing strand are stiffer as compare with the reference beams and the percentage of stiffening increase with increasing the eccentricity locations, while, the maximum load deflection increase to 0.173%, 26.086%, 33.043%, 48.521%, 13.739 % and 69.565 % with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam, on the other hand the increasing percentage in deflection at mid span decrease to -29.094%, -7.753%, -19.764%, 11.976%, -8.965% and -23.779% with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam and the quarter span deflection to mid span deflection ratio (δ quarter / δ mid) is bout (0.497) .

Keyword: *Deflection behavior, strengthening of steel beams, prestressing strand, eccentricity location.*

تاثير الحديد المسبق الجهد على تصرف حمل الانحناء للعتبات الفولاذية

الخلاصة: في هذا البحث تم أجراء التحري العملي بأستخدام تقنية الأجهاد المسبق الخارجي في تقوية العتبات الفولاذية باستخدام الاجهاد المسبق الجهد الخارجي حيث شمل الجانب العملي على فحص سبعة عتبات فولاذية والمقواة بواسطة الحديد المسبق الجهد.جميع العتبات الفولاذية لها نفس مساحة المقطع وطول الفضاء الصافي والمقواةمنها انجزت بنفس نوع الحديد المسبق الجهد بعدد اثنين وبقطر (12.7) ملم.قسمت هذه النماذج الى مجموعتين رئيسيتين حسب وجود الحديد المسبق الجهد. تحتوي المجموعة الاولى على نموذج فولاذي واحد غير حاوي على حديد مسبق الجهد واعتبر كمرجع (مصدر) للمقارنة مع النماذج الاخرى. بينماتحتوي المجوعة الثانية على العتبات الفولاذية المقواة بالحديد المسبق الجهد وتضم ستة نماذج حسب موقع الحديد المسبق الجهد في العتبة الفولاذية وباجهاد سحب مقداره (814.589 نت/ملم^2). من خلال الفحص وجد انة سلوك منحني الحمل مع الهطول للعتبات الفولاذية المقواه بحديد مسبق الجهد تكون اكثر انحدارا وان نسبة الانحدار تزداد كلما زادت بعد موقع الحديد المسبق الجهد عن مركز العتبة الفولاذية .وان نسبة الزيادة في الحمل الاعظم المسلط تزداد بمقدار (0.173%و26.086%و33.043%و48.521%و13.739%و69.565%) عند زيادة بعد موقع الحديد المسبق الجهد عن المركز وعند مقارنتها مع العتبة الفولاذية المرجعية (المصدر). ومن ناحية اخرى فان مقدار الهطول الحاصل في العتبات المقواة بالحديد المسبق الجهد تقل بمقدار(29.094-%و 7.753- %و 19.764-%و-1.976%و8.965-%و23.779-%) عند زيادة بعد موقع الحديد المسبق الجهد عن عند مقارنتها مع العتبة الفولاذية المرجعية (المصدر).وكذلك فان نسبة هطول ربع الفضاء الى نصف الفضاء ($\delta_{quarter} / \delta_{mid}$)) تكون بمعدل (0.479).

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1. Introduction

Steel is the most important construction material at the present time due to a high strength to weight ratio, uniform and homogeneous properties, high ductility, can be easily recycled, high elastic modules, high amount of energy absorption in seismic action, easier, quicker to fabricate and erect. Dimension of beams and column in steel frame can be reduced because of the low ultimate load to self-weight ratio. As a result self-weight ratio between reinforced concrete and steel building can be reduced down to 1/10[1].

Producing permanent stress in the structural member to improve resistance against service loads is called as prestress or prestressing. Prestressing is a purposeful phenomenon aims to generate internal stress in structural member to counter balance stressed caused by external loads so as to enhance performance and durability of the structural members [2, 3].

2. External Prestressing.

External prestressing refers to a posttensioning method in which tendons are placed on the outside of a structural member and prestressing forces are transferred to the structural member through anchorages and deviators. It is a wonderful method in strengthening and rehabilitation of old structural members, generally it is used for developing buildings and bridges for fatigue state and over loading design expected[4].
The concept of external prestressing of steel beams is achieved by means of high strength strand anchored at the two ends of steel beams. The strand profile can be fixed on the internal span length by a specific number of saddles which it prevent slipping occurs in the strand and help to give the design profile shape of the external prestressing strand (draped, or parabolic) depending on the applied load and bending moment diagrams introduced [5] as shown in Fig. (1), then the strand was tensioned simultaneously from one ends using the same jacking force used in tensioning the prestressing strand. Special care must be taken to balance the prestressing force in the strands to avoid biaxial bending and distortion of the specimens [8]

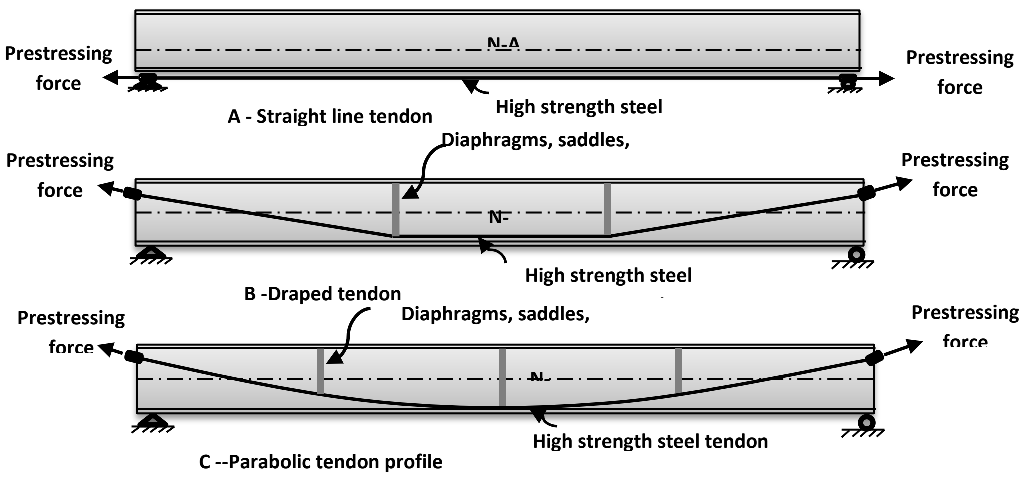


Figure (1) Strenthening by external high strength steel strands.

3. Research Significance

Steel structures have been used in the construction industry for centuries. Many modification and developments have been made to improve the performance of steel properties by adding a new material to the row material of steel manufactures. Engineers have found new mothed to improve of the original steel section strengths by external prestressing strand. The main objective of the work described in this study is to investigate and to get more information and more understanding about the deflection behavior of I-steel beams strengthening by external prestressing strands and compared with the reference steel beam.

4. Tested Program.

4.1 Description of Specimens.

During the design phase of the experimental stages, the variable parameters included in this study are focused mainly on the existence of prestressing strands and layout of prestressing level (i.e. the eccentricity of the prestressing strand (e)). Six simply supported steel beams strengthening by external prestressing under one point load and one reference beam without prestressing strands were tested. All specimens have same I-section, two external prestressing strands of (12.7mm) diameter, the ends steel plate (25x125x250) mm and clear span length (2580) mm.

4.2 Specimens Identification and Retrofitting Schemes.

To identify the tested specimens with different retrofitting schemes, which it depending on different parameters such as amount of prestressing jacking stress and the layout of prestressing strands, the following system is used:

X_1 X_2 X_3, X_4, X_5

Where:

X_1: refer to type of tested beam type.

O : for original reference steel beam without any prestressing strand.

X_2: refer to initial jacking stress(fp_j) .

L= initial prestressing jacking stress (814.589 MPa) applied.

X_3= eccentricity of prestressing strand at mid span

0= when the eccentricity of prestressing strand at neutral axis of steel beam

1= when the eccentricity of prestressing strand at (96 mm) below neutral axis of steel beam

2= when the eccentricity of prestressing strand at (165 mm) below neutral axis of steel beam

X_4= eccentricity of prestressing strand at end span

0= when the eccentricity of prestressing strand at neutral axis of steel beam

1= when the eccentricity of prestressing strand at (20 mm) below neutral axis of steel beam

2= when the eccentricity of prestressing strand at (96 mm) below neutral axis of steel beam

3= when the eccentricity of prestressing strand at (165 mm) below neutral axis of steel beam

X_5 = eccentricity of prestressing strand at critical effective depth for shear span

0 = when the eccentricity of prestressing strand at neutral axis of steel beam

1 = when the eccentricity of prestressing strand at (19.15 mm) below neutral axis of steel beam

2 = when the eccentricity of prestressing strand at (35.45 mm) below neutral axis of steel beam

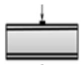
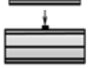
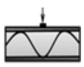
3 = when the eccentricity of prestressing strand at (96 mm) below neutral axis of steel beam

4 = when the eccentricity of prestressing strand at (165 mm) below neutral axis of steel beam

5 = when the eccentricity of prestressing strand at (39 mm) above neutral axis of steel beam

All definition of samples can be listed in flow-chart shown in Fig.(2) and the table (1) illustrates the used specimen identification system used based on specimen identification pattern described, while, the details of test specimens are shown in Fig. (3).

Table (1) Description details of tested specimens

Categories	Groups	Beams No.	Serial Symbols	Prestressing Strand Profile	Beams Shape	Eccentricity (e), (mm)		
						e_1*	e_2**	e_3***
1	1	Ref.	O	----		----	----	----
2	2	1	OL000	Straight with $e_1e_2e_3$ (000)		0	0	0
		2	OL101	Draped with $e_1e_2e_3$(101)		96	0	19.514
		3	OL112	Draped with $e_1e_2e_3$ (112)		96	20	35.45
		4	OL123	Straight with $e_1e_2e_3$ (123)		96	96	96
		5	OL234	Straight with $e_1e_2e_3$ (234)		165	165	165
		6	OL105	Sinewave profile with $e_1e_2e_3$ (105)		96	0	-39

Where: - e_1* = Eccentricity at mid span. e_2** = Eccentricity at end span. e_3*** = Eccentricity at effective depth for shear zone.

Tested Samples (7 specimens)

- **Ref. (1 specimen)**
  - O
- **Steel Beams Strengthening with Prestressing Strands (6 specimens)**
  - **Divided according to Eccentricity Location**
    - **OL000** | **Ol101** | **OL112** | **Ol123** | **Ol234** | **OL105**

Figure (2) Flow chart of the experimental details of tested beams

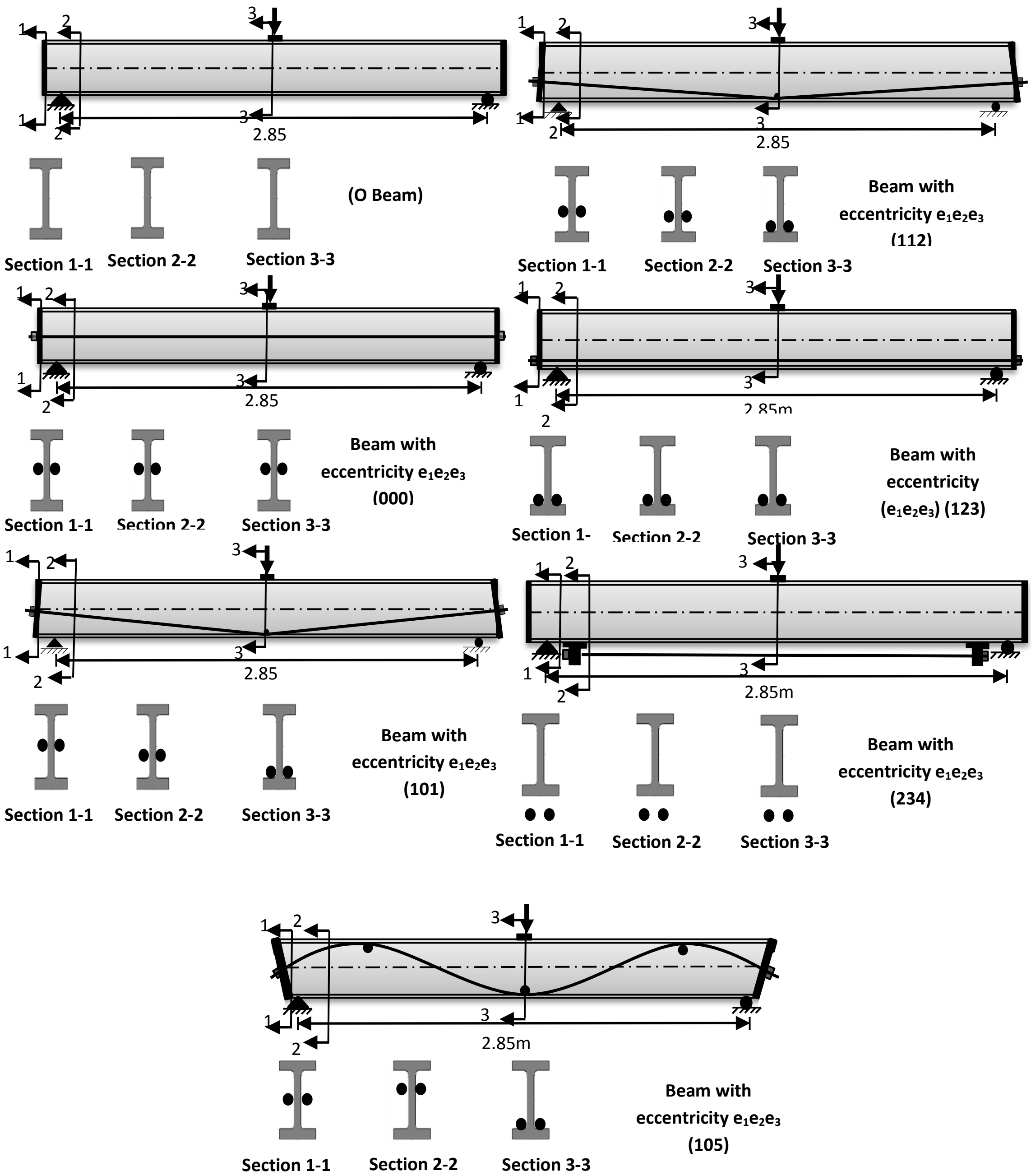


Figure (3) Details of tested beams

4.3 Material Properties of the Test Specimens and Fabrication.

4.3.1 Structural Steel Type.

SS400 steel is one commonly hot rolled steel and used in the general structural element applications. SS400 is a material grade and designation defined in JIS G 3101 standard. JIS G 3101 is a Japanese material standard for hot Rolled steel plates, sheets, strips for general structural usage, according to this specification, the thickness for this SS400 material starts from 6 mm to 120 mm, the chemical composition of SS400 steels is listed in table (2), while the mechanical properties of SS400 Steels is listed in table (3) [7,8].

Table (2) Chemical Composition for SS400 Specification [7, 8]

Grad	*Chemical composition,% by weight*				
	Carbon Max.	Silicon Max.	Manganese Max.	Phosphorus Max.	Sulfur Max.
SS400	*	*	*	0.05	0.05

* = Content is not controlled

Table (3) Mechanical Properties for SS400 Specification [7, 8]

Grad	*Min .Yielding Strength according to Thickness (MPa)*		*Tensile strength, (MPa)*	*Elongation according to Thickness, (mm)*			*Min Impact resistance, (J)*
	not over 16 mm	over 16 mm		not over 5 mm	5 to 16 mm	over 16 mm	
SS400	245	235	400-510	21	17	19	*

* = Content is not controlled

4.3.2 Structural Steel Section, Fabrication and Plate Tests.

I-shape is a structural element which has a cross section forms the letter H and is the most widely used structural member. It is designed so that its flanges provide strength in a horizontal plane, while the web gives strength in a vertical plane. I-shapes are used as beams, columns, truss members, and in other load-bearing applications [9]. Hot rolled steel I-section with 25.7 kg/m mass per meter which it is manufactory in China and it used in this study. Table (4) shows geometrical details of steel section, while the end Steel plate can be welded directly to the steel beam by using welding process. The welds are 5 mm fillet welds made with E7018 electrodes. The end plates have two holes to allow to the prestressing strand to pass through them. End plate must be normally to the strand profile area as possible to reduce the stress concentration around the hole in the end plate and its can be problematic if the structural member is already under strength also local stiffeners may be required at end plate to prevent local buckling occur in the end plate [10]. The cutting process was conducted by using automaticity technique by using Computer Numerical Control (CNC) (ajan cnc) plasma machine to obtain exact design dimension and smooth cutting shapes.

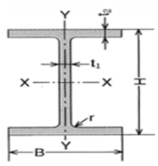


Table (4) Dimension and properties of steel section [11]

Size mm	Thickness mm		Radius of curvature mm	Cross sectional area mm^2x10^2	Mass per meter Kg/m	Moment of inertia mm^4x10^4		Radius of gyration mm		Elastic section modulus $mm^3x\ 10^3$	
H x B	t1	t2	r	Ag		Ix. x	Iy. y	rx	ry	Sx	Sy
248 x124	5	8	12	32.68	25.7	3540	255	104	27.9	285	41.1

The direct tension test was performed in the National Center for Constriction Laboratories and Research (NCCLR), the used machine for tests is (Zwick/Roell) universal hydraulic machine of (1200kN) capacity which used in testing direct tension steel symbols. The results of three specimens testing are listed in table (5) and the stress strain curve of the three specimens testing is shown in Fig. (4).

Table (5) Material properties of steel test symbols based on direct tension test

Standards Specifications	*Symbols No.*	*Min .Yielding Strength(Fy), MPa*	*Min. Ultimate Tensile strength (Fu), MPa*	*Total Elongation, %*
NCCLR according to ASTM A36/ A36-2005[12]	PL 10	356	524	25.2
	PL 20	369	507	17.5
	PL 30	360	507	15.9
	Average value	362	513	19.6
American ASTM A36/ A36-2014[13]		≥250	≥400	≥20 *
Japan of JIS G 3101[7]		≥245	≥400	≥17
Teste of results		Conforming	Conforming	Conforming

*=For wide flange shapes with flange thickness over (75 mm),the (550 MPa) maximum tensile strength does not applied and the minimum elongation of 19 % is applied [12,13]

So, one can be observed that all results value obtained from NCCLR were conforming to the technical standards specifications.

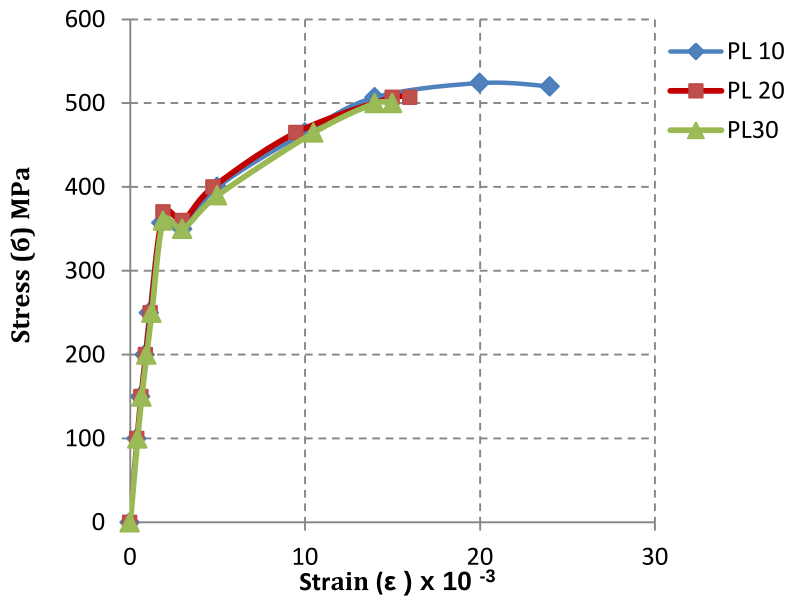


Figure (4) stress strain curve of steel plate specimens

4.3.3 Prestressing Steel Strands.

4.3.3.1 Prestressing Steel Strands test.

Prestressing strand grade 270 low relaxation Seven-wire strands of (12.7mm) nominal diameter which manufactured by national meatal manufacturing and casting company (MAADANIYAH, Kingdom of Saudi Arabia) which used in this study. They strand was tested in the National Center for Constriction Laboratories and Research (NCCLR) and confirming to ASTM A416/ A416M-12a [14].The properties of the strand is shown in Fig. (5).

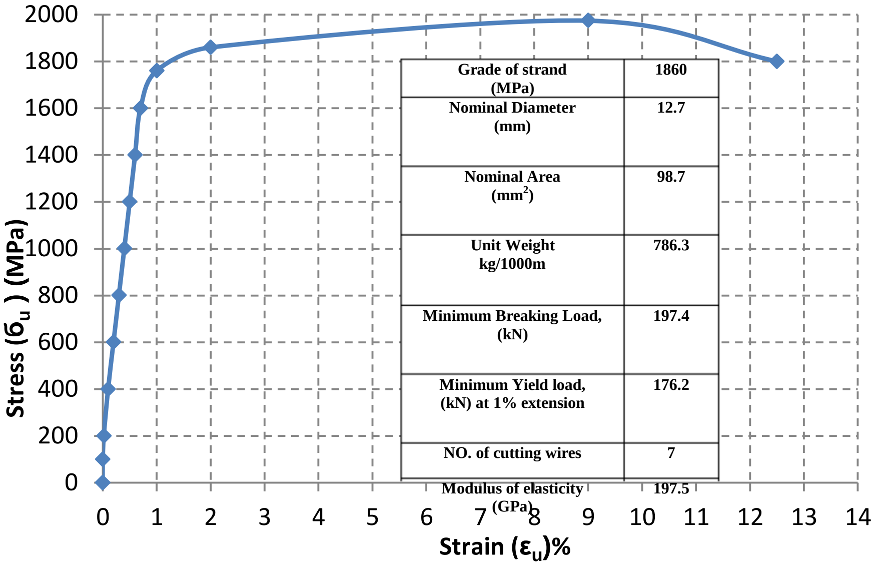


Figure (5) stress -strain curve of grade 270 low relaxation seven wire strands at (12.7 mm) diameter

4.3.3.2 Jacking Stress Applied.

Tow low relaxation seven wire strands at (12.7 mm) diameter were selected and arranged at different location of eccentricity ranging from (0 to 165) through the longitudinal axis of the tested beams. Prestressing strands are passed through out a thick steel bearing plates (25 x250x125) mm fixed at both ends of tested beams by welding process. The welds are 5 mm fillet welds made with E7018 electrodes, which have two holes, were formed to allow to the prestressing strand to pass through them. Prestressing strands are fixed firstly at the dead end using special wedge anchored (grips) and finally anchored at the jacking end, then the steel strands are individually tensioned with the jacking end by using single strand jack operated by a motor-driven hydraulic pump. The two strands were tension simultaneously from one end with gradually increasing in jacking stress until reaching to denoted jacking stress to balance the prestressing stresses and avoid the biaxial bending stress which introduce in the steel section during applied jacking stress(fp_j). Prestressing level was applied at (200 bar), the prestressing stress converter from (bar) to (MPa) are listed as the following:

Bar converter to Mpa:

1bar = 1.01975[15] kgf/cm ^{2}

The specific of gravity (g) = 9.80665[16] m/s^2

Then the converter factor will be =1.01975x9.80665=10
Jacking prestressing stress= 200x10= 2000 N/cm^2
The ram area of single-pull jack = 40.2 cm^2.
Jack force = jacking prestressing stress x ram area
= 2000x40.2
Jack force = 80400 N
Jacking prestressing stress = Jack force/strand area = 80400/98.7
=814.589 MPa
Then the percentage of jacking prestressing stress to ultimate stress ratio will be Jacking prestressing stress/ultimate stress = 814.589/1860
= $0.438 f_{pu} < 0.7 f_{pu}$ ok
For post tensioning tendons at anchorage devices and coupler immediately after force transfer $< 0.7 f_{pu}$ [17]
The hydraulic machine consists of motor-driven hydraulic pump, hydraulic pipes attached to the four hydraulic jacks and to the single strand jack and measuring gauge to notice the applied pressure with (bar unit) which graduated from 0 to 600 bar, as shown in Fig. (6).

Figure (6) Hydraulic machine and single strand jack prestressing strand.

4.4. Deflection Measurements.

Deflection measurements are taken at two points by using two dial gauges of (0.01mm) accuracy with (300mm) capacity. For each tested beam, one dial gauge is placed under concentrated point load at mid span, while, the other one is placed at quarter span. The locations of the dial gauges are shown in Fig. (7).

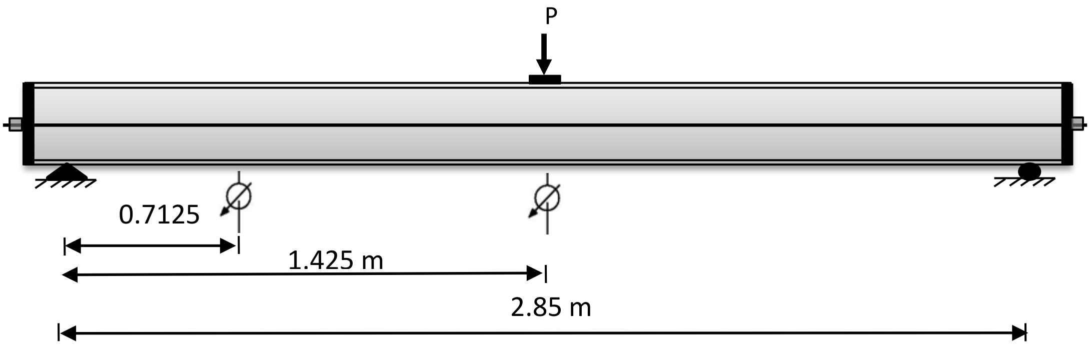


Figure (7) Locations of dial gauges for tested beams

4.5. Load Measurements and Testing Procedure.

Steel beams test were conducted in the Structural Laboratory of the Civil Engineering Department, at the College of Engineering, University of Al-Mustansiriyah. The used machine for tests is (MFL) universal hydraulic machine of (3000kN) capacity. Simply supported steel beams are tested under one concentrated point load at mid span, steel beam are placed with clear span of (2850mm). Steel bearing plate (12x100) mm is used to convert the applied load to line load over the steel beam surface,

At time of test, steel beam is placed over supports; deflection dial gauges of (0.01 mm) accuracy with (30 mm) capacity are fixed in the designated locations at mid and quarter span. All dial gauges were rested to zero. Load of (5kN) is applied and removed in order to recheck the zero readings. All the tests are carried out under load step of (2kN) and measurements are taken at each (10kN) increment, strain gauges reading and dial gauges are taken at each increment. Measurements are recorded until the failure of steel beams at which the applied load is drop with increasing deformation, the test machine and instrumentation details show in Fig.(8)

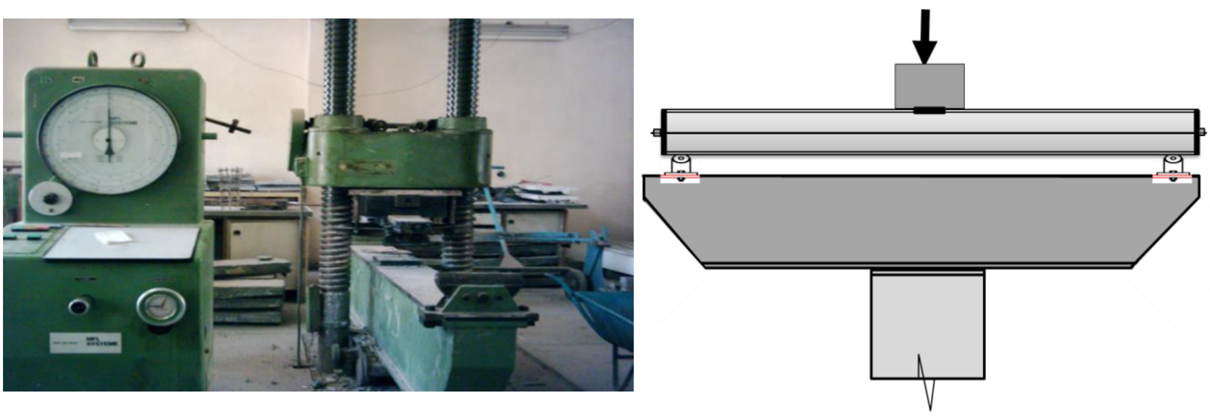


Figure (8) Test machine and loading arrangements

5. Experimental parametric studies.

The tested beams are divided into two categories according to existing of external prestressing strands, the first category consists of one steel beam as a reference, while, the second group deals with steel beams strengthening by external prestressing strands consists of six steel beams divided according to the eccentricity location of prestressing strand (e) ranging from (0 to 165) mm with jacking stress (fp_j = 814.59 MPa). This experimental study has been carried out to investigate the effect of eccentricity location on the deflection behaviors of steel beams strengthening by external prestressing strand under one point load. The experimental deflection information's for tested beams were monitored through two dial gauges fixed at quarter and mid span length during applied load until failure occurs. Full experimental results of tested beams are illustrated in table (6).

Table (6) Experimental load deflection results of tested beams

Categories	Beams No*.	Series Symbols	Maximum Exp. applied load (Pu) (kN)	Maximum Exp. deflection at quarter span (mm))	Maximum Exp. deflection at mid span (mm)
1	*Ref.*	O	287.50	13.200	28.890
	1	OL000	288.00	11.700	20.500
	2	OL101	362.50	15.000	26.650
2	*3*	OL112	382.50	12.100	23.180
	4	OL123	327.00	14.850	26.300
	5	OL234	487.50	12.400	22.020
	6	OL105	427.00	14.750	32.350

5.1 Load Deflection Response.

In order to investigate the effect of the locations of eccentricity on the load deflection curves of tested beams, the tested beams are divided into six beams tested at different location of eccentricity ranging from (0 to 165) mm with jacking stress (fp_j = 814.589 MPa).During the test, it can be observed that the load deflection curves for tested beams strengthening with external prestressing strand are stiffer as compare with the reference beam and the percentage of stiffening increase with increasing the eccentricity locations. That due to exist of external prestressing strand which improved the web resistance and bottom flange and it's also contribute to resist the applied load, as shown in Fig.(9) and Fig.(10). While the comparison between the mid and quarter span deflection at same condition for tested beams are shown in Fig. (11).

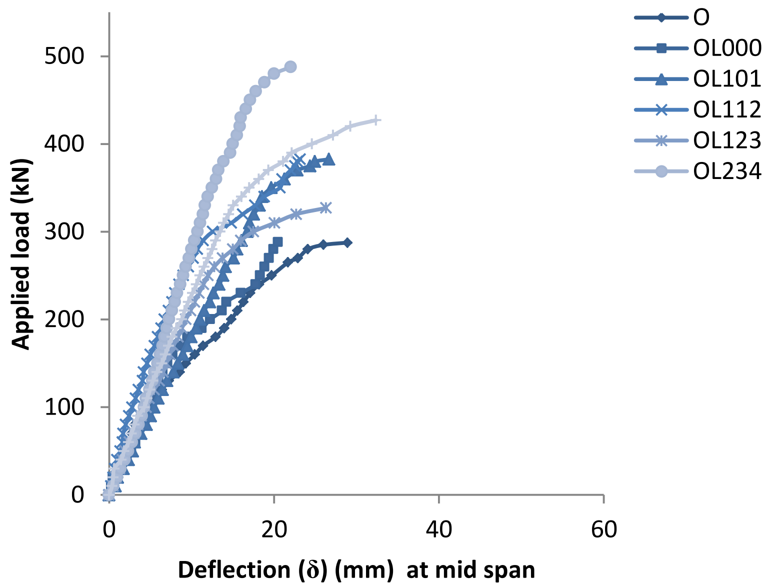


Figure (9) Effect of eccentricity location of prestressing strand on the load deflection curves of tested beams at mid span

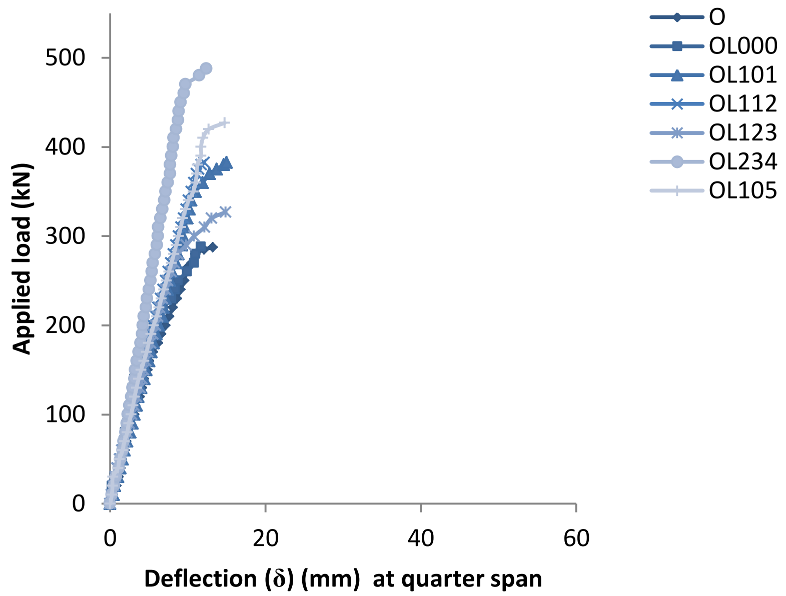


Figure (10) Effect of eccentricity location of prestressing strand on the load deflection curves of tested beams at quarter span

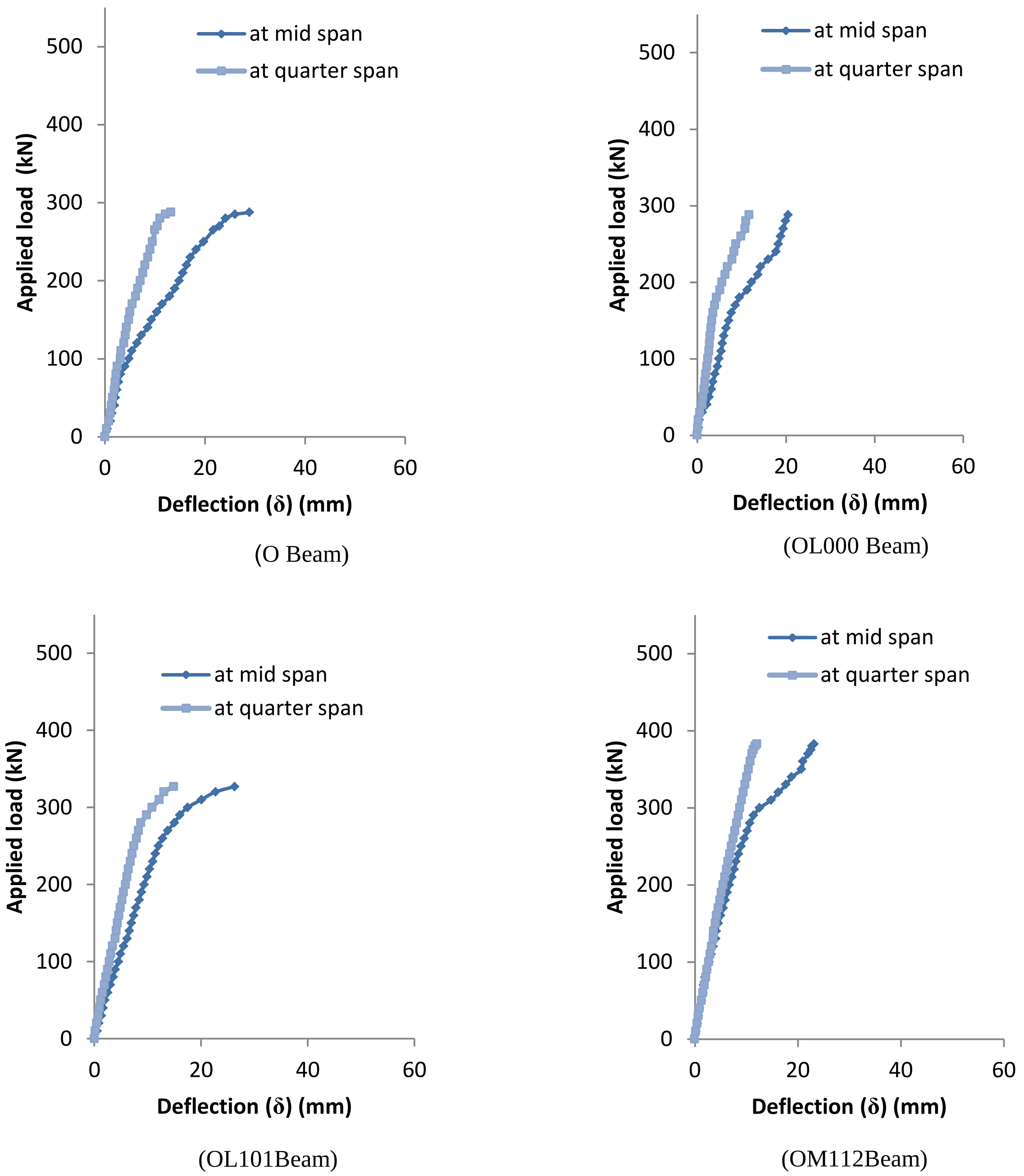
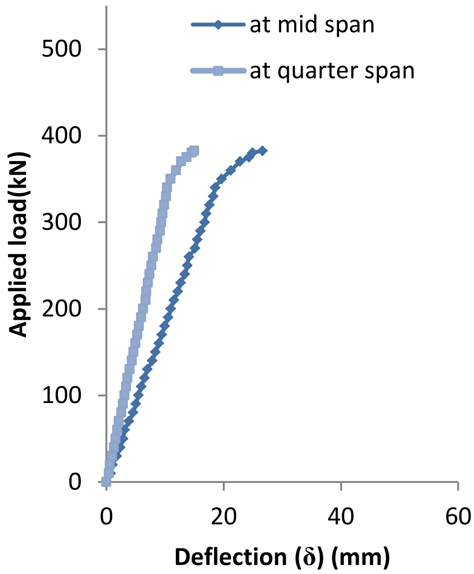
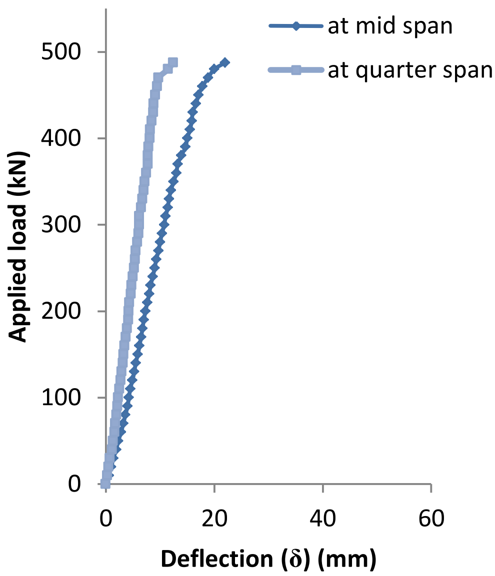


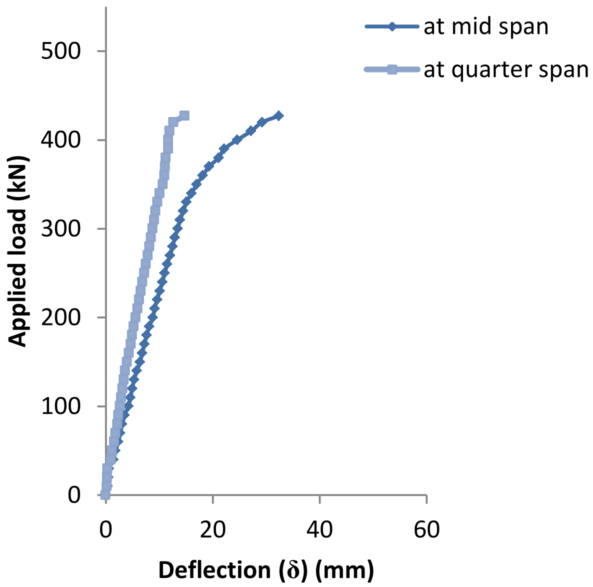
Figure (11) Load deflection curves at mid and quarter span for tested beams



(OL123Beam)



(OL234Beam)



(OL105Beam)

Figure (11) continue

5.2. Maximum Applied Load of the Tested Beams.

To study the influence of eccentricity locations on the maximum applied load of the tested beams, the beams were tested at different location of eccentricity changed from (0 to 165) mm. During the tests, it was found that the maximum applied load increase to 0.1739%, 26.086%, 33.043%, 48.521%, 13.739% and 69.565% with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam, as listed in table (7). The increasing percentage in maximum load deflection of tested beams is shown in Fig. (12) and Fig (13). So, one can be observed that the maximum applied load increase with increasing the eccentricity locations that due to exist of external prestressing strand which improved the web resistance and bottom flange and it's also contributed with the steel beams to resist the applied load.

Table (7) Load deflection of tested beams

Beams No.	Series Symbols	Maximum Exp. applied load (P_u) (kN)	Percentage of maximum load(%),as compare with reference
1	O	287.500	0
2	OL000	288.000	0.1739
3	OL101	362.500	26.086
4	OL112	382.500	33.043
5	OL123	327.000	13.739
6	OL234	487.500	69.565
7	OL105	427.000	48.521

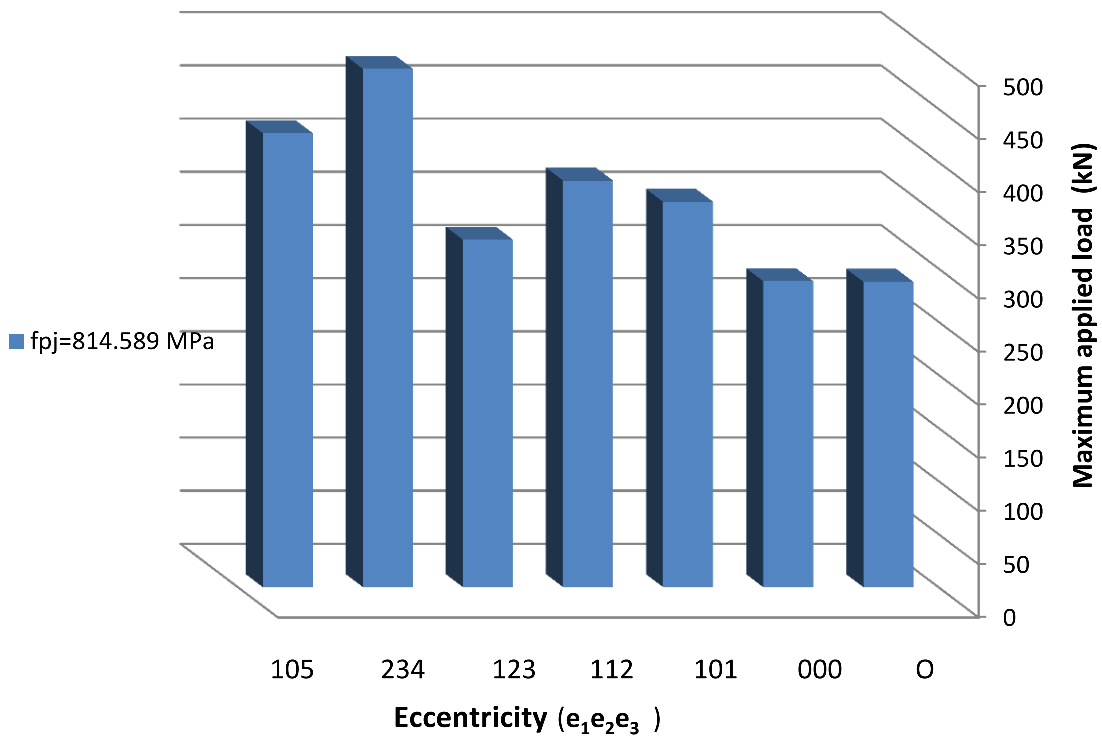


Figure (12) Maximum applied load of tested beams at different values of eccentricity and jacking stress

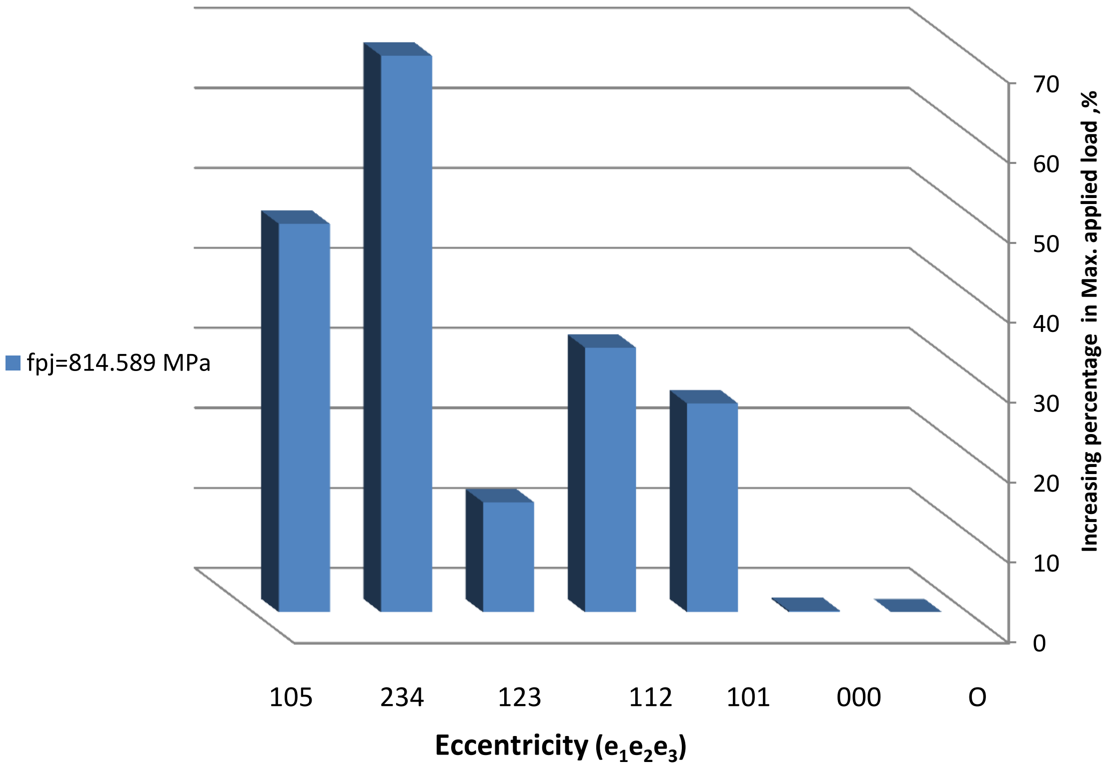


Figure (13) Percentages increase in maximum applied load of tested beams at different values of eccentricity and jacking stress as compare with the reference

5.3 Deflection Values of The Tested Beams

To study the effect of eccentricity locations on the deflection values for steel beams, the beams were tested at different location of eccentricity changed from (0 to 165) mm at jacking stress (fp_j=814.589 MPa). During the test it was found the changing percentage decrease to -29.094%, -7.753%, -19.764%, 11.976%, -8.965% and -23.779% with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam. On the other hand the positive sing in the percentage increasing due to increasing in deflection occur at mid span as result improving of the resistance strength of section to applied load by external prestressing strand that lead to increasing the applied load which lead to increase the deflection occur at mid span. So, one can be observed that the maximum deflection at mid span are decrease with increasing the eccentricity locations at mid span that due to exist of external prestressing strand which improve the web resistance and bottom flange and it's also contribute with the steel beams to resist the applied load.

Also it was found that the quarter span deflection to mid span deflection ratio ($\delta_{quarter}/\delta_{mid}$) with bout (0.497) when increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam, as listed in table (8). While, the deflection at mid and quarter span ($\delta_{quarter}/\delta_{mid}$) and the percentage increase in deflection of tested beams is shown in Fig.(14) to Fig.(16) respectively.

Table (8) Experimental deflection values for tested beams

Beams No.	Series Symbols	Maximum Exp. deflection (δ)(mm) at		Percentage increase in mid span deflection of tested beams, %	Quarter span deflection to mid span deflection ratio ($\delta_{quarter}/\delta_{mid}$)
		Quarter span	Mid span		
Ref.	O	13.200	28.890	0	0.456
1	OL000	11.700	20.500	-29.041	0.570
2	OL101	15.00	26.650	-7.753	0.562
3	OL112	12.100	23.180	-19.764	0.522
4	OL123	14.850	26.300	-8.965	0.564
5	OL234	12.400	22.020	-23.779	0.563
6	OL105	14.750	32.350	11.976	0.455

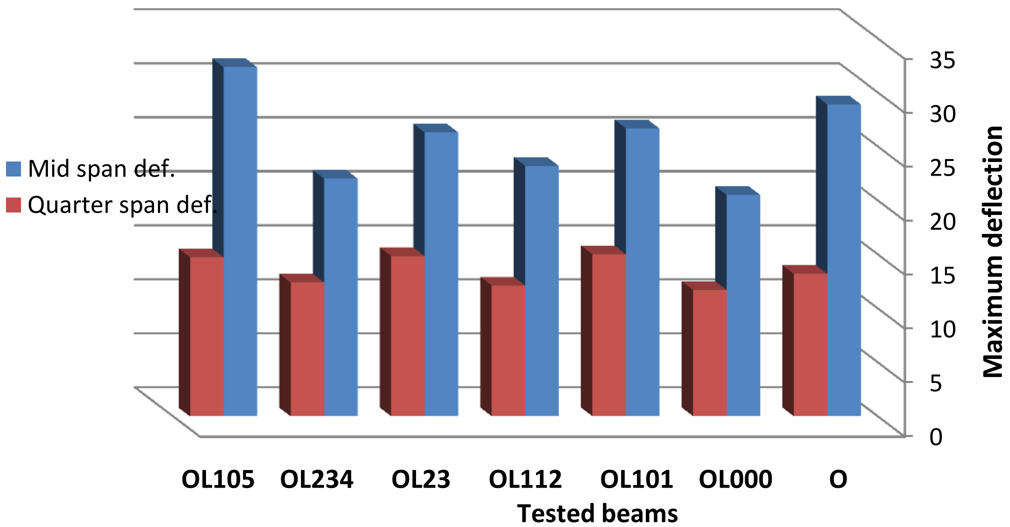


Figure (14) Maximum deflection of tested beams at different values of eccentricity

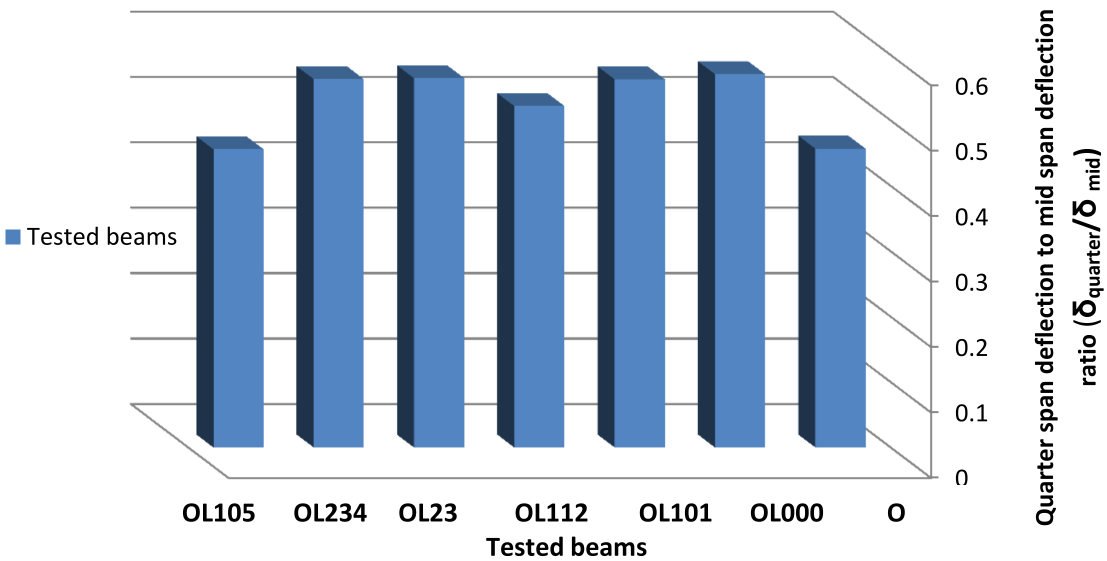


Figure (15) Quarter span deflection to mid span deflection ratio ($\delta_{quarter}/\delta_{mid}$) for tested beams at different value of eccentricity

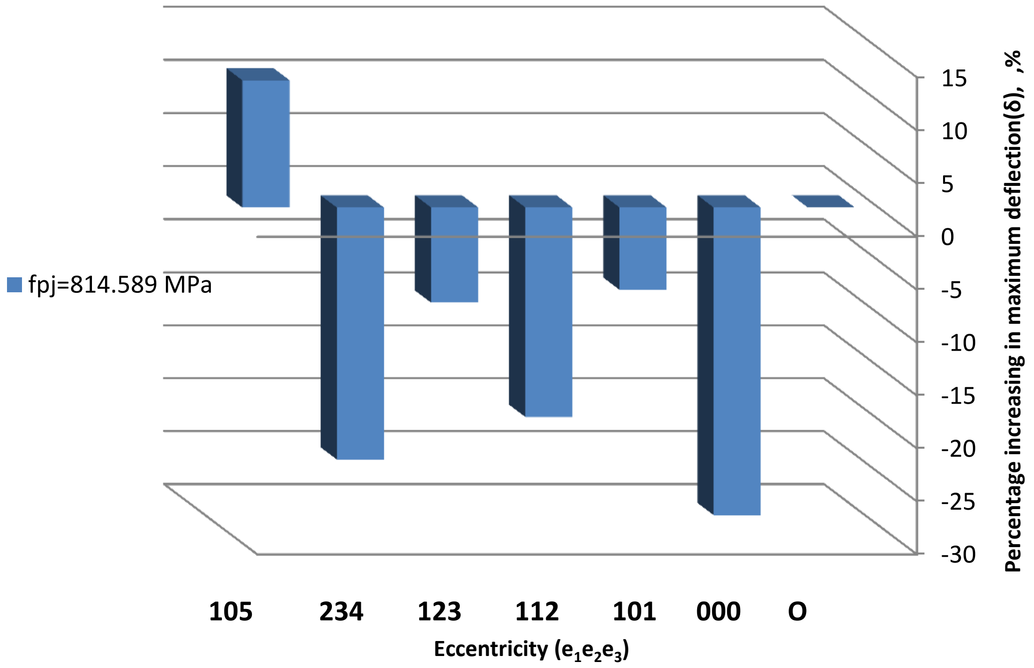


Figure (16) Percentages increase in maximum deflection for tested beams at different values of eccentricity and jacking stress as compare with the reference

6. Conclusions.

Based on the tested beams results of this experimental investigation on the deflection behavior of steel beams strengthening by prestressing strands, the following conclusions are drawn.

1. The load deflection curves for tested beams strengthening with external prestressing strand are stiffer as compare with the reference beam and the percentage of stiffening increase with increasing the eccentricity locations that due to exist of external prestressing strand which improved the web resistance and bottom flange and it's also contribute to resist the applied load.
2. The maximum applied load increase to 0.173%, 26.086%, 33.043%,48.521%, 13.739% and 69.565% with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam,
3. The increasing percentage in deflection at mid span decrease to -29.094%, -7.753%, -19.764%, 11.976%, -8.965% and -23.779% with increasing the eccentricity location from (0 to 165) mm respectively as compare with the reference beam, so the positive sing in the percentage increasing due to increasing in deflection occur at mid span as result improving of the resistance strength of section to applied load by external prestressing strand that lead to increase the applied load which lead to increase the deflection occur at mid span.
4. The quarter span deflection to mid span deflection ratio ($\delta_{quarter}$ /δ_{mid}) is bout (0.497) when increasing the eccentricity location from (0 to 165) mm respectively.

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