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RESPONCE OF R.C BEAMS UNDER EXTERNAL ECCENTRIC COMPRESSION FORCE

BY

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ABSTRACT:

Some methods and techniques for strengthening of R. C. beams were used in the present years. These methods aimed to increase the ultimate strength capacity, decrease the elastic deformations, increase the structure safety, and serviceability.
The aim of this present study is to investigate the response of R. C. beams strengthened using external eccentric compression force.
In this investigation ten beams were studied, one reference and another nine beams were divided into three groups (1, 2, and 3). Each group contains three beams. The main investigated parameters are the magnitude and different eccentric ratios of external forces. The magnitude was taken constant in each group, which equals to (2.0, 2.5 and 3.0) tons for groups (1, 2, and, 3) respectively. While the eccentricity equals to (.025, 0.05, and, 0.075) meters for each beam in each group respectively.
Deflection under load, mid-span, longitudinal tensile, compressive deformations about mid span, and initial cracking loads were recorded for each beam during loading up to till failure. The ultimate loads were recorded as well as modes of failure. Comparison between the tested and calculated results were considered and discussed to achieve the best recommendations.
The tested results indicated the efficiency of these technique of the strengthened investigated in this research, suitability, cheaper, quickly and the simplicity for applications.

Keywords: Strengthening, Eccentricity, and External Compression force, R. C. Beams.

1. INTRODUCTION

Deteriorated structures are very expensive when demolished and reconstructed. It is more appropriate from the engineering point of view to repair and strengthening the defected structural elements. For this reason a need for efficient methods for strengthening and repair of exiting buildings has arisen. When the actual loads increased than the design loads for any reason such as changing the use of a reinforced concrete building,
The ultimate strength capacity of the beam must be checked. In some cases it is found that this value is more than the value allowed by the cross section, which require a suitable method for increasing the ultimate strength capacity of the beam. Extensive researches have

been carried out to evaluate the adequacy of the different methods commonly used for the repair and strengthening of RC beams. The use of fiber reinforced polymers (FRP) [1,2], ferrocement laminates [3,4] as external reinforcement as well as steel plates [5] are considered as advanced techniques for repair and strengthening of reinforced concrete structural elements. These techniques are relatively new and still not yet applied in the field on large scales. A lot of experimental data related to these applications are still required to increase the available database concerning different application forms.

Post-tensioning of R. C. beams is an efficient system and competitive alternative for maintenance and strengthening of R. C. beams. Prestressing the R. C. beams will achieve small strains, deformations, and higher ultimate load capacity.

The main objective of this research is to investigate and compare the efficiency of using eccentric post tension technique to strengthening of R.C beams, as well as to increase the ultimate strength capacity.

The present study was undertaken to furnish data on the performance of strengthened concrete beams using three different post-tension forces, which used to cover these item as constant in one of each groups (1, 2, and, 3) respectively. While three different eccentricities (0.025, 0.05, and, 0.075) m for each group was studied respectively. The two tension steel bars over all the beam length give external post-tension force acting in lower part of the section at tension zone for the beam.

The used aggregates (gravel and sand) were brought from Abasa zone. Ordinary Portland cement high-grade steel of diameter 10 mm at compression zone and normal plane mild steel bars of diameter 8 mm in tension side were also used.

The torq-key were used to produce variable post-tension force using two screw high grade steel bars, which reversed this force by two rigid steel plates on the face of beam cross-section as internal compression force.

The ultimate loads, deflections, strains and cracking characteristics of the strengthened beams are reported, discussed, and concluded.

2. MODEL PREPARATION AND TEST PROGRAM

Some trial of concrete mixes were designed to produce an average cube compressive strength after 28 days equals 250 kg/cm^2, with the following proportion: -

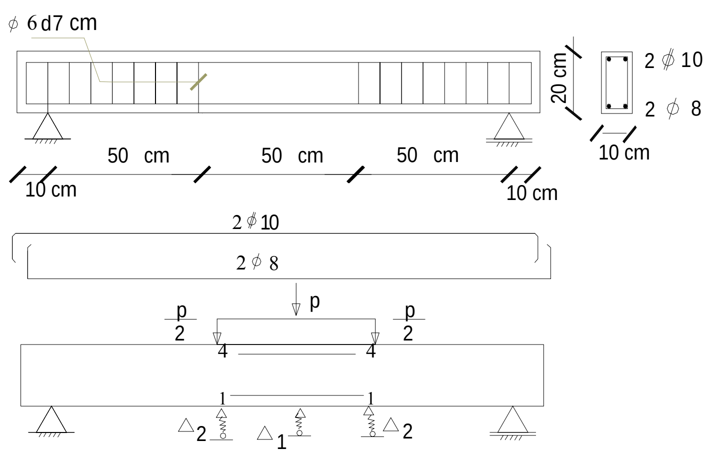
Cement: sand: gravel: water, are: - 1**:** 2.79 **:** 4.19 **:** 0.56 by weight respectively. The maximum nominal size was 10 mm for aggregate and the cement used was ordinary Portland cement.

One reference beam was casted and all tested beams had a 10 x 20 cm cross-section and a total length 170 cm with steel reinforcement of a typical test specimen containing upper reinforcement 2 Φ 10 mm and lower reinforcement 2 ϕ 8 mm and stirrups 1 ϕ 6 mm / 7 cm. These beams were tested under two concentrated loads, one load at each third of the beam. Fig: 1 Shows reinforcement details and measurements position for a typical beam. The amount of steel satisfied the Egyptian code requirements for the under reinforced section ensured tension failure. A mechanical vibrator was used to compact the concrete and ensures homogenous distribution around steel bars. Six cubes were casted for every group, and tested to get the average compressive strength after 28 days. The beams and cubes were cured by water followed by 14 days.

Ten beams one reference and nine were divided into three main groups. Each group contains three beams (B2, B3, and B4), (B5, B6, and B7), and (B8, B9, and B10) for groups (I, II, and, III) respectively.

One of three different post-tension force such as (2.0, 2.5 and 3.0) tons were used as constant variable in each group (1, 2, and, 3) respectively. The different eccentricity was taken (0.025, 0.05, and, 0.075) for each beam in each group such as (B2, B3, and B4), in group (1), (B5, B6, and B7), in group (2), and (B8, B9, and B10) in group (3), respectively.

For all groups, the beams were strengthening at tension zone on the half bottom side of the section overall beam length. Table: (1) show the Program of the Tested Beams and position of the Post- tensioned bars.
The reference specimen were tested for determining cracking, ultimate loads capacity strains about the mid-span and maximum deflection in order to taken into consideration, and evaluate the required post-tension force.
All beams were tested under 4-points of bending using avary-dension hydraulic 100 ton capacity, the effective span was 150 cm, 10 cm supporting length at each ends and the applied loads were 50 cm apart. Photos, (1), (2), (3), and (4) shows the typical tested beams B1, B4, B7, and B9 respectively after failure. The central, under loads



vertical deflection was measured by using digital gauge of 100 - mm maximum range and accuracy 0.0001-mm. Also, the horizontal deformations at (tension and compression) sides, which turn by calculations into compressive and tensile strains, were measured about mid-span of the beam using a 300-mm length digital demec and accuracy of 0.0001 mm, after each load increment, vertical deflections and strains were recorded and the beam was inspected for cracking and failure.

Photo N<u>o</u> : 1 reference beam B1

Photo N<u>o</u> : 2 beam B4

Photo N<u>o</u> : 2 beam B7

Photo N<u>o</u> : 1 beam B9

Table: (1) Program of the Tested Beams and position of the Post- tensioned bars.

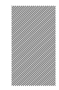
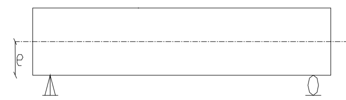
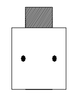
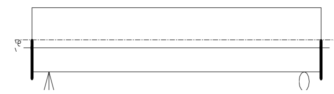
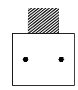
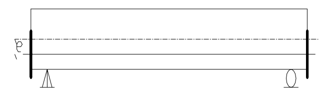
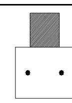
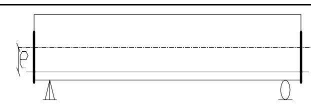
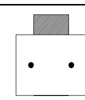
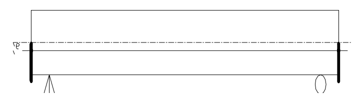
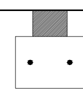
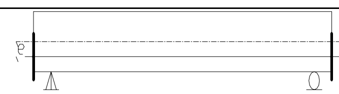
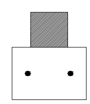
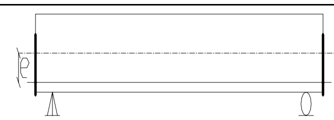
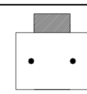
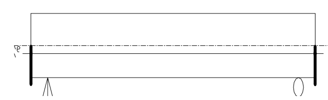
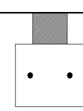
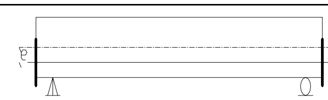
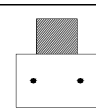
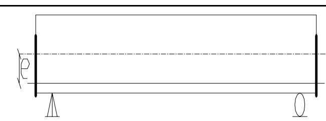
Group NO	*Beam NO*	*Compressive Force. (ton)*	*Eccentricity (e) Cm*	*Description of section*	*Description of Post- tensioned bars*
Reference	*B1*	*0*	*0*		
I	*B2*	*2.0*	*2.5*		
	B3	*2.0*	*5*		
	B4	*2.0*	*7.5*		
2	*B5*	*2.5*	*2.5*		
	B6	*2.5*	*5*		
	B7	*2.5*	*7.5*		
3	*B8*	*3.0*	*2.5*		
	B9	*3.0*	*5*		
	B10	*3.0*	*7.5*		

Table 2: Analysis of tests results for all specimens.

Group NO		PCr Kn	PU Kn	Δ 1 mm	Δ 2 mm	Ductiliy Ratio	€1 x 10^{-3} +Ve	€2 x 10^{-3} -Ve	*p*PCr/ PCrr %	*p*PU/ PUr %	*p*Δ 1 / Δ 1r %	*p*Δ 2 / Δ 2r %	*p*€1 / €1r%	*p*€2 / €2r %
Reference B1		27.0	30.0	25.09	19.90	2.92	9.70	2.60	0.0	0.0	0.0	0.0	0.0	0.0
1	*B2*	30.4	37.6	13.25	10.85	3.07	8.20	2.35	+ 13	+ 25	- 47	- 50	- 16	- 10
	B3	37.0	44.9	23.97	14.40	4.21	7.51	2.21	+ 37	+ 50	- 4.5	- 27	- 23	- 15
	B4	40.0	62.4	18.99	15.32	7.90	6.92	1.97	+ 48	+108	- 24	- 23	- 29	- 24
2	*B5*	35.0	49.0	24.80	15.40	9.54	7.10	2.13	+ 30	+ 63	- 1.0	- 23	- 27	- 18
	B6	44.0	58.0	22.87	15.49	5.72	6.52	1.95	+ 63	+ 93	- 9	- 22	- 33	- 25
	B7	53.0	69.8	17.59	15.51	6.28	5.85	1.76	+ 96	+ 133	- 30	- 22	- 40	- 32
3	*B8*	42.0	61.0	25.40	16.80	7.91	6.22	1.92	+ 56	+ 103	+ 1.2	- 16	- 36	- 26
	B9	51.0	72.0	21.00	16.27	11.35	5.53	1.75	+ 89	+ 140	- 16	- 16	- 43	- 33
	B10	62.0	79.0	17.00	15.87	6.67	4.70	1.55	+ 130	+ 163	- 32	- 20	- 52	- 40

* Pc, Pu : are the crack and ultimate loads in (kN).
* Δ1, Δ2 : are the mid-span and under machine load deflections at the comparative levels.
* €1, €2 : are the tensile and compressive strains at tension and the compression sides about mid-span at ultimate loads.
* (*p*PCr/ PCrr %)%, and (*p*PU/ PUr %)%, : is the percentage of increasing or decreasing in cracking, and ultimate loads comparing with the corresponding results from reference.
* (*p*Δ 1 / Δ 1r) %, (*p*Δ 2 / Δ 2r)%, (*p*€1 / €1r)% , and (*p*€2 / €2r) % : are the percentage of increasing or decreasing in deflections Δ1, Δ2, €1, and €2 comparing to the corresponding from the reference.

3. ANALYSES AND DISCUSSION OF EXPERIMENTAL RESULTS

The ultimate load of the tested beam was defined as the load at which the specimen cannot sustain any more capacity load. The cracking load was determined by using two methods, by direct visual inspection or from the load-deflection relationship, which was plotted experimentally for each specimen in the same instant of applied load on the tested beam incrementally for every 5 (KN) till failure.

The test results were summarized in table (2), which indicate the cracking, and ultimate loads, mid-span, under machine loads deflections and tensile, compressive strains for each concrete beams after 28 days receptively. Also comparison between all these results for each strengthened beams with control beam for each group and between similar eccentricities in all groups had been described. All results described the strengthened beam nearly linear response up to cracking, large deflections, and strains at ultimate loading, which indicated high ductility.

3.1 Deflections

The deflection curves plotted up to failure for all beams were smooth and symmetrical about the beam center.

3.1.1 Mid- Span Deflection (Δ_1)

3.1.1.1 Mid- Span Deflection (Δ_1) constant post tension force & variable eccentricity.

Figure 2, 3, and 4 compares the load deflection curves of beams in Groups 1, 2, and 3 respectively, which clear the effect of (constant post tension force & variable eccentricity) inside each group

Figure 2 shows the load deflection (Δ_1) relations for beams (B1 , B2, B3, and B4) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-47 %), (-4.5 %), and (-24 %) for (B2, B3, and B4) respectively.

Figure 3 shows the load deflection (Δ_1) relations for beams (B1 , B5, B6, and B7) in group 2, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-1 %), (-9 %), and (-30 %) for (B5, B6, and B7) respectively.

Figure 4 shows the load deflection (Δ_1) relations for beams (B1 , B8, B9, and B10) in group 3, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (+1.2 %), (-16 %), and (-32 %) for (B8, B9, and B10) respectively.

3.1.1.2 Mid- Span Deflection (Δ_1) variable post tension force & constant eccentricity.

Figures 5, 6, and 7 compare the load deflection curves of beams are satisfied the above items in Groups 1, 2, and 3, which show clearly the effect of (variable post tension force & constant eccentricity) in all groups.

Figure 5 shows the load deflection (Δ_1) relations for beams (B1 , B2, B5, and B8) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-47 %), (-1 %), and (+1.2 %) for (B2, B5, and B8) respectively.

Figure 6 shows the load deflection (Δ_1) relations for beams (B1 , B3, B6, and B9) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-4.5 %), (-9 %), and (-16 %) for (B3, B6, and B9) respectively.

Figure 7 shows the load deflection (Δ_1) relations for beams (B1 , B4, B7, and B10) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-24 %), (-30 %), and (-32 %) for (B4, B7, and B10) respectively.

3.1.2 Under load Deflection (Δ_2)

3.1.2.1 Under load Deflection (Δ_2) constant post tension force & variable eccentricity.

Figure 8, 9, and 10 compares the load deflection **(Δ_2)** curves of beams in Groups 1, 2, and 3 respectively, which show clearly the effect of (constant post tension force & variable eccentricity) inside each group

Figure 8 shows the load deflection (Δ_2) relations for beams (B1 , B2, B3, and B4) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-50 %), (-27 %), and (-23 %) for (B2, B3, and B4) respectively.

Figure 9 shows the load deflection (Δ_2) relations for beams (B1 , B5, B6, and B7) in group 2, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-23 %), (-22 %), and (-22 %) for (B5, B6, and B7) respectively.
Figure 10 shows the load deflection (Δ_2) relations for beams (B1 , B8, B9, and B10) in group 3, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-16 %), (-16 %), and (-20 %) for (B8, B9, and B10) respectively.

3.1.2.2 Under load Deflection (Δ_2) variable post tension force & constant eccentricity.

Figure 11, 12, and 13 compares the load deflection curves of beams are satisfied the above items in Groups 1, 2, and 3, which show clearly the effect of (constant post tension force & variable eccentricity) in all groups.
Figure 11 shows the load deflection (Δ_2) relations for beams (B1 , B2, B5, and B8) in alls groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-50 %), (-23 %), and (+16 %) for (B2, B5, and B8) respectively
Figure 12 shows the load deflection (Δ_2) relations for beams (B1 , B3, B6, and B9) in alls groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-27 %), (-22%), and (+16 %) for (B3, B6, and B9) respectively
Figure 13 shows the load deflection (Δ_2) relations for beams (B1 , B4, B7, and B10) in alls groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-23 %), (-22 %), and (+20 %) for (B4, B7, and B10) respectively

3.2 Strains

The deflection curves plotted up to failure for all beams were smooth and symmetrical about the beam center.

3.2.1 Tensile Strains (ε_1)

3.2.1.1 Tensile Strains (ε_1) constant post tension force & variable eccentricity.

Figure 14, 15, and 16 compares the load deflection curves of beams in Groups 1, 2, and 3 respectively, which show clearly the effect of (constant post tension force & variable eccentricity) inside each group
Figure 14 shows the load deflection (ε_1) relations for beams (B1 , B2, B3, and B4) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-16 %), (-23 %), and (-29 %) for (B2, B3, and B4) respectively.
Figure 15 shows the load deflection (ε_1) relations for beams (B1 , B5, B6, and B7) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-27 %), (-33 %), and (-40 %) for (B5, B6, and B7) respectively.
Figure 16 shows the load deflection (ε_1) relations for beams (B1 , B8, B9, and B10) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-36 %), (-43 %), and (-52 %) for (B8, B9, and B10) respectively.

3.2.1.2 Tensile Strains (ε_1) variable post tension force & constant eccentricity.

Figure 17, 18, and 19 compares the load deflection curves of beams are satisfied the above items in Groups 1, 2, and 3, which show clearly the effect of (constant post tension force & variable eccentricity) in all groups.
Figure 17 shows the load deflection (ε_1) relations for beams (B1 , B2, B5, and B8) in alls groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-16 %), (-27 %), and (-36 %) for (B2, B5, and B8) respectively.
Figure 18 shows the load deflection (ε_1) relations for beams (B1 , B3, B6, and B9) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-23 %), (-33 %), and (+43 %) for (B3, B6, and B9) respectively.

Figure 19 shows the load deflection (ε_1) relations for beams (B1 , B4, B7, and B10) in alls groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-29 %), (-40 %), and (+52 %) for (B4, B7, and B10) respectively**.**

3.2.2 Compressive Strains (ε_2)

3.2.2.1 Compressive Strains (ε_2) post tension force & variable eccentricity.

Figure 20, 21, and 22 compares the load deflection curves of beams in Groups 1, 2, and 3 respectively, which show clearly the effect of (constant post tension force & variable eccentricity) inside each group

Figure 20 shows the load deflection (ε_2) relations for beams (B1 , B2, B3, and B4) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-10 %), (-15 %), and (-24 %) for (B2, B3, and B4) respectively.

Figure 21 shows the load deflection (ε_2) relations for beams (B1 , B5, B6, and B7) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load are (-18 %), (-25 %), and (-32 %) for (B5, B6, and B7) respectively.

Figure 22 shows the load deflection (ε_2) relations for beams (B1 , B8, B9, and B10) in group 1, which indicate the effect of eccentricity on the deflection compared with control beam B1 at ultimate load **are** (-26 %), (-33 %), and (-40 %) for (B8, B9, and B10) respectively.

3.2.2.2 Compressive Strains (ε_2) variable post tension force & constant eccentricity.

Figure 2,3, and 4 compares the load deflection curves of beams are satisfied the above items in Groups 1, 2, and 3, which show clearly the effect of (constant post tension force & variable eccentricity) in all groups.

Figure 23 shows the load deflection (ε_2**)** relations for beams (B1 , B2, B5, and B8) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-10 %), (-18 %), and (-26 %) for (B2, B5, and B8) respectively.

Figure 24 show the load deflection (ε_2) relations for beams (B1 , B3, B6, and B9) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-15%), (-25 %), and (-33 %) for (B3, B6, and B9) respectively.

Figure 25 shows the load deflection (ε_2) relations for beams (B1 , B4, B7, and B10) in all groups, which indicate the effect of post tension on the deflection compared to the control beam B1 at ultimate load are (-24 %), (-32 %), and (-40 %) for (B4, B7, and B10) respectively**.**

3.3 Cracking of Reinforced Concrete beams

First cracking loads were recorded for all investigated reinforced concrete beams. Crack Patterns are marked at different loading stages.

Figure 26, 28 and the analysis in table (2) compare the results of cracking loads for all beams in the different groups. The measurable differences were recorded for all beams compared to the control beams clear the increases in the initial cracking load recorded for all beams B2, B3,… to B10 were about 13 %, 37 %, 48 %, 30 %, 63 %, 96 %, 56 %, 89 %, and 130 %, respectively.

3.4 Ultimate Load Capacity of Reinforced Concrete beams

The ultimate load capacity mainly depends on the pre-loading level prior to repair, and the methods of strengthening. The ultimate loads were recorded for all models experimentally and compared.

Figure 27, 29 and comparative study based on test results in table (2) showed that: **-**

All strengthened beams indicated the ultimate load capacity more than that recorded for the control beam B1**.** Beams (B2, B3, and, B4) in group 1, which were compressed by constant post tension force 2.0 ton, beams (B5, B6, and, B7) in group 2, which were compressed by constant post tension force 2.5 ton, and beams (B2, B3, and, B4) in group 3, which were compressed by constant post tension force 3.0 ton, comparison of that recorded results with the control beam B1 clear the increases in the ultimate loads recorded for all beams B2, B3,… to B10 were about 25 %, 50 %, 108 %, 63 %, 93 %, 133 %, 103 %, 140 %, and 163 %, respectively.

3.5 Ductility Ratio

In this investigation, the ductility and the energy absorption of the tested beams were compared. Ductility of beam is defined as the ratio between the maximum deflection due to the ultimate load and the maximum deflection at the first cracking load. Energy absorption is defined as the area under the load-deflection curve at failure. Table 2 gives the test results for the ductility ratio for different specimens. All beams showed noticeable increase in the ductility ratio. The increases in all beams B2, B3,… to B10 were about 3.07, 4.21, 7.9, 9.54, 5.72, 6.28, 7.91, 11.35, and 6.67 respectively compared to the control beam B1. This is important for resisting the dynamic and earthquakes loads.

4. CONCLUSIONS

From this study, the following conclusions are drawn:

1 - All types of eccentricity or any different magnitude of post tension force used in this research for retrofitting and strengthening the R. C. beams were effective in restoring and improving the structural performance in terms of flexural rigidity, deflection, strain, initial cracking load and the ultimate carrying capacity.

2 - Applying any post tension force at the tension side for strengthening beam gives good improvement compared to reference beam. The maximum increase in ultimate strength capacity about 163% over than reference beam.

3 - Using post tension force gives good improvement in mid-span, and under load deflections compared to reference beam at failure loads. The maximum decreasing in mid-span and under load deflections about -47 %, and -50% respectively over than reference beam.

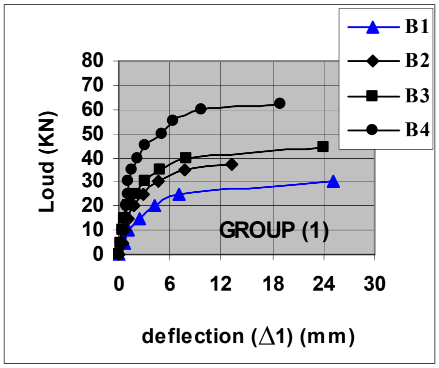
4 - As the magnitude of eccentricity increase the mid-span, under load deflections, tension, and positive strains decrease compared to reference beam at failure loads. The maximum decreasing over than reference beam in mid-span, under load deflections, tension, and positive strains about -32 %, -20 %, -52% and -40% respectively.

5 - Applying any magnitude of eccentricity at the tension side for strengthening beam were very effective and improved the overall behavior of the beams as well as increasing the ultimate strength capacity compared to reference beam. The maximum increasing in ultimate strength capacity over than reference beam about 163 %.

6 - Using post tension force and any magnitude of eccentricity at the tension side for retrofitting or strengthening beam compared to the control beam. The maximum ductility ratio of the beams was increased by about 11.35 %.

7 **-** The best and important result of this research, it can be define the mode of failure and calculate the required magnitude of post tension force and suitable eccentricity to satisfy safe ultimate load capacity in future strengthened or rehabilitated beams by using post tension force technique.

8 **-** The technique using in this study is cheaper, quick, suitable, and easy for construction. Moreover, it's good for strategic structures, such as, bridges or any structures needs to urgent retrofitting or rehabilitation.



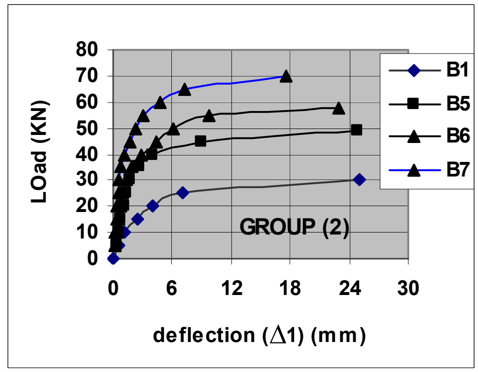
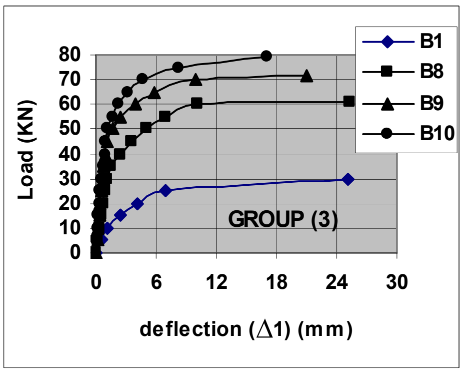


Fig (2):Effect of eccentricity on deflection

Fig (3): Effect of eccentricity on deflection



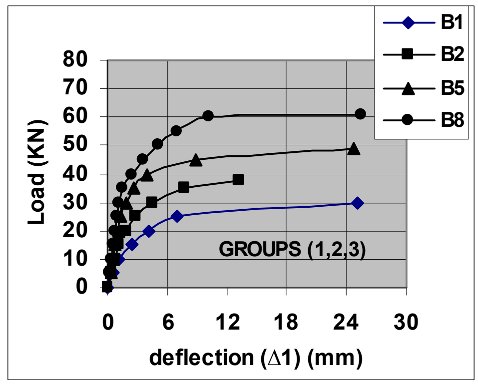
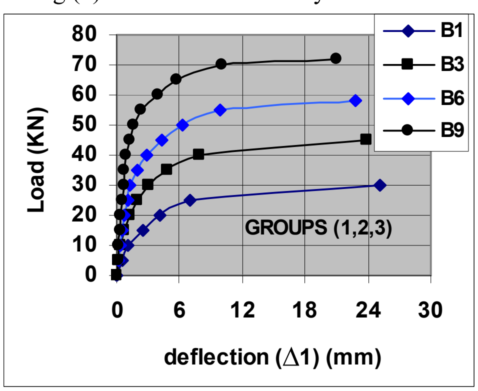


Fig (4): Effect of eccentricity on deflection

Fig (5): Effect of post tension on deflection



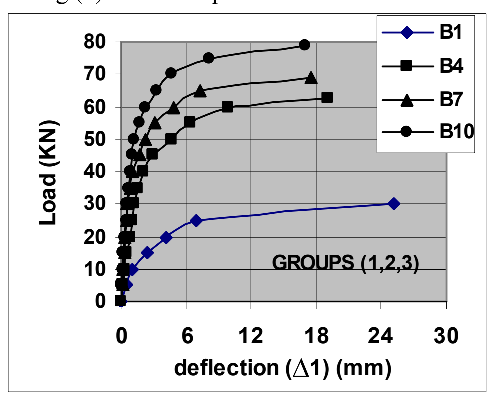
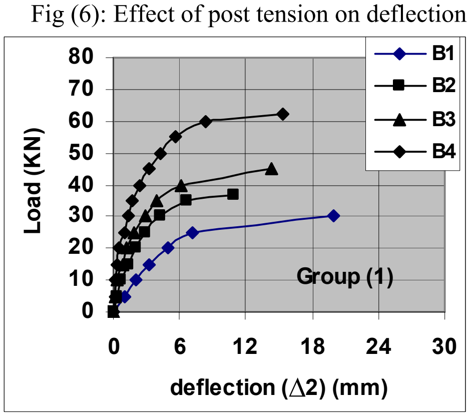


Fig (6): Effect of post tension on deflection

Fig (7): Effect of post tension on deflection



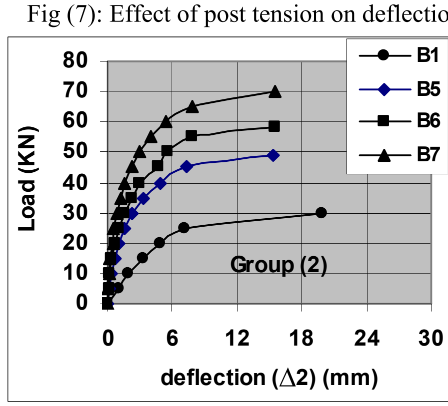


Fig (8): Effect of eccentricity on deflection

Fig (9): Effect of eccentricity on deflection

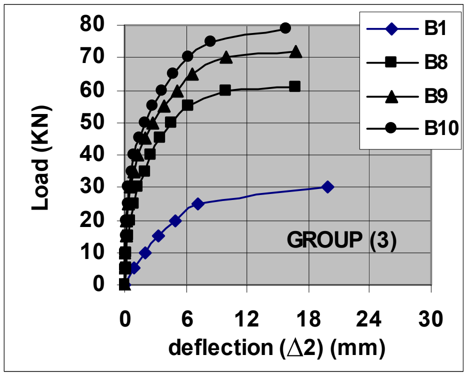


Fig (10): Effect of eccentricity on deflection

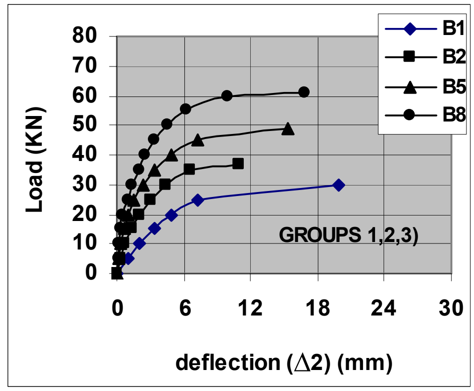


Fig (11): Effect of post tension on deflection

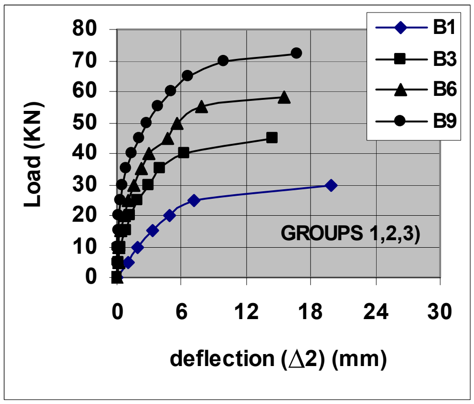


Fig (12): Effect of post tension on deflection

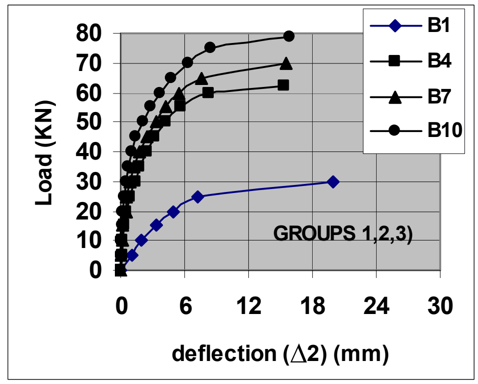


Fig (13): Effect of post tension on deflection

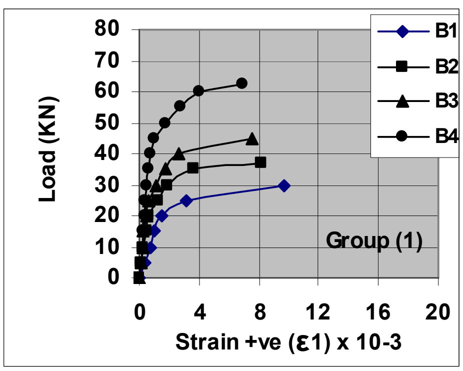


Fig (14): Effect of eccentricity on strain

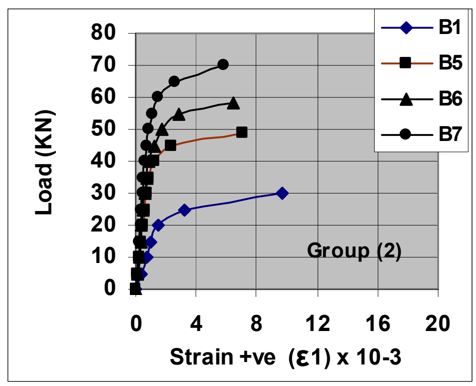


Fig (15): Effect of eccentricity on strain

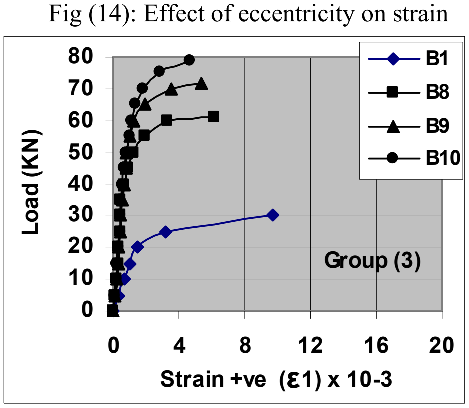


Fig (16): Effect of eccentricity on strain

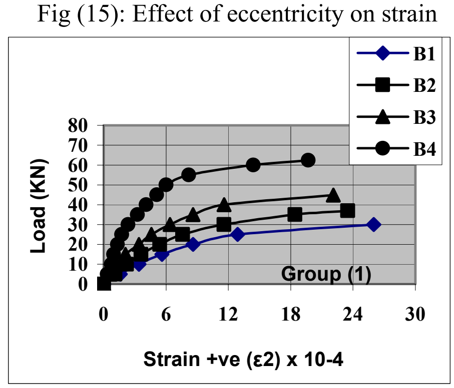


Fig (17): Effect of post tension on strain

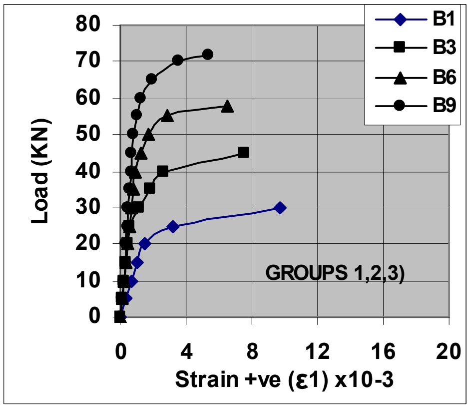


Fig (18): Effect of post tension on strain

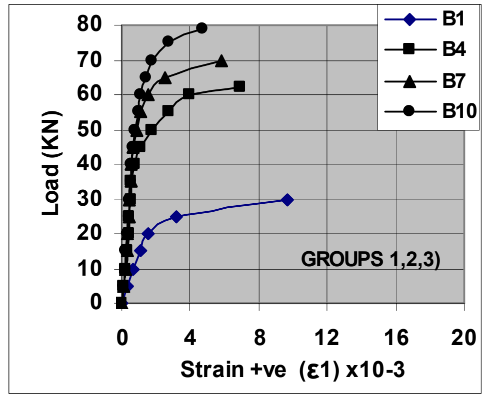


Fig (19): Effect of post tension on strain

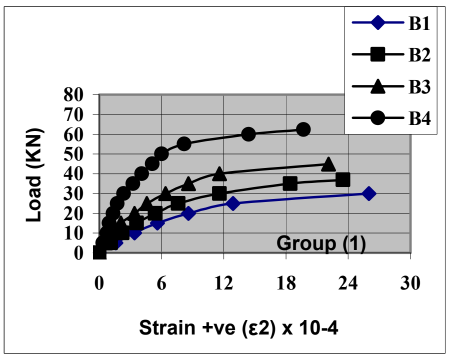


Fig (20): Effect of eccentricity on strain

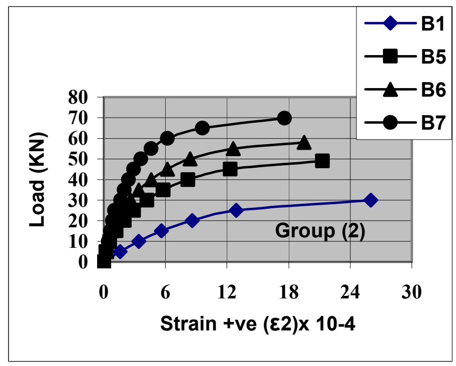


Fig (21): Effect of eccentricity on strain

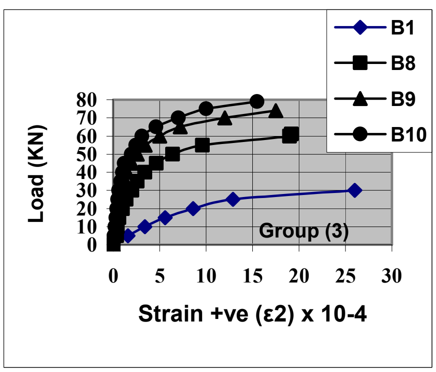


Fig (22): Effect of eccentricity on strain

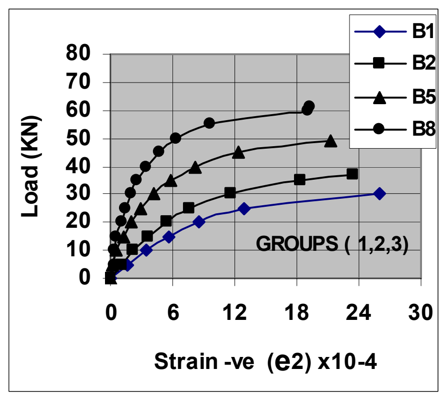


Fig (23): Effect of post tension on strain

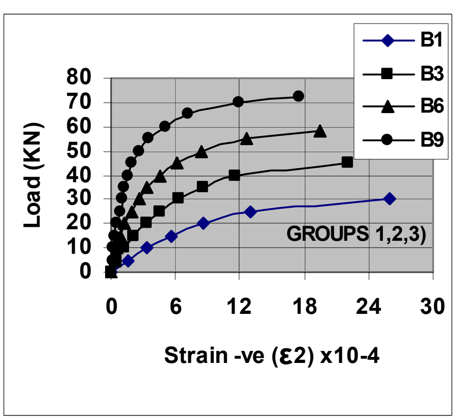


Fig (24): Effect of post tension on strain

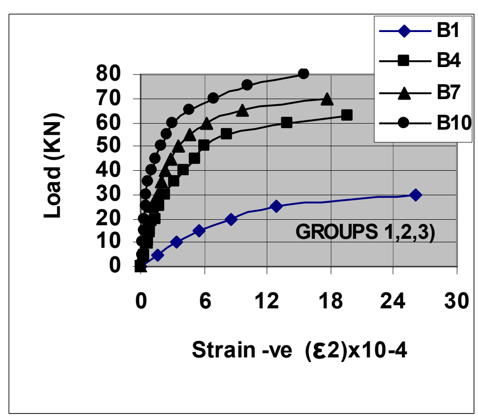


Fig (25): Effect of post tension on strain

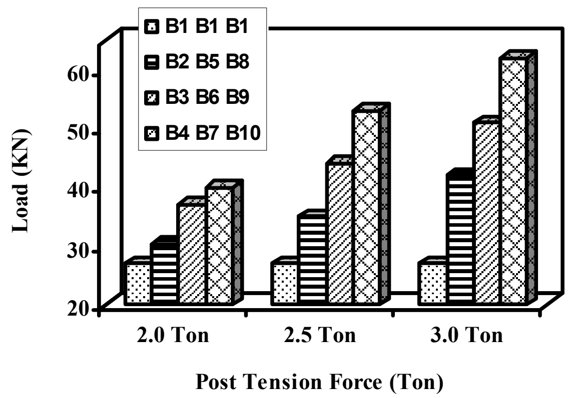


Fig (26): Histograms show the cracking load and Post Tension Force for groups (I, II and III).

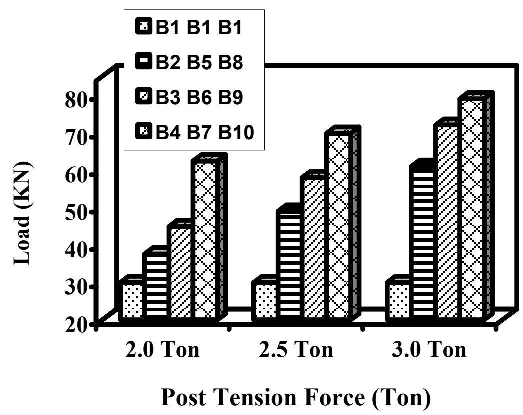


Fig (27): Histograms show the ultimate load and Post Tension Force for groups (I, II and III).

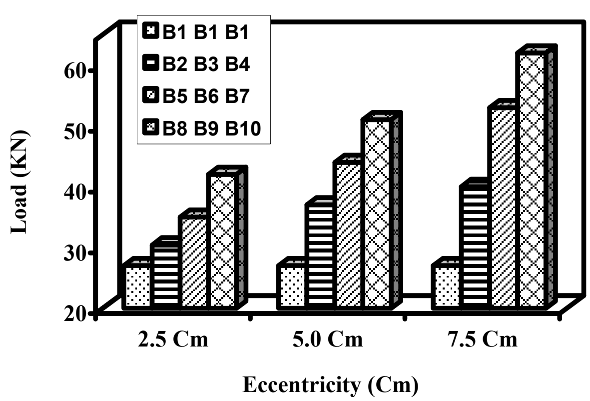


Fig (28): Histograms show the cracking load and Eccentricity for groups (I, II and III).

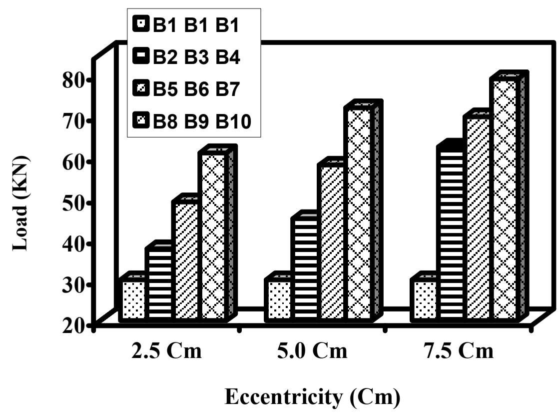


Fig (29): Histograms show the cracking load and Eccentricity for groups (I, II and III).

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