CONCRETE STRAIN DISTRIBUTION OF STRENGTHENED BEAMS WITH ADDITIONAL POST-TENSIONING

Abdussalam M. Akasha[1] *and György Farkas*[2]
Technical University of Budapest, Department of reinforced Concrete Structures
H-1521 Budapest

SUMMARY

Comparison of the concrete strain distribution results, at the maximum positive and negative moment sections, of two equal spans reinforced concrete tee beams, before and after strengthening with additional post-tensioned tendons are presented. Two series of strengthening beams were tested. Each series consists of two beams, with equal reinforcement ratio, and different tendon's profile namely; straight and deviated one. The concrete strains are considerably decreased after strengthening, specially for deviated tendons' profiles, which imply significant improvement in the flexural behaviour of the strengthening beams.

Keywords: external prestressing, strengthening, continuous R.C. T-beams

1. INTRODUCTION

Nowadays, some of the concrete structures that built in the past years were inadequate to carry the loads. This insufficient load carrying capacity has resulted from poor maintenance, increasing in legal load limit, insufficient reinforcement, excessive deflections, structural damages(such as vechicient impact or fire damages) or reinforcement corrosion. These structures almost are classified as deficient and need of strengthening or replacement. The required functional life of the structure plays a major role in the decision whether to strengthening the existing structure or to demolish and reconstruct with a new structure. Such a decision is largely influenced by site conditions, operational requirements, possible technical solutions, and the cost-benefit relationship.

For the strengthening, a number of methods have been developed to satisfy the demand for an increased maximum load bearing capacity or to fulfil the serviceability requirements. In many cases external prestressing technique is relatively often used to strengthen existing reinforced concrete structures. However, in the last years arrival of the using of external prestressing, to strengthening structures, is observed in many counters in the world.

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[1]PhD Student
[2]Professor in Structural Engineering, Supervisor.

2. EXPERIMENTAL PROGRAM

Tests on two series of cracked reinforced concrete tee beams, of eight meter length, strengthening by externally prestressed tendons, were carried out at the Structural Laboratory of the Reinforced Concrete Department, at the Technical University of Budapest. To simulate actual condition of concrete flexural beams that require strengthening, concentrated loads are applied at 3/8 and 5/8 of each span of the beam up to crack perior strengthening them by external tendons as shown in Fig.1. Each series consists of two beams (as shown in Tab.1) with same length, number of span and cross section .

Series	Beam reference	Bounded reinforcement	Tendon profile
First Series	B1S	average (see tab.2)	Straight
	B1D		Deviated
Second Series	B2S	minimum (see tab.2)	Straight
	B2D		Deviated

Tab.1 Beams references for both series

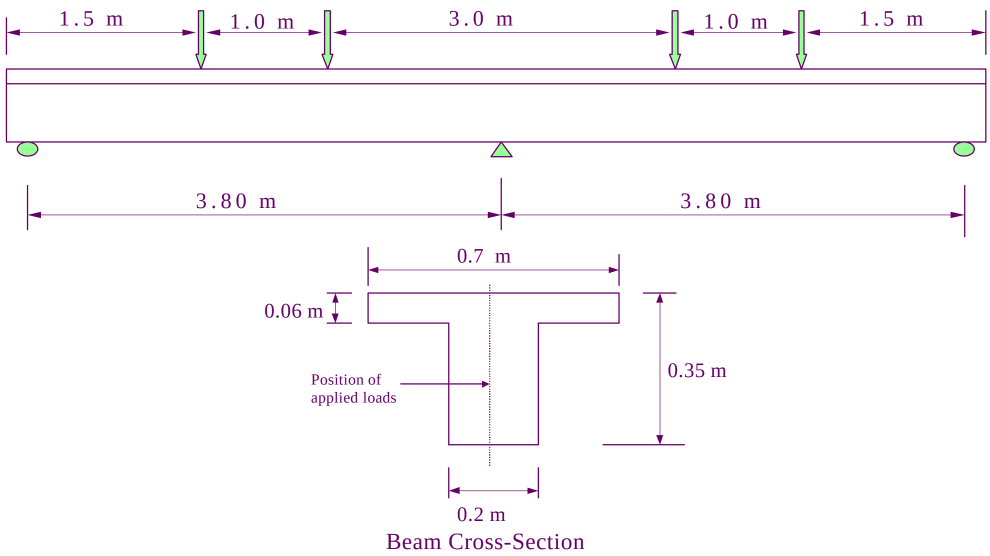


Fig.1 Beams set-up and the load position

2.1 Materials

The concrete mix was prepared using ordinary Portland cement (type I cement), uncrushed aggregate, with max. aggregate size 20mm. The aggregate:sand:cement proportions by weight were 2.2:1.8:1, with water cement ratio equal to 0.40. The materials were mixed in a mixer, then the concrete was cast in the beam form. The casted beams then introduced to accelerated curing, the shuttering was removed and the beams transported to the structural laboratory for testing. The concrete strength was verified from 150*150mm cubes taken from each specimen.

The average compressive strength at the time of testing for all the beams are 23.5N/mm^2. The yield strength of the longitudinal steel and stirrups (8 mm diameter) was 400 and 250 MPa, respectively. The elastic module of the steel was 200000 MPa. The summary of mild reinforcing steel parameter was shown in Tab.2. The arrangement of the steel and the beams dimension is shown in Fig 2.

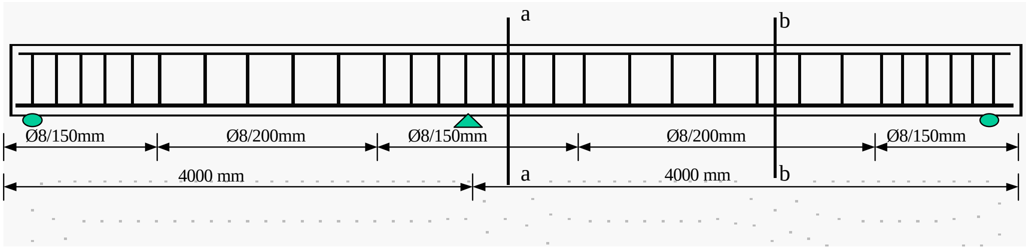


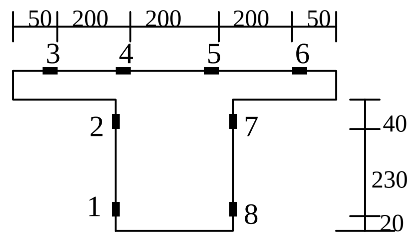
Fig.2 Beam reinforcement arrangement

Beam Specimen	Strengthening Tendon Lay-out	Longitudinal reinforcement Steel				Shear Reinfo-cement	Yield Stress N/mm^2	Concrete strength N/mm^2
		Section a-a		Section b-b				
		A_s(mm)	A_s'(mm)	A_s(mm)	A_s'(mm)			
B1S	Straight	3 ∅ 18	3∅18+2∅12	3 ∅ 18	2 ∅ 12	∅ 8 mm	400 for	
B1D	Deviated	(763)	(989)	(763)	(226)	distributd	bending	23.5
B2S	Straight	2 ∅ 12	3 ∅ 12	2 ∅ 12	2 ∅ 12	as shown	250 for	
B2D	Deviated	(226)	(339)	(226)	(226)	in Fig.2	shear	

Tab.2 Summary of the mild reinforcing steel parameter

2.2 Testing Instrumentation

The strains in the concrete were measured using electronic strain gages attached to the surface of the concrete. Eight strain gages are placed at the max. positive and negative moment sections as shown in Fig. 3 to measure the distribution of the strain in the concrete at different load stages. All strain gauges readings during the testing were monitored automatically using a computerised data acquisition system.

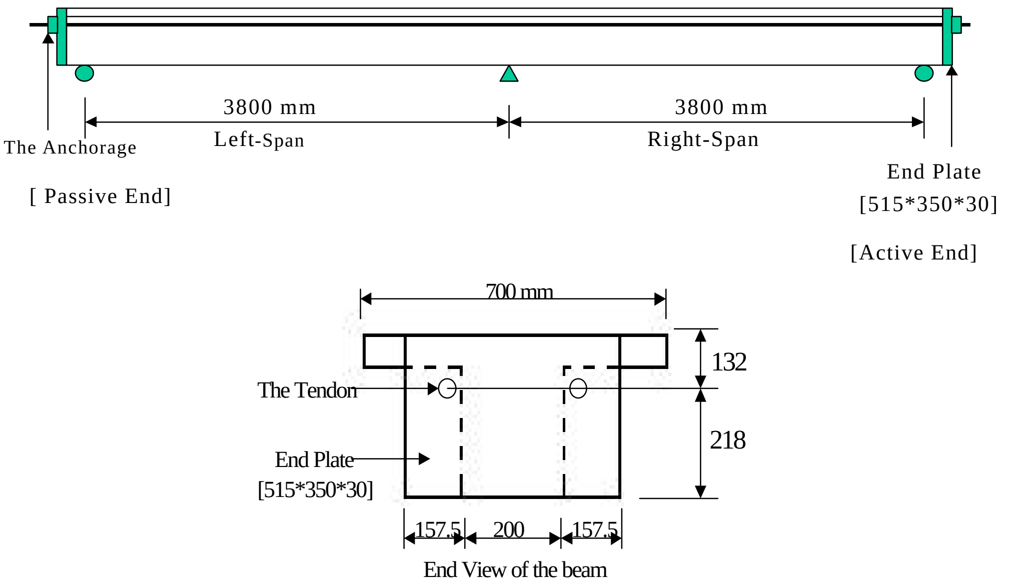


The position of the strain gauges (1- 8)
at sec. a-a and sec.b-b (all dimension in mm)

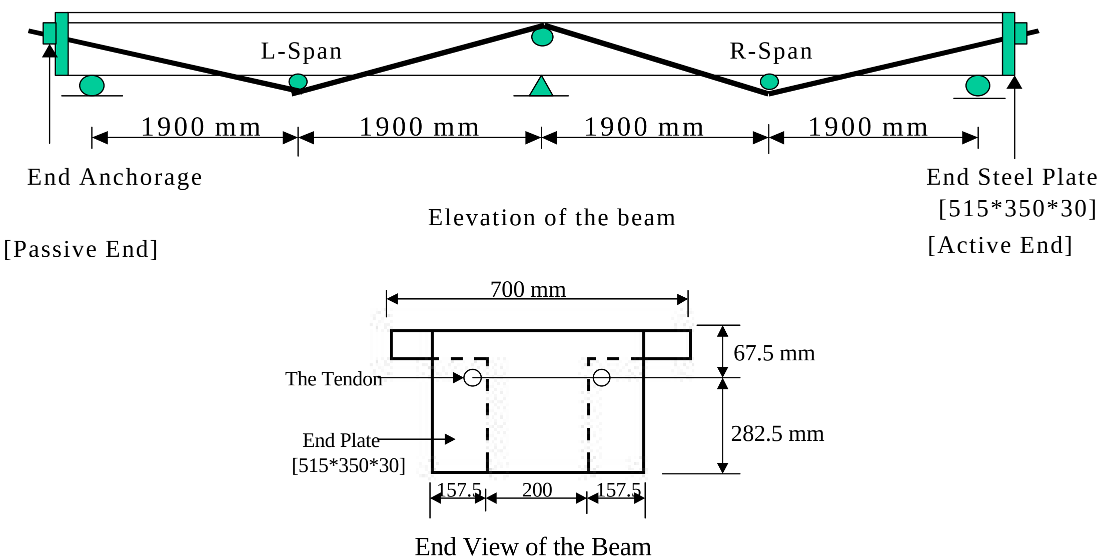
Fig.3 Position of the strain gages

2.3 External Prestressing

After pre cracking, each beam was externally prestressed, using two 150 mm^2 unbonded coated greased tendons. The tendons were anchored at the centroied of the cross section at each end of the beam, for the straight one, and deviated at the middle of each span, by using a tapered bearing plate, to comply with their inclined profile for the deviated one. The wedge anchored prestressing tendons was supported directly on an (515*400*30mm) thick bearing plate attached to the end of the beam.
The two tendons were tensioned simultaneously from one end by using jacking machine up to 150 and 180 KN on each tendon for the deviated and straight one respectively. The tendon lay-out is shown in Fig.4



a- Lay-out of Straight Tendon Profile



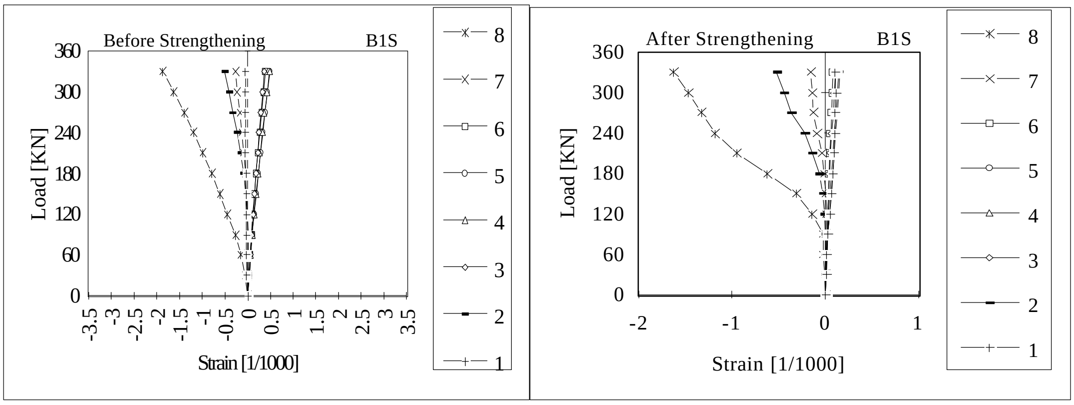
b- Lay-out of Deviated Tendon Profile

Fig.4 Tendons Layout

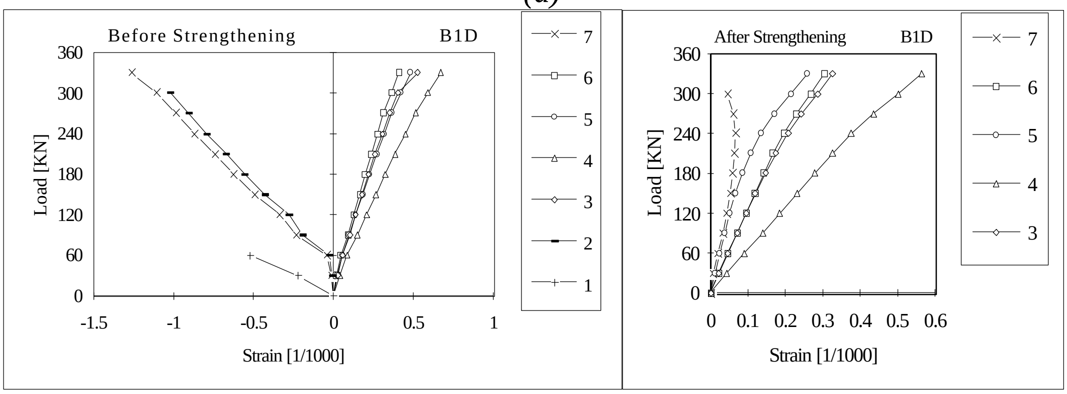
3. RESULT

3.1 Concrete strain distribution at the max. positive moment section

Fig 5 and 6 shows the increases of the concrete strain with the load before and after strengthening of the beams in series I and II respectively, at the maximum positive moment section.



(a)



(b)

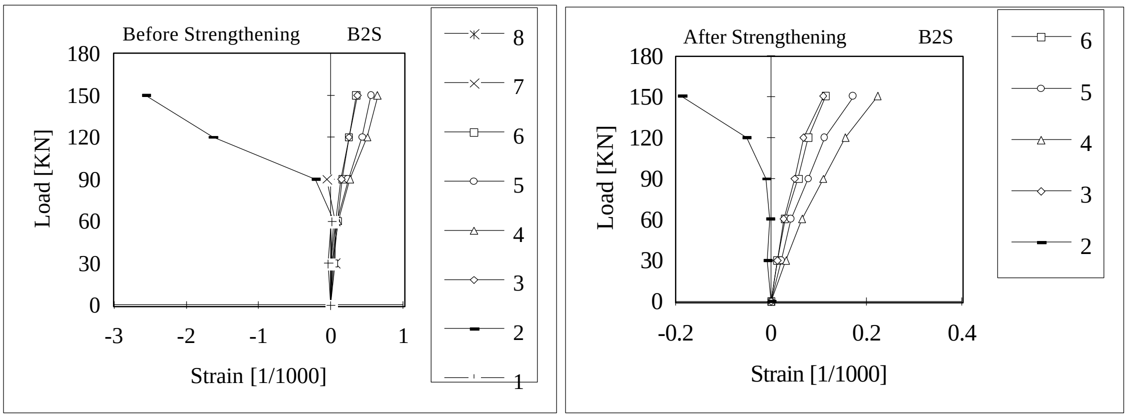
Fig.5 Concrete strain distribution with increasing of the loads at the max. positive moment section of beams in series I

Fig.5b gives the increases of the concrete strain with the load before, and after strengthening of the beam B1D at the maximum positive moment section. Eight positions are chosen to record the strain values (see Fig.4). At this section, the strains before strengthening on the flange at position (3,4,5,6) which are in compression and at the lower portion of the web at the position (1,8) which are in tension, was 670 and 1265 microstrain receptively. After strengthening, at the same load value (330KN) the strain at the flange was decreased to 563 microstrain.

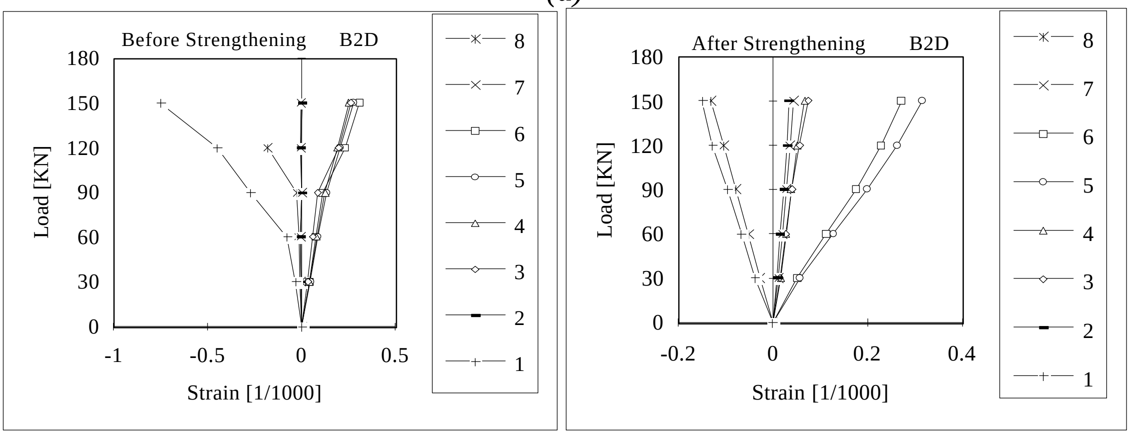
In Fig.6a at the maximum positive moment section, of beam B2S, the maximum strain before strengthening on the flange at position (3,4,5,6) which are in compression, was 650 microstrain. After strengthening, at the same load value the strain was decreased by 65 percent.

In Fig.6b at the maximum positive moment section of beam B2D, the maximum strains before strengthening on the flange at position (3,4,5,6) which are in compression and at the lower portion of the web at the position (1,8) which are in tension, was 309 and 752 microstrain receptively.

After strengthening, at the same load value (150 KN), the strain was decreased, the higher reduction achieved by the tension strain at the bottom portion of the beam, where the reduction is 75 percent.



(a)



(b)

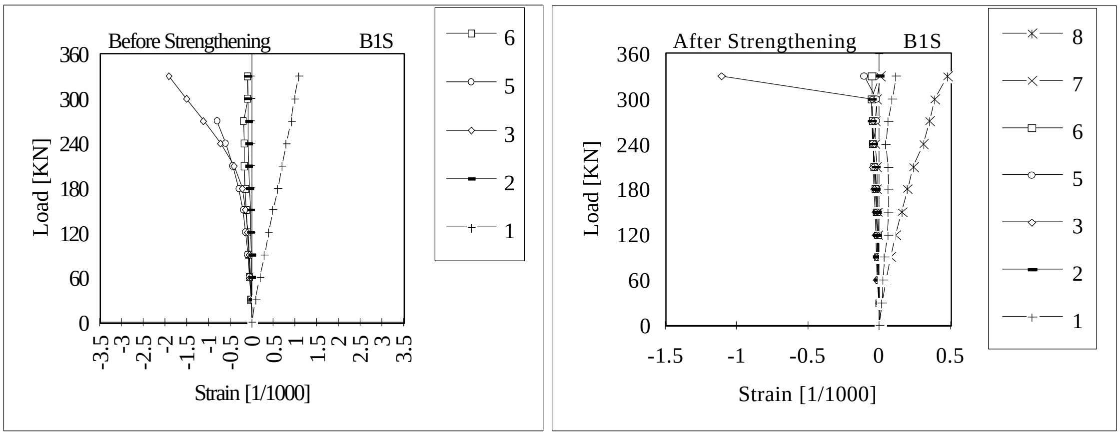
Fig.6 Concrete Strain distribution with increases of Loads at the max. positive moment section of beam in series II

3.2 Concrete strain distribution at the max. negative moment section

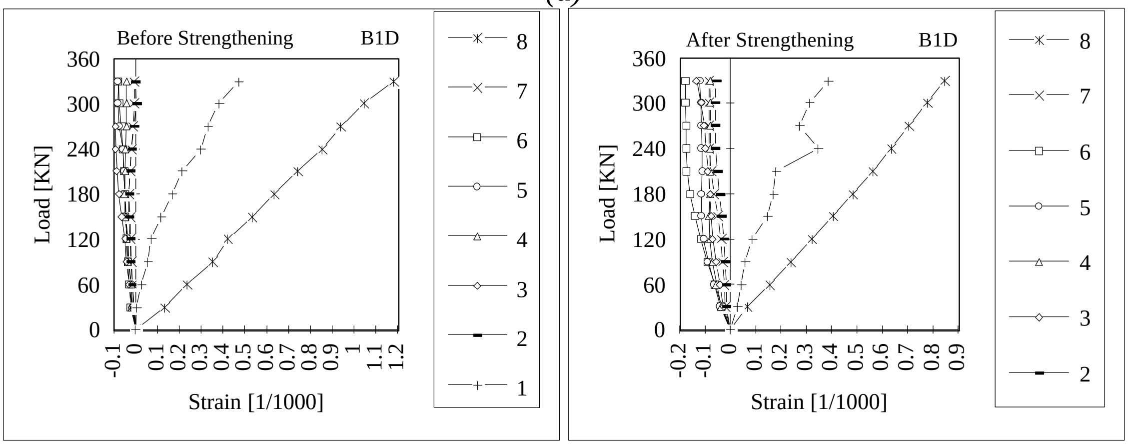
Fig 7 and 8 shows the increases of the concrete strain with the load before and after strengthening of the beams in series I and II respectively, at the maximum negative moment section.

In Fig.7b at the maximum negative moment section of beam B1D, the strains before strengthening on the flange at position (3,4,5,6) which are in tension and at the lower portion of the web at the position (1,8) which are in compression was 79 and 1182 microstrain receptively.

After strengthening, at the same load (330KN) the strain at the flange was increased up to 177 microstrain and at the lower portion of the web decreased to 845 microstrain.



(a)

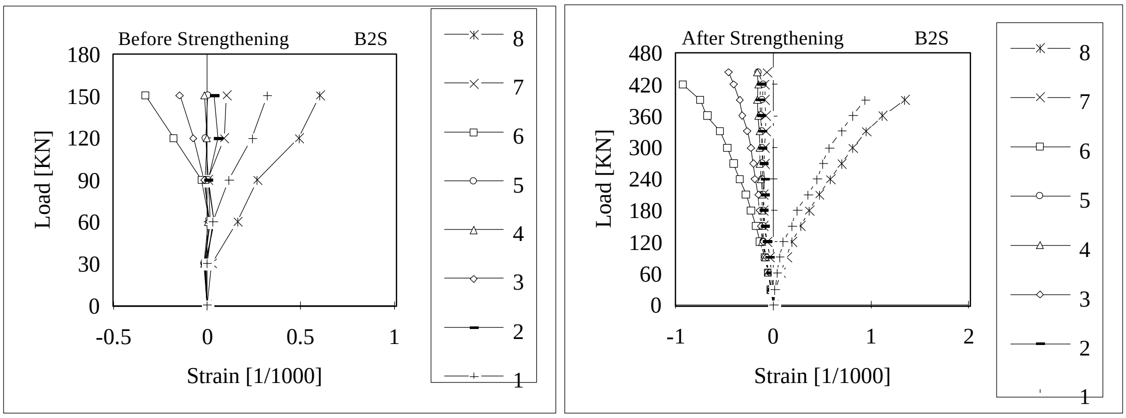


(b)

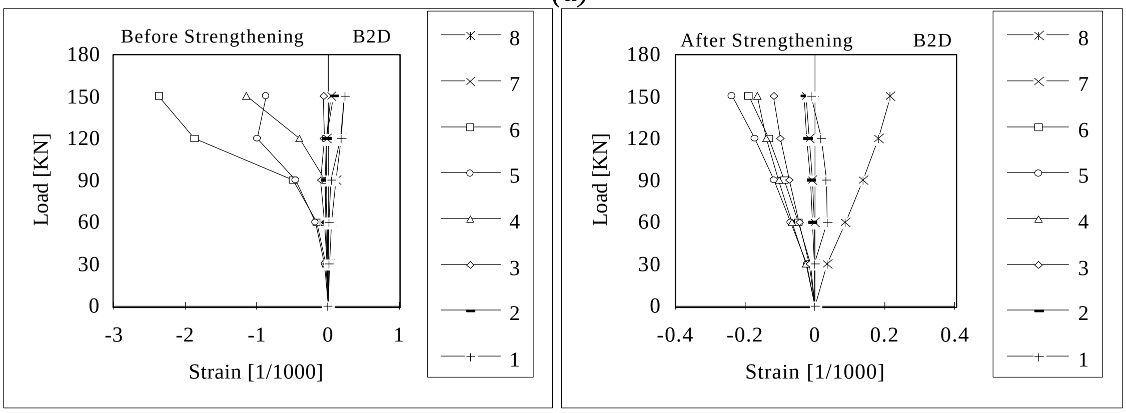
Fig.7 Concrete strain distribution with increasing of the loads at the max. negative moment section of beams in series I

As shown in Fig.8a, the maximum strains before strengthening of beam B2S on the flange at position (3,4,5,6) which are in tension and at the lower portion of the web at the position (1,8) which are in compression was 331 microstrain and 601 microstrain receptively, the strain at position (2,7) which are near to the neutral axis tends to zero. After strengthening, at the same applied load (150KN), the strains are considerably decreased, the reduction was 48 percent in the tension strain at the top portion of the beam, and 53 percent in the compression strain at the bottom portion of the beam web.

In Fig.8b at the maximum negative moment section of beam B2D, the maximum strains before strengthening on the flange at position (3,4,5,6) which are in tension and at the lower portion of the web at the position (1,8) which are in compression was 2368 and 232 microstrain receptively, the strain at position (2,7) which are near to the neutral axis tends to zero. After strengthening, at the same applied load (150KN), the strains are considerably decreased, the higher reduction achieved by the tension strain, at the top portion of the beam, where the reduction is 89 percent.



(a)



(b)

Fig.8 Concrete Strain distribution with increases of Loads at the max. negative moment section of beams series II

4. CONCLUSION

1. The strengthening of concrete beams with additional post-tension can be used very effectively to close cracks and decrease both tension and compression concrete strain.
2. Due to Strengthening, at the same applied load (a) At maximum positive moment section, the concrete compressive strain, at the flange decreased by 16 and 65 percent for B1D and B2S respectively, and the tension strain by up to 75 percent for B2D.(b) At the maximum negative moment section, the concrete compressive strain at the web of the beam decreased by 28.5 and 53 percent for B1D and B2S respectively, and the tension strain by up to 48 and 89 percent for beam B2S and B2D respectively.
3. Compared with straight tendon profile, deviated tendons profile was more effectively to decrease the concrete strain, the decreases were up to 41% higher than the straight one.

5. REFERENCES

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