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Effect steel reinforcement ratio on the behavior of RC beam without concrete at tension zone using truss-system reinforcement

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Abstract. Massive exploration of the natural materials for producing concretes affect to the environment condition and global warming that may cause natural disasters. Therefore the using of the concrete materials should be as efficient as possible. According to its natural behavior of the concrete material, it is strong in compression and weak in tension. Therefore the contribution of the tensile stresses of the concrete to the flexural capacity of the beams is neglected. However, removing concrete on the tension zone affects to the decreasing of flexural capacity. Based on the previous studies, beam without concrete at the tension zone using truss-system reinforcement causes the tension crack near the supports. This crack might because decreasing the flexural capacity of the beam. One of the solutions to solve this problem is by strengthening the beams using steel reinforcements. Therefore, this study aims to investigate the effect of steel reinforcement near the supports on the behavior of beam without concrete at the tension zone using truss-system reinforcement. The parameter of this study was the length of the additional reinforcement near the support. It was varied into 40D, 60D and 80D, where D is the diameter of longitudinal reinforcement. The results indicated that the tensile cracks near the support could be avoided by adding the longitudinal reinforcement. Finally, the flexural capacity of RC beams without concrete at the tension zone can be increased.

1. Introduction

The current concept of sustainable construction is being developed in the world of construction. This concept aims to make construction at the time of production, design, purpose, maintenance and destruction does not spend resources in the form of money, energy, and materials. As an experimental effort to achieve consideration, a series of studying is being done in reducing the volume of concrete on tension parts. In order to clarify the flexural capacity of the beam without concrete on the tension parts in the construction, especially on the beam, which is still giving safe building for its users. A variety of ways have been made to increase the flexural capacity of the beam, such as adding a tensile reinforcement rod to a reinforced concrete beam of the truss system. Previous research on Composite steel and concrete trusses used in floor and bridge structures are analyzed with respect to the shear connection between a steel truss and a concrete slab. Elastic and elastic-plastic behavior of the shear connection [1]. All specimens were longitudinally reinforced with deformed A1035 steel bars with measured stresses at the peak load from 695 to 988 MPa (100 to 143 ksi), significantly higher than the design stress limits defined in current codes of practice. The applied loading is incremented until one or more of the struts, ties, or nodes reach its defined stress limit [2,3]. In this study, separate strut-and-tie models were solved for the cases with or without web reinforcement, as shown in figure 1.

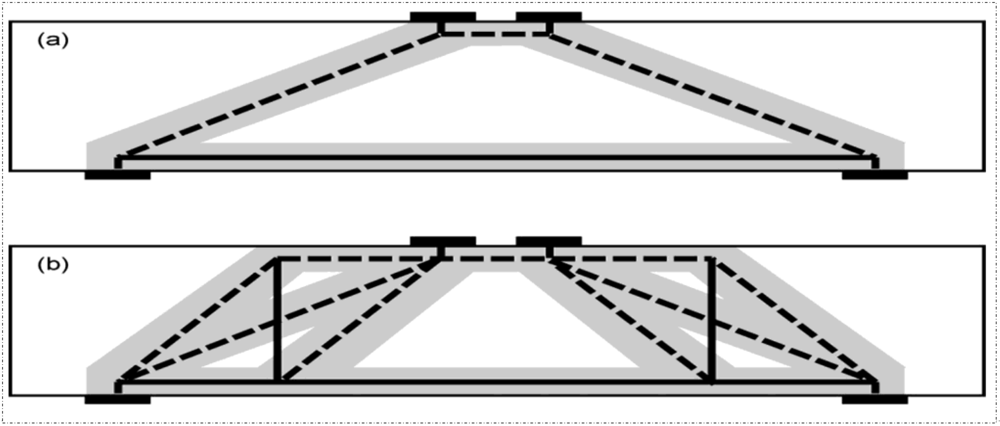


Figure 1. Strut-and-tie models: (a) members without web reinforcement; and (b) members with web reinforcement

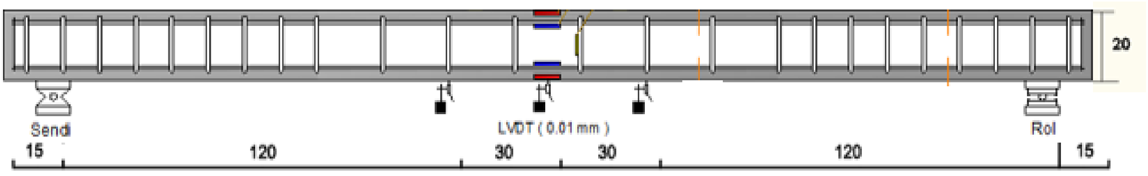
Figure 2. The crack at support.

The contribution of the tensile stresses of concrete to the flexural beam capacity is negligible [4,5]. The structure of the truss system can be an alternative to overcome the decrease in flexural capacity [6]. The results show that the truss system is required for external reinforced concrete beams. Truss concrete block system without concrete in tension zone (BR) can develop a capacity similar to a normal beam (BN). The result showed that sensitivity analysis and numerical application to spacing enhanced specific bone reinforcement system frame contributed significantly. BTR beam strength is reduced by 7.29% from normal Beam (BN). The cracks formed on reinforced concrete blocks result in failures such as cracks in the truss analogy based on relevant experimental evidence, tends to assume that cracks formed on reinforced concrete blocks result in failures such as cracks in the support areas, as shown in figure 2.

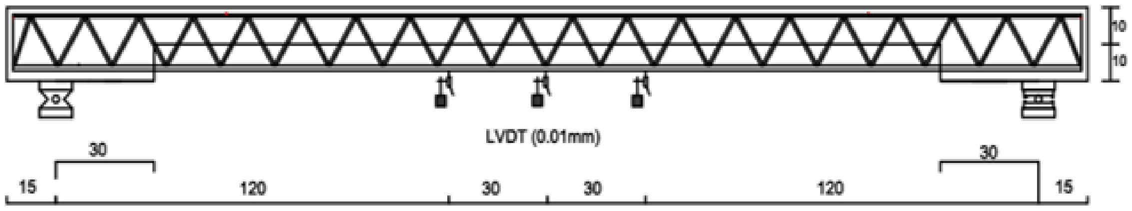
2 Experimental program

2.1. Specimens

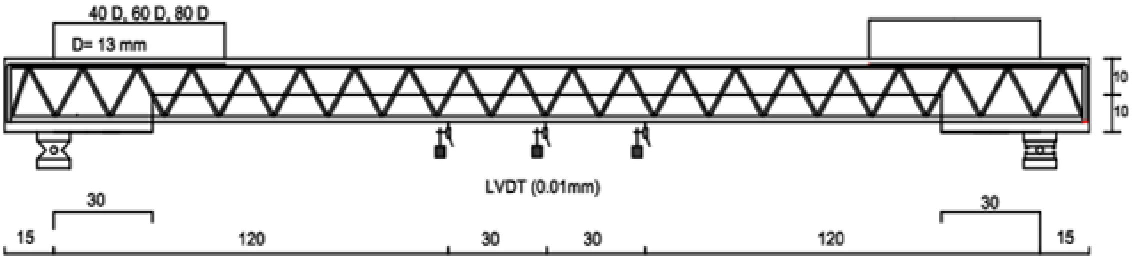
Five beams with different variations were tested in this study. It consisted of one beam with normal reinforcement (BN), one beam with truss-system reinforcement (BTR), three beams with additional reinforcement at the supports (BTRP-40D, BTRP-60D and BTRP-80D). The 40D means that the length of additional reinforcement was 40 times the diameter of the longitudinal reinforcement of the beam. The dimension of the beam was 330 cm x 15 cm x 20 cm, as shown in figure 3.



(a) Normal Beam (BN) speciment



(b) Truss system beam without reinforcement steel strengthened (BTR) speciment



(c) Truss system beam with reinforcement steel strengthened (BTRP)

Figure 3. Beam specimens.

2.2 Material properties

Table 1 shows the properties of concrete and reinforcement. The material properties of all beams were the same. The compressive design strength of concrete in 28 days was 25 MPa. The elastic modulus of concrete was 23500 MPa. The aggregate test based on ASTM is performed on coarse aggregate (gravel) and fine aggregate (sand). From the calculation result and mix design experiment by using the Development of Environment (DoE) obtained aggregate composition, water cement factor, concrete material characteristic, and proportion of the mixture. Two types of reinforcing steel according to SNI 0136-80 standards [1], each of which is a plain diameter of 8 mm with a yield strength of fy = 400 MPa used as diagonal reinforcement as well as the longitudinal top. Plain rebar of 13 mm diameter with yield strength f_y = 400 MPa is used as longitudinal reinforcement and tensile strength reinforcement. Details of reinforcement shown in figure 3.

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Tabel 1. Material properties

Concrete		Reinforcement	
Compressive strength ($f'c$)	25 MPa	Yield strength (f_y)	400 MPa
Tensile strength (f_t)	3 MPa	Ultimate strength (f_y)	474 MPa
Bending stress (f_r)	3.74 MPa	Elastic modulus (E_s)	193086 MPa
Modulus elasticity (Ec)	23500	Yield strain ($\mathcal{E}_y$)	0.00199

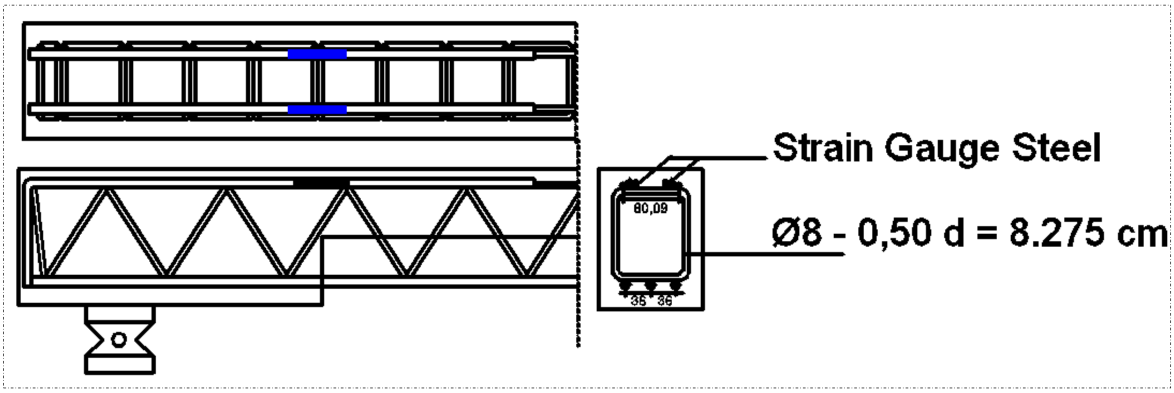

Figure 4. Strengthening the beams using steel reinforcements.

2.3 The setup tests

The beam test was performed with two point load on a concrete beam used in monotonic loading, which was given in displacement control with constant ramp speed of actuator 0.03 mm/dt until the beam collapsed. The data reading on the data logger is taken for each deflection increased under normal conditions. Showing several LVDT were installed to record vertical deflection at several locations on the data logger is taken at each deflection increase under normal conditions. The test setup is illustrated schematically, showing several LVDT installed to record vertical deflection at several locations on the specimens. The deflection for the beam test was carried out with each additional load of 1.00 kN - 2.00 kN with an acceleration rate of 0.1 kN/sec. The position of the placement of the concrete strain gauge is placed in the center of the span, and another strain gauge was placed 1.5 cm and 5 cm from the top of the beam. The setup test of the beam, as shown in figure 5.

3. Result and discussion

3.1 Load and deflections relationship

The results of the reinforced concrete beam test of Truss system BTRP, BTR, and BN, about the maximum load, first crack, and final moment. The maximum capacity and initial cracks for each specimen. When the ultimate load is calculated under conditions where there was a compressive failure on the concrete after reinforcement steel, in general, the maximum capacity increases for BTRP 40D, BTRP 60D, and BTRP 80D, when compared to the BN beam, the maximum load for the BTR beam is lower than the BN and BTRP blocks. The first crack is almost the same when compared to BN, for more details shown in table 2.

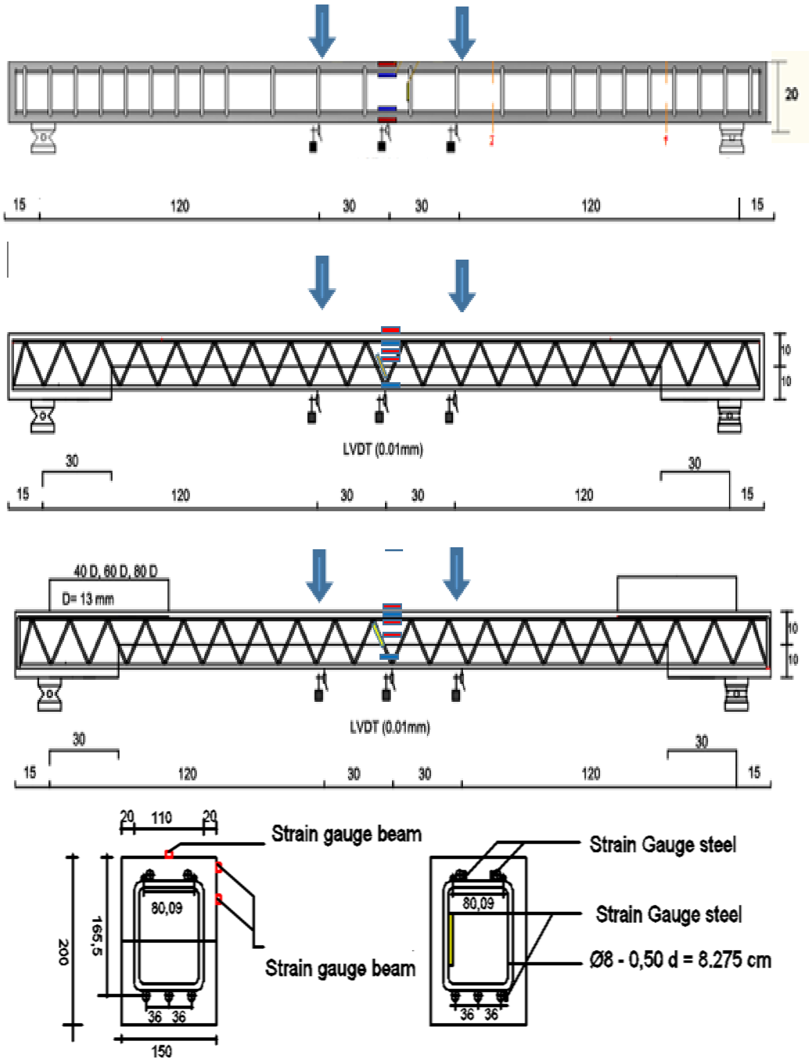

Figure 5. Location of instruments.

Figure 6. The photograph of setup tests.

Table 2. Maximum capacity and ultimate moments.

Specimen	First Crack	Maximum Capacity		Ultimate Moment
		Loading	Deflection	kN.mm
BN	5.27	28.84	31.71	17.30
BTR	5.81	17.89	24.22	10.81
BTRP 40D	4.53	34.39	33.06	20.63
BTRP 60D	5.33	34.72	24.26	20.83
BTRP 80D	5.26	34.59	21.52	20.75

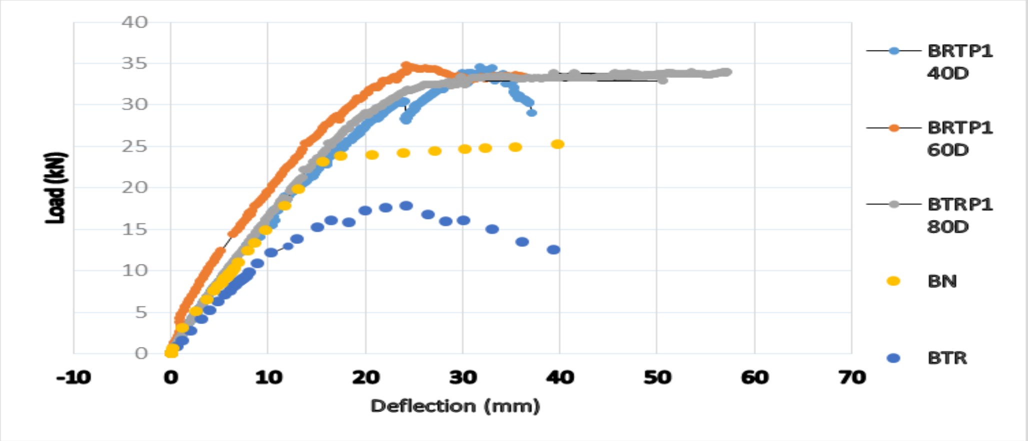

Figure 7. Chart load – deflection curve.

The load deflection behavior of the specimens may be observed in figure 7 as a load-deflection relationship curve. The load deflection was measured at the center point of the beam span. All beams are un-cracked and stiff. The test results obtained maximum load on the beam BTRP 40 D 34.39 kN, with a deflection of 33.06 mm, BTRP 60 D of 34.72 kN with a deflection of 24.26 mm, BTRP80 D maximum 34.59 kN, deflection of 21.52 mm, and on BTR beam maximum load 17.89 kN with deflection 24.22 mm. After observing the maximum load and deflection that occurred from the test results, there was a significant increase in the case of loading capacity up 19.22% of the normal beam (BN). However, the biggest deflection is in the beam BN of 31.705 mm. As for concrete beam with frame reinforcement (BTR), it has maximum load capacity lower than normal beam to 37.96%.

3.2. Load relations – a strain of longitudinal reinforcement

Steel strain values were measured by using a strain gauge type FLK-6-11 (gauge factor of 2.12 ± 1%). The increased strain is recorded through TDS 530 data logger. Graphic of BTRP 40 D, BTRP 60 D and BTRP 80 D shown in figure 8. Figure 8 shows that the load-strain steel between test specimens BTRP 40 D, BTRP 60D, and BTRP 80 D BTR. BTRP beam stretched 1616.98 mm at maximum load 34.39 kN, BTRP 60D strain of 3243.40 mm at the maximum time of 34.72 kN and BTRP 80 D strain of 5221.70 mm at maximum 34.57 kN. On the three beams of the BTRP 40 D, BTRP 60 D and BTRP 80D resulted in the ultimate load. While on the beam, BN melted at 28.84 kN load with a strain of 2655.4 mm.

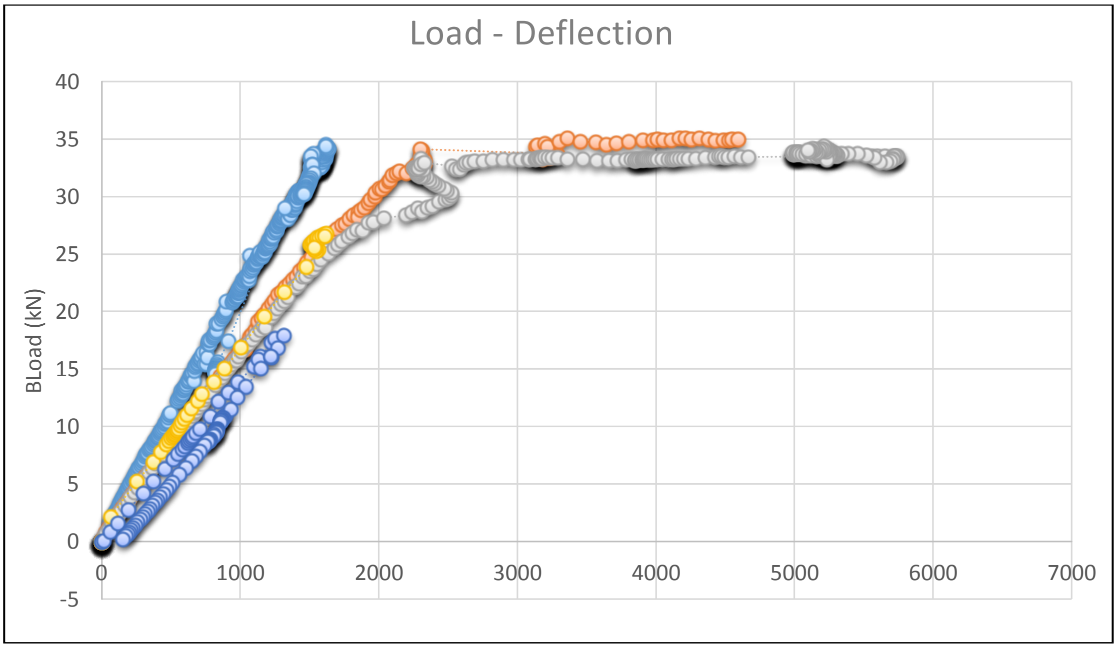

Figure 8. Load-strain of longitudinal reinforcement.

3.3 Load relation - a stretch of concrete

Graphic of load-concrete strain relationship was shown by changing of load and deformation in Fig. 9. The relation of load strain on BTRP 40 D, BTRP 60 D and BTRP 80 D. At BTRP 40 D with ultimate load of 34.39 kN with strain of 721.154 mm, BTRP 60 D with maximum load 34.72 kN strain of 1638.46 mm and BTRP 80D beam with ultimate load 34.58 kN with strain load of 2532.69 mm. Figure 7 shows the relationship between load and deflection of each test material. In the BTRP beam (40D, 60D, 80D), the initial load showed linear behavior elastic behavior until the average load is 5 kN (working stage). As the load increases, relation with load and deflection are more smooth than before. This happened to an average load of 30 kN (yielding stage). When the reinforcing steel is the yield, it was characterized by a large increment of deflection without being followed by a significant load increase, the graphic load and deflection relationship showed are much flatter than before. This happens until the ultimate load stuck approximately of 35 kN.

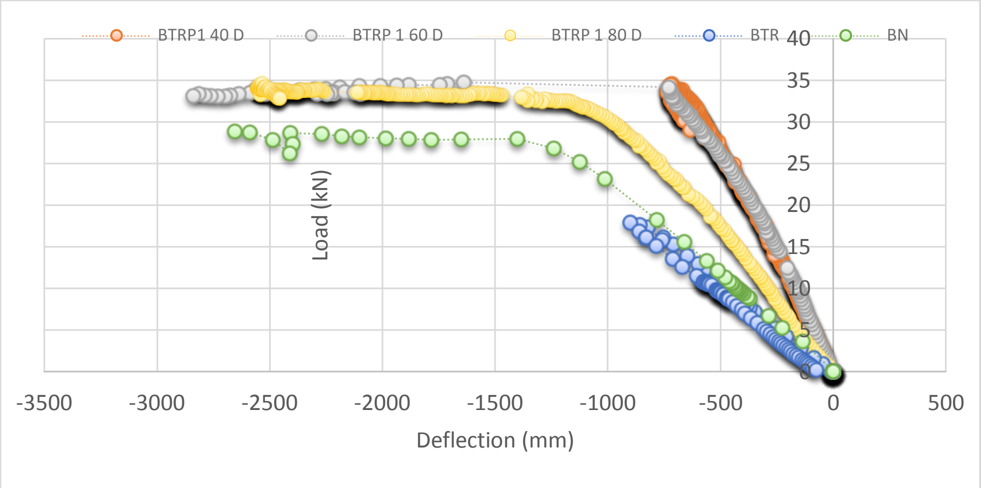

Figure 9. Load-concrete strain relationship.

3.4 Load strain of rebar

Base on figure 10, reinforcement steel can increase the flexural capacity of the beam with a variation of reinforcement lengths of 40D, 60D and 80D.

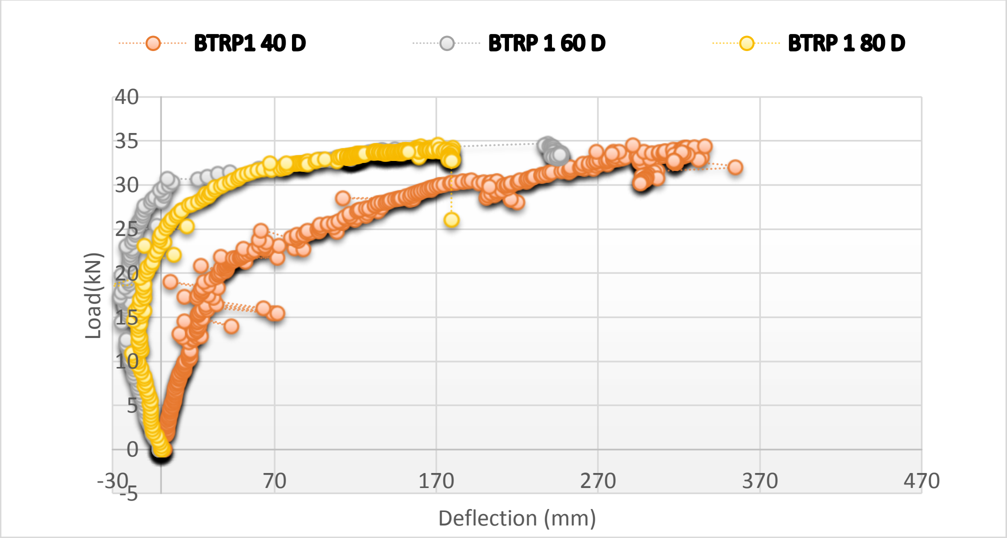

Figure 10. Chart relationship load - a strain of rebar.

4 Conclusions

- The additional longitudinal reinforcement at the support has a significant effect on the behavior of the reinforced beam without concrete at the tension zone where the cracks occurred near the support can be avoided.
- The flexural capacity of the beams with additional reinforcement (BTRP-40D, BTRP-60D and BTRP-80D) increased compared to the normal beam (BN) and truss-system beam (BTR).

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