Reinforcement method of reinforced concrete beam by using non-stressing strand

A Susanto*, H Kasyanto and S Susilahadi
Civil Engineering Department, Politeknik Negeri Bandung, Bandung, Indonesia

*ambar.susanto@polban.ac.id

Abstract. Many methods can be used in the repair of bridges or other structural buildings. The aim is to increase the existing capacity. In the reinforced concrete beam structure, capacity of structural elements can be carried out by reinforcement method. The research was done by experimental loading test in laboratory. The test objects are consisted of 2 (two) reinforced concrete beams: a normal beam without reinforcement (NB) and a reinforcement beam by using non-stressing strand (RB1). The dimensions of the beams are 150mm x 300mm x 3200 mm. All beams are loaded by static-monotonic load until collapses. From the results of the research, the first yield load for the NB beam and RB1 beam respectively are 22 kN and 29kN. The deformations that occur at the conditions are 9.5mm and 14mm respectively. The collapse occurring on the NB beam is the bending collapse, whereas in the RB1 beam is a bending-shear collapse.

1. Introduction
Some considerations in the repair of bridges, or other buildings, include: age of the building, corrosion of steel reinforcement, defects in construction, transfer of function of the structure, and damage caused by natural disasters.

Reinforcement of structural elements is carried out when the load increases. This reinforcement serves to increase the capacity of these structural elements. Reinforcement can be done, among others, by addition of external prestressed, FRP (fiber reinforced polymer), and steel plate.

The selection of the reinforcement type depends on existing condition, location of the reinforcement, structure capacity, cost, and material. An example is reinforcement by using FRP. The weakness of this material is brittle, not resistant to fire and low durability. For that reason, it is proposed method of strengthening structural elements by using non-stressing strand. The strand, attached to beam by using epoxy, is supported by a U-shaped anchor.

External reinforcement of the beam elements using strand material is one of the methods to restore or increase the capacity of structures that have failed or degraded. On external reinforcement, strand is selected because the material has a high elastic modulus.

2. Literature review
Renata et al., used 15mm x 30mm T-shaped CFRP reinforcement, on reinforced concrete beam. The proposed system successfully combines the advantages of two developed reinforcement techniques i.e. near surface mounted (NSM) and externally bonded (EB) methods. The results of this study can increase the bending capacity and reduce the maximum deformation that occurs [1].
Jain et al., mentioned that the use of FRP for structural reinforcement is very popular. This is because FRP has many advantages, such as on the strength-to-weight ratio and excellent corrosion resistance. The research on reinforced concrete shear reinforcement, Glass Fiber Reinforced Polymer (GFRP) materials are used. Apparently, U-shaped GFRP reinforcement produces better strength compared to reinforcement installed on both sides of the beam [2].

Limpaninlachat et al., utilizes ultra-high strength fiber in prestressed concrete beams. The results showed an increasing in the flexural capacity and structural durability. This study focused on the behavior of bending beams reinforced with strands. The strand is choosed because of the high tensile capacity [3].

Gul et al., examines the reinforcement by adding reinforced steel to the bending area. The results of this study indicate that there are relatively large increasing in flexural capacity, high ductility of the beam, as well as uniform cracks distribution [4].

Hamad et al., conducted research on reinforced beams with steel reinforcement and angle steel. Overall, there is a significant increase in yield. The cross-sectional capacity of the beam increased 3.2 times compared to the normal beam. This means higher shear strength and higher moment resistance [5].

Manisekar et al., examines the use of external prestressing on reinforced concrete beam elements. The beam has decreased strength to 85% of its tensile steel strain. The result, by installing external prestressing can increase the ultimate load by 48% and restore deflection as the original condition [6].

Susanto et al., tested the 2 reinforced concrete beam: Bo (beam without reinforcement) and B1 (beam with reinforcement). As a result, the first yield load on B1 is 27% higher than first yield load on Bo. Because of loading test, the Bo specimen has a bending crack on vertical direction. While on the test of B1 specimen, the crack occurs in the diagonal direction. This happens because of the installation of U-shaped anchor. This anchor becomes the support of the strand, whose function is similar to shear reinforcement [7].

3. Methodology
The study was conducted by experimental testing in the laboratory. The specimens consist of 2 (two) reinforced concrete beam, dimension 150mm x 300mm x 3200mm, as shown in Figure 1.

- NB (beam without reinforcement).
- RB1 (beam with strand reinforcement, with 3 pcs anchors).

Anchor is U-shaped reinforcing steel. The placement of 3 pcs of anchors can be seen in Figure 2. The two specimens are simple beam structures. The test is carried out with static-monotonic loads according to ASTM-C293 until collapses by displacement control method [8].

![Figure 1. Beam without reinforcement (NB).](image-url)
4. Analysis and discussions

4.1. Load and deformation

Loading test on 2 specimens result load and deformation values that occur in the first crack condition and the first yield conditions as shown in Table 1. The relationship between load and deformation can be seen in Figure 3.

Table 1. Load ratio and deformation ratio.

| Specimen | Load (kN) | Deformation (mm) | Load Ratio to NB | Deformation Ratio to NB |
|----------|-----------|------------------|-------------------|-------------------------|
|          | P<sub>first crack</sub> | P<sub>y</sub> | δ<sub>first crack</sub> | δ<sub>y</sub> | P<sub>first crack</sub> | P<sub>y</sub> | δ<sub>first crack</sub> | δ<sub>y</sub> |
| NB       | 15,76     | 22 | 7,48 | 9,5 | 1 | 1 | 1 | 1 |
| RB1      | 18,84     | 29 | 7,90 | 14 | 1,19 | 1,32 | 1,06 | 1,47 |

Figure 2. Beam with strand reinforcement (RB1).

Figure 3. Relationship between load and deformation.
From Table 1 and Figure 3 above, the addition of U-shaped anchor on the bottom side of the beam, i.e. in the tensile region, influences the magnitude of the force and the deformation that occurs.

4.1.1. The first crack conditions. On the NB beam, the first crack occurs at load $P=15.76\text{kN}$, while deformation $= 7.48\text{mm}$. On the RB1 beam, first crack occurs at the load $P=18.84\text{kN}$, while deformation $= 7.9\text{mm}$. Thus, on first crack conditions, load increases 19% and deformation increases 6%.

4.1.2. The first yield conditions. On the NB beam, the first yield occurs at $P_y=22\text{kN}$ load, while deformation $= 9.5\text{mm}$. On the RB1 beam, the first yield occurs at $P_y = 29\text{kN}$, while deformation $= 14.0\text{mm}$. It means that on the first yield conditions, yield load increases 32% and deformation increases 47%.

4.2. Pattern cracks and collapse
Beside of to the load and deformation values described above, from the loading test results can also be determined the pattern of cracks and collapse that occur from each samples.

4.2.1. NB beam. Crack pattern that occurs in NB beam is crack bending on vertical direction. Few shear-bending cracks also occur at 1/3 middle span. As the load increases, crack occurs vertically perpendicular to the axis of the beam causing bending failure, as seen in Figure 4.

4.2.2. RB1 beam. Three (3) pcs U-shaped anchors are installed at a distance of 750 mm along 1500 mm. Anchors are functioned as support of strand that produces bending-shear collapse on the beam. This is because the anchor that inserted into the beam behaves like a shear reinforcement. Many bending-shear, crack occur at the reinforced area and shear crack occur at the outside of reinforced area.

The pattern of crack and collapse of the beams can be seen in Figure 5.

4.3. Composite action
Non-stressing strand for reinforcement contributes to increase bending capacity of beam due to loading system as shown in Table 1. Strands are installed on the bottom side of the beam which glued with epoxy. At a certain distance this strands are supported by U-shaped anchor. Initially, after the first yield, strand on the bottom of beam is detached from concrete and there is not attachment between the concrete
and the strand. In this condition between strand and anchor still working together, so there is still a composite action between concrete cross section with strand. As the addition of the load approaches the maximum capacity of the beam, the strand is detached from the anchor. The original anchorage position parallel to the concrete cross-section turned into a tilt because of the tensile force on the strand. At this stage, there is no more composite action between the concrete beam and the strand.

5. Conclusion
From the above discussion it can be concluded that.
- The addition of reinforcement by non-stressing strand can increase the load capacity of the beam until 30% compared to the non-reinforced beam condition (NB).
- Cracks that occur on non-reinforcement beam are bending cracks, whereas the crack pattern that occur on reinforced beam are shear-bending crack. This is because of the addition of U-shaped anchor inserted into the beam as a support of the strand.
- The composite action that occurs between the strand and cross section of the beam only occurs when between the anchor and the strand is still a unity. By the time anchors have begun to tilt, the composite action has been lost.

References
[1] Cholostiakow R K S 2015 Flexural Strengthening of Reinforced Beams Using CFRP T-Shape Profiles Polymers 2461-2477
[2] Jain N and Sikka V K 2015 Strengthening Of RC Beams with Externally Bonded gfrps IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) e-ISSN 2278-1684
[3] Limpaninlachat P, Matsumoto K, Nakamura T, Kono K and Niwa J 2016 Flexural strengthening effect of pre-tensioned UFC panel on reinforced concrete beams Journal of JSCE 4(1) 181-196
[4] Gul A, Alam B, Khan F A, Badrashi Y I and Shahzada K 2015 Strengthening and Evaluation of Reinforced Concrete Beams for Flexure by Using External Steel Reinforcements International Journal of Scientific Engineering and Technology 4(4) 260-263
[5] Hamad B, Masri A, Basha H and Baalbaki O 2011 Behavior of T-shaped reinforced concrete beams partially confined by structural steel Construction and Building Materials 25(2) 1037-1043
[6] Manisekar R, Sivakumar P and Lakshmikandhan K N 2014 Experimental investigations on strengthening of RC beams by external prestressing Asian Journal Of Civil Engineering (BHRC), India
[7] Susanto A, Kasyanto H and Susilahadi S 2018 Studi Perkuatan Balok Beton Bertulang Dengan Strand Tanpa Penegangan Dan Tulangan U Jurnal Poli-Teknologi 17(1)
[8] American Society Testing and Material(ASTM)