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The Analysis Of the Addition Of Steel Plates Reviewed to The Compressive Strength Capacity Of The T-Beam

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Abstract. Reinforced concrete is used in various constructions, such as buildings, bridges, dams, road pavement, tunnels, etc. Structural strengthening of the reinforced concrete beam can be done in various ways, one is the addition of steel plates bonded to the compression area. Steel plates with a width of 150 mm and 300 mm with a thickness of 2 mm are expected to increase the compressive strength of reinforced concrete beams. Plate installation uses Sikadur 31 CF-Normal adhesive to attach steel plates and beams, and it is hoped that composite properties will occur on both of them. The test object samples were 5 beams consisting of 1 control beam and 4 reinforcement beams with a quality of 10 MPa. The beam sample has dimensions of 75 mm flange width and 80 mm flange height, 150 mm bottom width, 250 mm h height, and 300 mm top width. The flexural strength test was carried out with a loading frame in two-point loading. The results of the study of adding plates showed an increase in beam capacity compared to the control beam. The percentage increase in beam capacity of test objects BP 1(1) and BP 1(2) with 150 mm wide plate reinforcement was 17.19% and 18.85%. The increase in beam capacity of BP 2(1) and BP 2(2) specimens with 300 mm wide plate reinforcement was 26.82% and 28.02% respectively.

Keywords: T Beam, Reinforced Concrete, Steel Plate

INTRODUCTION

The utilization of reinforced concrete in construction continues to rise [1]. This material is extensively used in various constructions including buildings, bridges, dams, paving, tunnels, and more [2]. To guarantee safe load carrying, the design of reinforced concrete must fulfill certain requirements [3]. One of the strengths of concrete is its ability to endure compressive forces and its ease of application [4]

Meanwhile, the drawback of concrete is that it cannot withstand tensile forces, and to overcome the weakness of concrete against tensile forces, steel reinforcement is needed [5]. During project implementation, various kinds of obstacles can arise, including pre-project, implementation, and post-project constraints [6]. Delays in the delivery of fresh concrete from the factory to the project site can lead to significant problems, reducing the quality of the concrete as it enters the initial setting time phase before the reinforcement has yielded [7]. Hence, it is essential to have a repair and strengthening method to restore the structure's strength [8]. Advancements in construction technology have produced various methods of reinforcement, including the use of steel plates for reinforcing reinforced concrete beams from the exterior [9]. This research concentrates on the use of steel plates as compression reinforcement in reinforced concrete beams.

A summary of research in this area is available from Pangestuti et al. (2020), who explains the behavior of flexural strengthening of beams with the placement of CFRP plates as external reinforcement (BF beam) is less effective because the bending strength decreases by 33.3% and the deflection decreases by 79% as compared with BN beam. That is because of the debonding failure of CFRP, so the concrete beam is not able to hold the pull force that occurs, and consequently, the beam collapses and fails due to its brittle condition [10]. Yohanes et all (2015) studied compressive strength and the strong bending relationship of the reinforced concrete beam. The value taken from the bending stress that occurs in the compression fiber section of the beam (concrete bending stress), ranges from 2.84 to 3.73, indicating a relationship between compressive strength and flexural strength of reinforced concrete beams.[11]. Thamrin et all (2015) explain that reinforcement with steel plates is more effective, easy to work with, economical, and has high rigidity. During the test, there was a difference when the crack first appeared, and proved that reinforcement with steel plates could increase the load bearing and deflection capacity of the beam.[12]. Khoirul et all (2010) Concluded that the reinforcement with channel steel profiles 70x30x1.2 mm increases the bending capacity by 37.858% and increases the stiffness by 7.529%.[13]

Formulation of T-beam Reinforcement

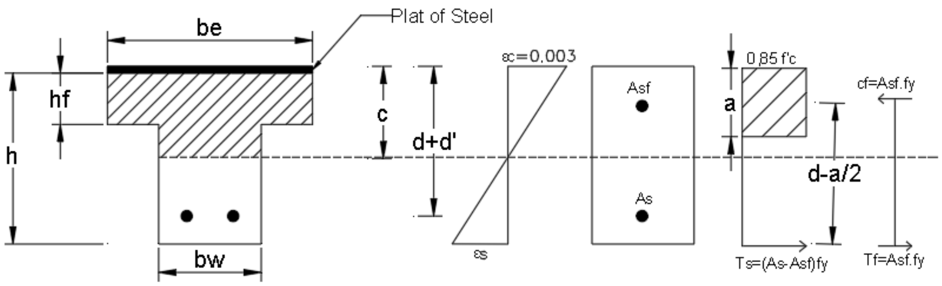

Figure 1. Stress-strain Diagram of Reinforced T Beam

The reinforced concrete T-beam is mounted to the steel plate external reinforcement, and the bending strength of the beam occurs as shown in Figure 1, where d+d' is the distance from Cc to Ts. The moment capacity of this concrete T-beam can be calculated using the simplified stress block method. The calculation of the effective height (d) after the addition of the plate uses a flexural method that takes into consideration the variable *n*, where *n* is the ratio between the modulus of elasticity of steel and the modulus of elasticity of concrete so that the quality of concrete and the quality of steel significantly affect the value of *n*.

$$n = \frac{Es}{Ec}$$

d' = Thickness of plate x n

where:
n = ratio of modulus of elasticity of steel to the modulus of elasticity of concrete
d' = Height of plate considered as concrete beam composite material
Es = modulus of elasticity of the steel
Ec = modulus of elasticity of the concrete

After that calculation, the new effective height is found, which is *d* + *d'* that can be used as a variable in analyzing T beams with steel reinforcement. The capacity of concrete T beams must increase because the effective height is greater than that of concrete T beams that are not strengthened with steel in the compression section **(d+d' > d)**.

Flexural Strength of Concrete T Beam

The analysis step can be applied based on the calculation of a T-beam with the neutral line (c) below the flange, in which case it can be applied in the same way as a square beam with double reinforcement, by replacing the slab part of the "flange" with an imaginary reinforcement area:

$$Asf = \frac{0{,}85.fc'.(b-bw).hf}{fy}$$

For beams that are considered "pure" T beams, the tension force As.fy of the reinforcement must be higher than the total flange area force capacity equal to 0.85.f'c.b.hf, therefore:

$$a = \frac{\mathrm{As.fy}}{0{,}85\ \mathrm{f'C.\ b}} > hf$$

or

$$a = 1{,}18\ .\ \omega\ .\ \mathrm{d} > hf$$

where, $\omega = \frac{As}{b.d}.\frac{fy}{f'C}$, and if a Parabola stress block is used then the equation can be written as:

$$c = \frac{1{,}18\ .\omega\ .\mathrm{d}}{\beta 1} > hf$$

Just like a double-reinforced beam, the reinforcement is divided into two parts As_1 which balances the concrete compressive force of the area *bw.a*, and As2 to balance the imaginary reinforcement area As_f, so that the nominal moment can be calculated. :

$$Mn = Mn1 + Mn2$$
$$Mn1 = As1\ .fy.\left(d - {}^{a}/_{2}\right) = (As - Asf)\ fy.\left(d - {}^{a}/_{2}\right)$$
$$Mn2 = As2\ .fy.\left(d - {}^{hf}/_{2}\right) = Asf.fy.\left(d - {}^{hf}/_{2}\right)$$

Properties Of Steel Plat

The steel plate served as reinforcing material for the T beam. The steel plate used in this study is a 2.0 mm-thick steel plate sheet cut to a width of 30 cm and 15 cm. The tensile strength of the steel plate after testing is 349 MPa.

Properties Of Epoxy

In the reinforcement of concrete T-beams with steel plates, a chemical adhesive is required to ensure that the steel plates can be perfectly attached and not peeled off. This adhesive consists of two materials, resin and hardener, which must be mixed before being used to bond the steel plate to the beam

TABLE 2. Properties of epoxy

Properties of Epoxy	
E-Modulus	12.800 MPa
Bond Strength	> 4 MPa

RESEARCH METHODOLOGY

The test object consisted of five reinforced concrete T-beams with a concrete quality of 10 MPa. consists of 1 control beam (BK), 2 beams with the addition of a 150-mm-wide plate, namely BP 1(1) and BP 1(2), and 2 beams with the addition of a 300-mm-wide plate, namely BP 2(1) and BP 2(2), as shown in Figures 2 and 3.

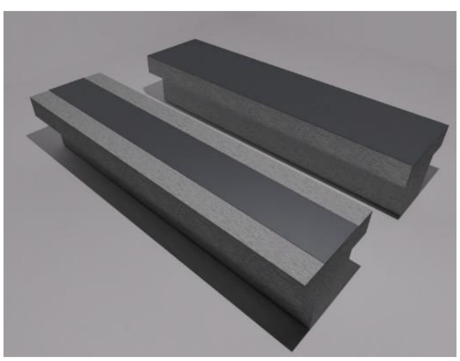

Figure 2. 3D Cross Section of Test Specimens

Concrete T beam sizes are 75 mm flange width and 80 mm flange height, 150 mm bottom width, 250 mm height, and 300 mm top width. The T beams were reinforced with four tensile reinforcement bars with a diameter of 16 mm and two compressive reinforcement bars with a diameter of 8 mm, as shown in Figure 3.

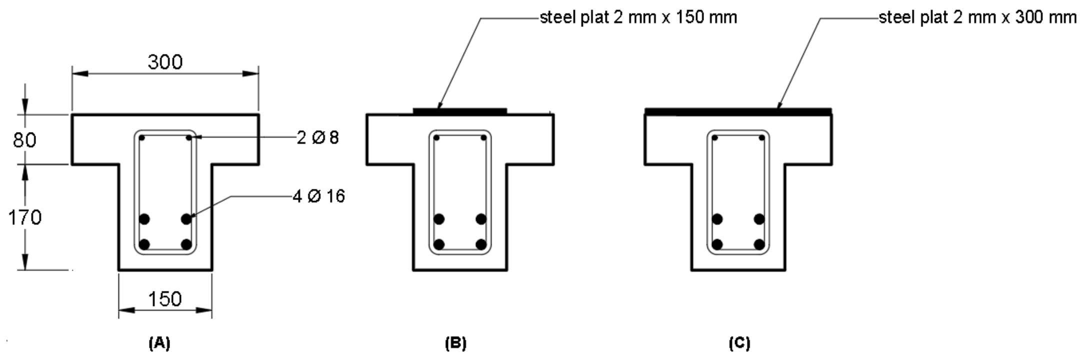

Figure 3. (A) Cross-section of Control Beam, (B) Cross-section of BP 1, (C) Cross-section of BP 2

After the specimens were 28 days old, testing was conducted. Tests in the form of flexural tests for T-beam test objects. Flexural tests were carried out utilizing test objects placed on loading frames given joint and roll supports. Loading is applied at two points 440 mm away from each support. When conducting the test, 3 dial gauges were placed under the beam to read how much the beam deflected. The dial gauges were placed at the center of the beam span, and below the loading point. Loading was carried out using a hydraulic jack with a maximum capacity of 20 tons and a load increase interval of 500 kg. Setting up of flexural test as shown in Figure 4.

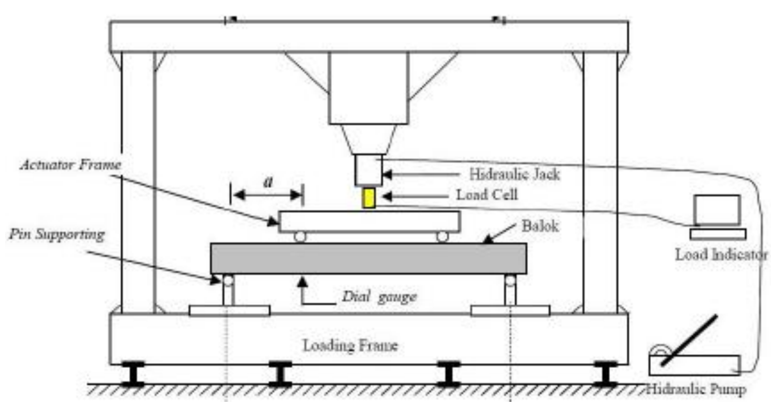

Figure 4. Beam Flexure Test Instrument

RESULT AND DISCUSSION

A. Research Result

a. Mix Design

From the mix design calculation, the material requirement per m3 is obtained, as are the material requirements for making cylinders and the material requirements per test object

TABLE 2. Material Requirement Per m^3 Of Concrete Mix Design

Material requirement per m^3		
Total weight	kg	2370
Water	liter	180
Cement	kg	285
Sand	kg	762
Gravel	kg	1143

Table 2 shows that the material requirement for 1 m^3, the material required for one mix of concrete to control the accuracy of the quality of the mixture is in the form of a cylindrical sample with a diameter of 15 cm and a height of 30 cm which was tested at the age of 28 days.

b. Concrete Compressive Strength

The compressive strength test of concrete was carried out when the specimen was 28 days old using a compression testing machine so that the maximum load was obtained, as shown in Figure 5. Compressive strength test was performed using 3 sample cylinders. The results of the average concrete stress of the 3 samples were 118.9 kgf/cm^2 or if converted in MPa units, cylindrical concrete had a compressive strength of 11.66 MPa MPa.

FIGURE 5. Compressive Strength Test

FIGURE 6. Beam flexural test

c. Momen and Load Capacity

Testing the flexural strength of a single reinforced concrete beam using a hydraulic jack machine, load cell, and load indicator, as shown in Figure 6. From these tools, the maximum load value (P) is obtained when the beam experiences the first crack (Cracking Load) and the value (P) when the beam reaches the strength limit (Maximum Load). From the laboratory test results, the maximum moment of BK is 15.20 kN.m. This result is different from the analytical calculation which is 17.71 kN.m. The test results can be shown in Table 3, it was found that all the moments of the T-beam with reinforcement increased when compared to the control beam (BK).

TABLE 3. Comparison of Ultimate Moment BK and BP

No	Specimen	Maximum Load (analytical) (kNm)	Maximum Load (Experimental) (kN)	Maximum Moment (experimental) (kNm)
1	BK	17,72	7,53	15,20
2	BP 1(1)	24,05	8,82	17,85
3	BP 1(2)	24,05	8,95	18,11
4	BP 2(1)	24,05	9,55	19,31
5	BP 2(2)	24,05	9,64	19,49

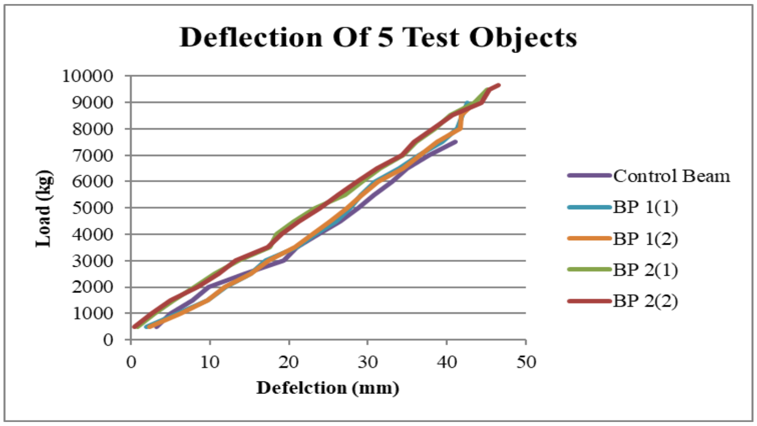

FIGURE 7. Graph of Test Object Bending Test

The deflection in the beam is obtained from the dial gauge during the test. It can be seen in Figure 7, that the average maximum deflection on the control beam is 41 mm. On reinforcement beams 1(1) and 1(2) the average maximum deflection is 42,53 mm and 43,5 mm. Meanwhile, the reinforcement beams 2(1) and 2(2) have an average maximum deflection of 45,17 mm and 46,50 mm. In terms of deflection, the reinforcement beam experiences a greater deflection than the control beam due to the less effective placement of the reinforcement.

d. Crack Pattern

The concrete enters the cracking stage, which indicates that the concrete has passed its tensile stress limit. The initial crack on the control beam occurs when the load reaches 35 kN; on the BP 1 beams, it occurs when the load reaches 40 kN; and on the BP 2 beams, the initial crack appears when the load reaches 50 kN. Thus, giving a steel plate to the beam can slow down the appearance of the initial crack on the beam. The crack pattern can be shown in Figure 8.

FIGURE 8. The crack pattern of the T-beam

CONCLUSIONS

1. The addition of steel plates to the beam compression section can increase the maximum load of the beam with a percentage of 17.19 % for BP 1(1), an increase of 18.85 % for BP 1(2), an increase of 26.82 % for BP 2(1)), an increase of 28.02 % for BP 2(2).
2. The maximum deflection on the control beam is 43.9 mm, the maximum deflection on the BP 1(1) beam is 43.3 mm, the maximum deflection on the BP 1(2) beam is 44 mm, the maximum deflection on the BP 2(1) beam of 51.5 mm, the maximum deflection on the beam BP 2(2) is 53 mm.

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