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Comparative analysis layers method of t-beam reinforcement

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Abstract. Wire rope commonly used by heavy equipments in order to operate lift weights. wire ropes have a high tensile strength, that in this study tried to use these materials as reinforcement material in the T-beam negative moment area. In this analysis the T beam reinforcement using method layers of this by comparing the layers1 method (ignoring the wing reinforcement) and layers2 method (considering the wing reinforcement). Results of the test showed that the maximum loading for BK, BP1, and BP2 specimens were 88.5 kN, 180 kN, and 259 kN, respectively. The comparative flexural capacity by layers1 method (ignoring the wing reinforcement) for BK, BP1, and BP2 specimens were 1.28, 0.76, and 0.78. The comparative flexural capacity by layers2 method (considering the wing reinforcement) for BK, BP1, and BP2 specimens were 1.28, 0.79, and 0.80, respectively. Comparative ratios of layers2 method for BK, BP1, and BP2 to layers1 method were 1, 0,96 and 0,975, respectively. This result means of comparative analysis layers methode similar and methods layers2 most closely with test results.

1. Introduction

Wire rope usually used to lift heavy materials on a construction or industrial. The form of wire rope in the form of steel wire strands, has great tensile strength and the flexible nature of the wire rope, so easily rolled up and stored. steel wire rope is 6 or more strands having a layer of zinc or without coated with zinc [1]. Strengthen structures on reinforced concrete T-beam negative moment by using wire rope and composite mortar based on the advantages possessed by these materials.

2. Methodology/experimental

Analysis using layers method can be used to determine the capacity of reinforced concrete beam section is based on the stress-strain diagram of the constituent materials [2]. Formulas in beam material used in analyzing the layers method include [3]:

- The concrete stress-strain model based on Popovics model (high strength), as shown in the following equations :

$$f_{ci} = -\left(\frac{\varepsilon_{ci}}{\varepsilon_p}\right) f_p \frac{n}{n-1+\left(\varepsilon_{ci}/\varepsilon_p\right)^{nk}} \text{ for } \varepsilon_{ci} < 0 \quad (1)$$

$$n = 0,8 + \frac{f_p}{17} \quad . \quad (2)$$

$$k = \begin{cases} 1{,}0 & \text{for } \varepsilon_p < \varepsilon_{ci} < 0 \\ 0{,}67 + \dfrac{f_p}{62} & \text{for } \varepsilon_{ci} < \varepsilon_p < 0 \end{cases} \tag{3}$$

$$E_c = \frac{f_p}{\left|\varepsilon_p\right|} . \frac{n}{(n-1)} \tag{4}$$

Where:
f_p : peak concrete compressive stress (MPa); ε_p : concrete compressive strain corresponding to f_p; f_{ci} : the stress occurs in the concrete (MPa); ε_{ci} : strain occurs at peak; n : curve fitting parameter for stress-stain response of concrete in compression; k : post-peak decay parameter for stress-strain response of concrete in compression; E_c : concrete elasticity modulus (MPa).

- The reinforced concrete stress-strain model was based on the trilinieri curve models, as shown in the following Equation :

$$f_s = \begin{cases} E_s \varepsilon_s & \text{for } \left|\varepsilon_s\right| \le \varepsilon_y \\ f_y & \text{for } \varepsilon_y < \left|\varepsilon_s\right| \le \varepsilon_{sh} \\ f_y + E_{sh}(\varepsilon_s - \varepsilon_{sh}) & \text{for } \varepsilon_{sh} < \left|\varepsilon_s\right| \le \varepsilon_y \\ 0 & \text{for } \varepsilon_u < \left|\varepsilon_s\right| \end{cases} \tag{5}$$

$$\varepsilon_u = \varepsilon_{sh} + \frac{(f_u - f_y)}{E_{sh}} \tag{6}$$

where:
ε_s : reinforcement strain; ε_y : yield strain; ε_{sh} : strain at the onset of strain hardening; ε_u : ultimate strain; E_{sh} : strain hardening modulus (MPa); f_y : yield strength (MPa); f_u : ultimate strength (MPa); E_s : elastic modulus (MPa).

- Wire rope stress strain model based on the Ramsberg-Osgood, as shown in the following Equation :

$$f_s = E_s \varepsilon_s \left\{ A + \frac{1-A}{\left[1 + (B\varepsilon_s)^C\right]^{1/C}} \right\} \le f_u \tag{7}$$

$$A = \frac{E_{sh}}{E_s} \tag{8}$$

$$B = \frac{E_s(1-A)}{f_s^*} \tag{9}$$

$$C = \text{transition coefficient} \tag{10}$$

where:
ε_s : reinforcement strain; E_s : elastic modulus (MPa); E_{sh} : strain hardening modulus (MPa); f_u : ultimate strength (MPa); f_s* : value at which the second linear branch intercepts the stress axis at zero strain; C : 10 [4].

2.1. Beam Specimens

There were three specimens of reinforced concrete beam: the controlling beam (BK), the reinforcing beam type 1 (BP1) and type 2 (BP2). Specifications of reinforced concrete beam specimens are presented on Table 1, Figure 1 and Figure 2 [5].

Table 1. Specifications of specimens off reinforce concrete beam

Speci-men	L (mm)	b_f (mm)	t_f (mm)	b_w (mm)	Main Reinforcement		Cross Bar Reinfor-cement	Reinforcement	
					Tensile	Com-presive		Tensile	Compressive
BK	2400	400	75	150	3D13	2P8	P8-40	-	-
BP1	2400	400	115	150	3D13	2P8	P8-40	4Ø10	-
BP2	2400	400	115	150	3D13	2P8	P8-40	4Ø10	2P8

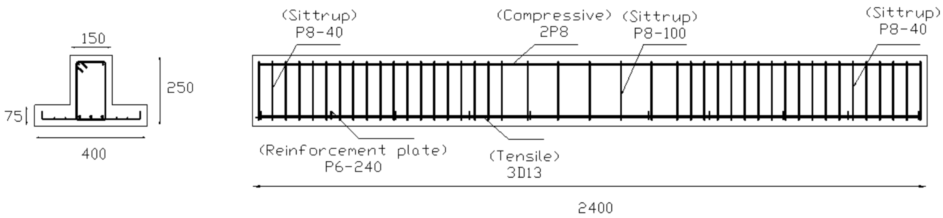

Figure 1. Controlling Beam (BK)

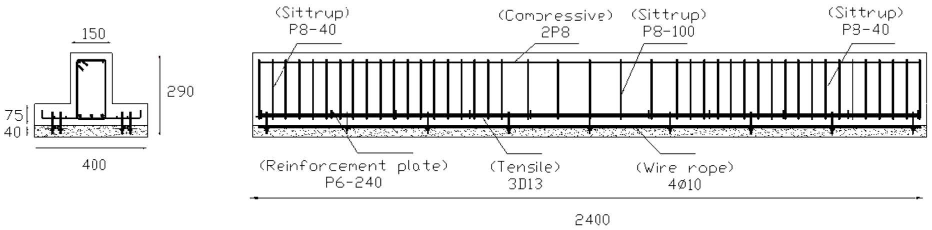

Figure 2. Reinforcing Beam (BP1)

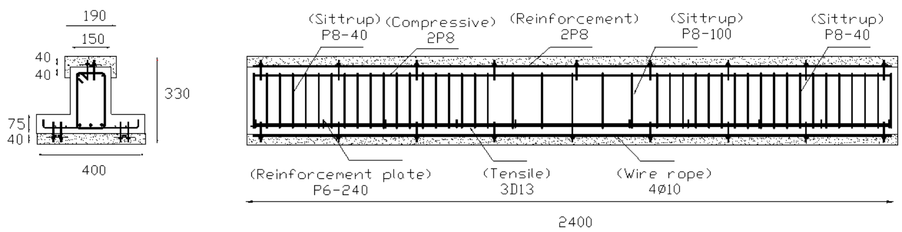

Figure 3. Reinforcing Beam (BP2)

3. Result and discussion

Load capacity calculation results received in the state crack, yield, and ultimited. The results given in of the calculation method of these layers only compare the condition of crack and ultimited with steel cables used parameter is the modulus of elasticity, rupture strain, and ultimate strength taken in accordance with the experimental results that 35725,02 MPa, 25,6 mm/m and 740,48 MPa respectively. Load - deflection occurs can be seen in Table 1 and Table 2 calculated based on the load provided by the load cell (load one point). Maximum load ratio is shown in Table 3 and Figure 1.

Table 2. The capacity of beam load and deflection by ignoring the wing reinforcement (layers method 1)

No.	Specimen	Load Capacity (kN)		Deflection (mm)		Ratio
		crack	max	crack	max.	P_{max}.
1.	BK	15,17	113,37	0.90	14,68	1
2.	BP1	22,87	137,50	0.15	13,32	1,21
3.	BP2	32,17	200,91	0.12	18,50	1,77

Table 3. The capacity of beam load and deflection with calculation on wing reinforcement (layers method 2)

No.	Specimen	Load Capacity (kN)		Deflection (mm)		Ratio
		crack	max	crack	max.	P_{max}.
1.	BK	15,17	113,37	0,90	14,68	1
2.	BP1	22,87	143,07	0,15	12,32	1,26
3.	BP2	32,17	208,28	0,12	17,59	1,84

Tabel 4. Comparison beam load capacity on two conditions

No.	Specimen	P_{max}. (kN)		Ratio
		layers method 1	layers method 2	P_{max}.
1.	BK	113,37	113,37	1
2.	BP1	137,50	143,07	1,04
3.	BP2	200,91	208,28	1,04

Based on Table 4 shows that the results obtained are close to each other. The maximum load value analysis ignores reinforcement layers with wings on BK, BP1 and BP2 113,37 kN, 137,5 kN, and 200,91 kN respectively. While the value of the maximum load analyzes take into account the reinforcement layers with wings on BK, BP1 and BP2 113,37 kN, 143,07 kN, and 208,28 kN respectively. Improvement occurring in the analysis layers 1, 1,04, and 1,04 respectively. This increase was influenced by the presence of the reinforcing wings be included in the calculation. Relations load deflections under both conditions can be seen in Figure 4 and Figure 5.

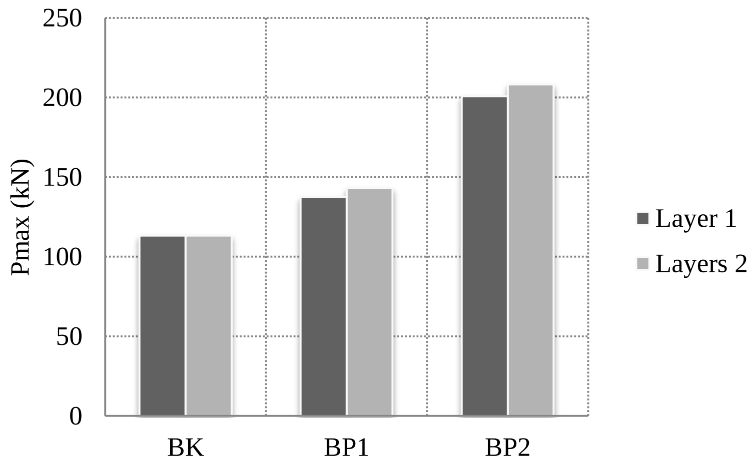

Figure 4. The ratio of beam load capacity on two conditions

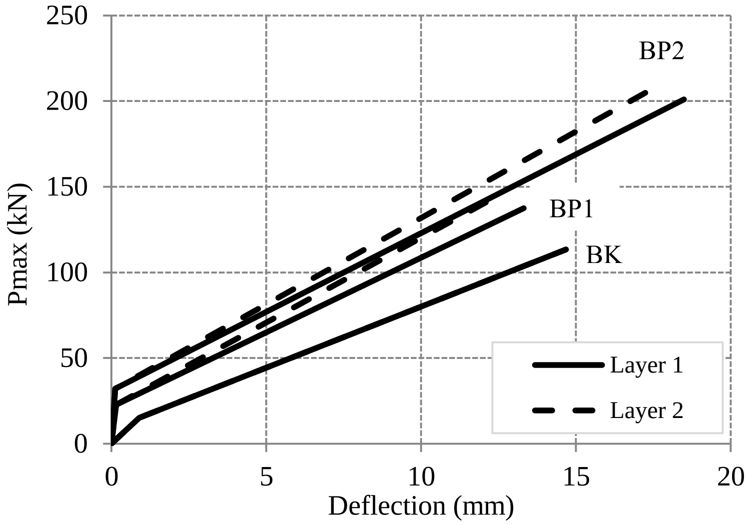

Figure 5. Comparison of the load and deflection relationship beam

4. Concluding

The comparative flexural capacity by layer1 method (ignoring the wing reinforcement) for BK, BP1, and BP2 specimens were 1.28, 0.76, and 0.78. The comparative flexural capacity by layer2 method (considering the wing reinforcement) for BK, BP1, and BP2 specimens were 1.28, 0.79, and 0.80, respectively. Comparative ratios of layer2 method for BK, BP1, and BP2 to layers1 method were 1, 0.96 and 0.975, respectively. The means of comparative analysis of the layer methods are similar. The method of layers2 is the closest with the test results.

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