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Partial prestressed concrete slabs as an alternative for vehicle decks of steel truss bridges

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Abstract

Steel truss bridges with continuous reinforced concrete slab as vehicle decks are often found in Indonesia. The use of continuous reinforced concrete slab along the steel truss bridges has still have some problems in the field such as the occurrence of cracks. Cracks that occur on the concrete slab are required to be repaired, which is mostly done by grouting method. However, the method are still unsuccessful in addition to costly expensive.

Study on partial prestressed concrete slab as vehicle decks of steel truss bridge was done. The system used was a partial prestressed concrete segmental slab in one direction which was set transversely the bridge. Two concrete slab specimens were cast which had a length of 7000 mm, a width of 1000 mm and a height of 250 mm, respectively. Symmetrical reinforcement consists of four non-prestressed steel bars and three strands, placed on the top and bottom sides of the slab. The steel bars have a diameter of 18 mm and the strands have a diameter of 0.5 inches. Plain steel bars with a diameter of 10 mm were used as stirrups, spacing at 200 mm. The slabs were then tested in the laboratory with a gradual loading increament. At every stage of loading, crack width and strain of steel reinforcement were measured.

The test results showed that at the service load condition according to the BMS standard, no cracks was occurred on the concrete slab and the non-prestressed reinforcing steels were still under compression. At maximum load condition, cracks occurred evenly spaced at 85,5 mm to 112,5 mm and a maximum crack width was 3.2 mm. Based on the test results, it can be concluded that such partial prestressed concrete segmental slab was very good to be used as an alternative for the vehicle decks of steel truss bridges.

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Keywords: partial prestressed; concrete; slab; vehicle decks; segmental

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1. Introduction

Steel truss bridges with the vehicle slab made of continuous reinforced concrete slab are often found in Indonesia. The use of continuous reinforced concrete slab along a steel truss bridge still have some problems in the field, such as the occurrence of cracks. Repairing the cracks in the vehicle concrete slabs is mostly done by grouting the concrete by certain materials. However the method had experienced failure in addition to costly expensive.

This study provides an alternative vehicle slab made of partially prestressed concrete one way segmental slabs, which is mounted transversely of the bridge. Some equations have been proposed by researchers in predicting the crack width of one way partial prestressed concrete beams or slabs, for example: Bruggeling [1] and unified approach [1; 2]. Crack width is also influenced by steel tensile strength after decompression, the type of prestressed and non prestressed reinforcement, concrete cover, concrete area in tension, distribution of tensile reinforcement in the tension area, the concrete strength, method of prestressing and the total area of steel reinforcement [2].

The crack width obtained from calculation using those approached formula gives large differences between one formula to another. Therefore, to be more convincing against cracking behavior of partially prestressed concrete slab, the designed specimens need to be investigated in laboratory.

2. Research Method

To determine the crack width, two specimens of one way partially prestressed concrete slabs with a width of 1000 mm, a height of 250 mm and a length of 7000 mm were cast. The reinforcement of the slabs was symmetrical. Four non-prestressed steel bars with a diameter of 18 mm and three strands with a diameter of 0.5 inches each at the top and bottom face were used. Plain steel stirrups with a diameter 10 mm spacing at 200 mm were also used. The concrete slabs were designed based on the requirements of Bridge Management System (BMS), as an alternative vehicle floor slab of steel truss bridges.

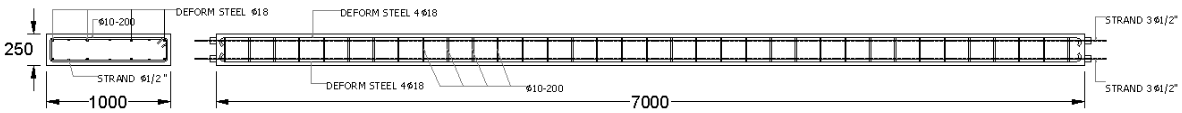

Fig. 1. Partial presetressed concrete slab

For measuring the strain of the steel reinforcement, 8 electrical strain gauges were attached on the reinforcement, 4 pieces in the middle of the span and 4 pieces near the supports.

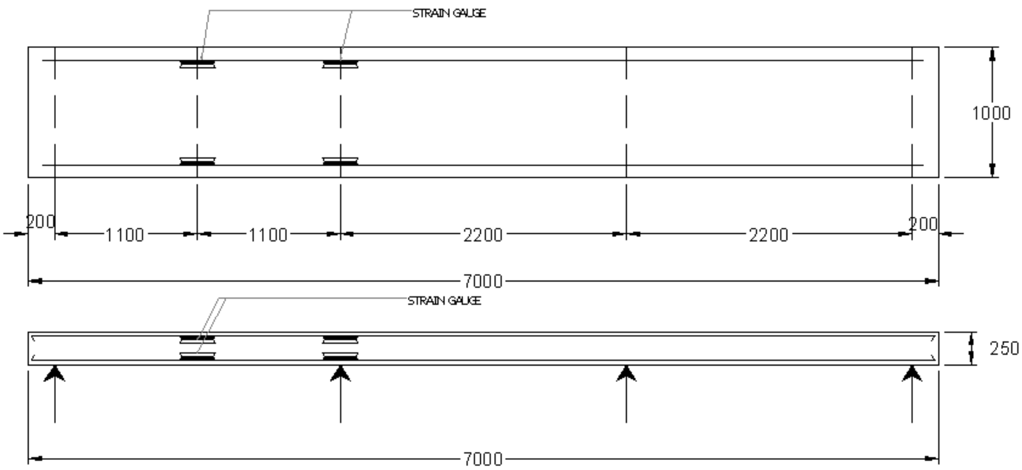

Fig. 2. Placement of electrical strain gauges

From the testing of constituent materials, the compressive strength of concrete (f_c') was 31.54 MPa, the rupture strength of prestressed steel was 1825 MPa, and the yield tensile strength of non prestressed steel was 330 MPa.

The concrete slabs were then tested in the laboratory with a gradual loading. During the testing, concrete crack width and strain of non prestressed steel reinforcement were measured for every stage of loading.

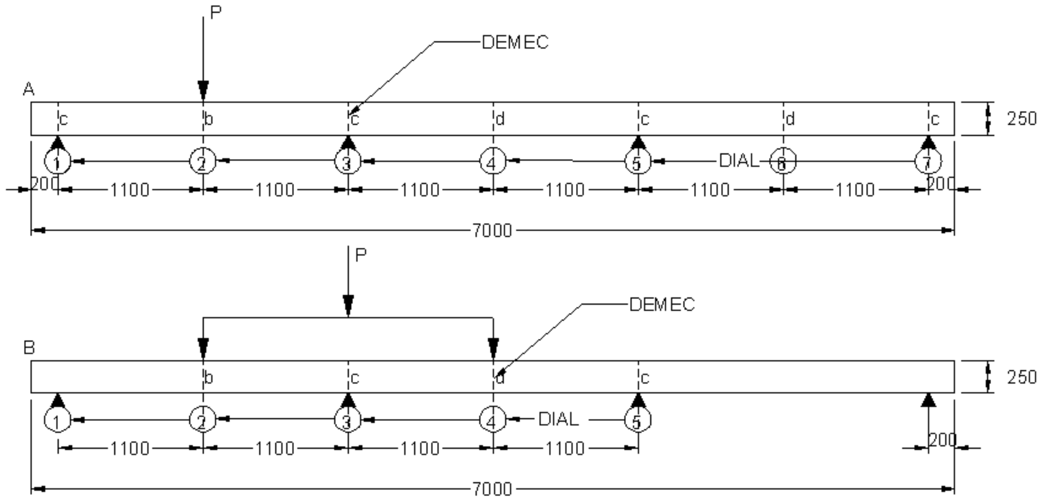

Fig. 3. Testing of concrete slab

Many variables affect the crack width of prestressed concrete beam or one way partial prestressed concrete slabs. Bruggeling, 1987 [3] provides an equation for calculating the average crack width of concrete as follows:

$$W_{mean} = S_{rm}.\varepsilon_{sm} \tag{1}$$

where:

W_{mean} : average crack width

S_{rm} : average crack spacing, measured at the time of testing

ε_{sm} : tensile strain of steel, measured at the time of testing

Calculation of crack width using the unified approach [1] and [2] which are emphirical, as follows:

$$W_{max} = k.f_s.d_c\left(A_t / A_s\right)^n \tag{2}$$

where:

k : coefficient, considering the type of prestressed and non prestressed reinforcement (Table 1)

f_s : steel tensile strength

d_c : concrete cover

A_t : tension area of concrete

A_s : steel reinforcement area

n : regression constant (n = ½ is the best value)

Table 1. Value of *k* for emphirical equations [1] and [2]

Category	Type of steel	k (10^{-6})
1	Deform steel - Strand	2.55
2	Deform steel - Wire	3.51
3	Only Strand	2.65
4	Only Wires	4.5

The Geergely-Lutz formula are stated as follows:

$$W_{\max} = k_1 . f_s .(d_c .A)^{1/3} \quad (3)$$

where:

k_1 : coefficient, considering the type of prestressed and non prestressed reinforcement (Table 2)

Table 2. Value of k_1 for emphirical equations [1] and [2]

Category	Type of steel	k_1 (10^{-6})
1	Deform steel - Strand	13.7
2	Deform steel - Wire	20.3
3	Only Strand	22.5
4	Only Wires	37.2
5	Unbonded Strand	25

3. Results and Discussion

3.1. Concrete Strength

Based on the testing of concrete cylinders having a diameter of 150 mm and a height of 300 mm, a concrete strength (f_c') of 31.54 MPa was obtained for two specimens [5], using the following equation:

$$f_c^{'} = 294705\varepsilon - 86460557\varepsilon^2 + 9164427368\varepsilon^3 \quad (4)$$

Meanwhile, based on the cylinder splitting test an average splitting tensile strength of 2.91 MPa was obtained. The splitting tensile strength obtained in this study was not reached 10% of the compressive strength of the concrete.

3.2. Steel Strength

Prestressing steel used in this study was seven wires grade 270, with a nominal diameter of 0.5 inch. The stress - strain diagram was created based on Strand Characteristics and Corresponding Stress-Strain Diagramme of Post-tensioning, VSL Engineers [4]. The non prestressing steel bars used in this study had a diameter of 18 mm, with a yield tensile strength f_y of 334 MPa.

3.3. Crack spacing

Crack spacing was measured manually with a measuring tape. The crack spacing was measured between the main cracks. The main crack was a crack which increased with the increasing load. For the first specimen, the average crack spacing was 112.5 mm. Meanwhile, a crack spacing of 85.0 mm was obtained for the second specimen.

3.4. Crack width

Crack width was determined in two ways, first one was based on theoretical method and the second one based on direct observation during testing. Theoretically, crack width is calculated based on stress or strain of the prestressed steel after decompression.

The amount of load that causes the first crack of concrete was difficult to be exactly determined. Concrete cracked at the first time was predicted occur at the large surge of concrete strain. Based on the approached formula, the section already cracked with a width of 0.057 mm to 0.181 mm and with a moment of 665,826 kg cm. Meanwhile, by observation method no cracks were observed on the two specimens of the partial prestressed concrete slab. Haired cracks on both specimens were observed when the moment reached a value of 1,035,847 kg cm. The approximated crack width was 0.103 mm to 0.744 mm. The crack width of the two specimens increased continuously to 1.2 mm, on the other hand the approached crack width was 0.152 to 1.111 mm with the moment of 1,299,126 kg cm.

Table 3. Crack width at the loading steps

Moment (kg.cm)	Crack width (mm)				
	Bruggeling	Empiric	Gergely Lutz	Slab #1	Slab #2
665,826	0.057	0.057	0.181	not detected	not detected
1,035,847	0.103	0.243	0.744	hair crack	hair crack
1,299,126	0.152	0.366	1.111	1.2	1.2
1,415,156	0.342	0.868	2.590	3.2	no data

Design moment of 522,500 kg cm was obtained which was 27.43% less than the predicted cracking moment. It meant that the specimens were not cracked at the design load condition. Therefore, it can be said that the partial prestressed concrete segmental slabs were appropriate to be used as an alternative vehicle slabs of steel truss bridges.

4. Conclusions

Based on the approached formula and test results of two specimens of partial prestressed concrete, the following conclusions were drawn:

1. With the approached formula (Bruggeling, Empiric and Gergely Lutz), the section already cracked with a width of 0.057 mm to 0.181 mm and with a moment of 665,826 kg cm. Meanwhile, no cracks were observed on the two specimens of the partial prestressed concrete slab.
2. The design moment of the specimens was 27.43% less than the predicted cracking moment, which meant no crack occurred on the specimens under design load.
3. Finally, it can be concluded that the partial prestressed concrete segmental slabs were appropriate to be used as an alternative vehicle slabs of steel truss bridges

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