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Research Paper

Experimental Study of Prestressed Concrete Track Slab at Railroad Crossings

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ABSTRACT

Currently, the prestressed concrete track slabs are testing installed at the field to replace the reinforced concrete track slabs at railroad crossings in Vietnam. Prestressed concrete track slabs used for 1000 mm gauge. The dimensions of each slab were designed with a length, width, and height of 2.5 m, 1.0 m, and 0.33m, respectively. This paper presents experimental measurements to analyze the behavior of the prestressed concrete track slab at railroad crossings under the action of train and truck dynamic load. Experiment measurements were implemented at the site. Eight strain gauges were mounted at three sections of the track slab to measure the deformation. HL-93 truck load and TY-7E train load were used in the test. The results show the eccentricity of the gravity center point of the prestressed wires to the centroidal axis of the transformed area. The deviation ratio between experimental and theoretical results is from 0.88% ÷ 1.25%. These results can be used to optimize the design process and limit cracks. In addition, tensile and compressive stresses in slabs are smaller than the allowable values. The results show that this track slab meets the requirements of durability and strength under the action of train and truck dynamic load.

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1 Introduction

Slab tracks have widely used in the world. Currently, the slab track structure in the world is mainly used for the 1067mm gauge (in Japan) [1] or the 1435mm gauge (in the United States [2]) but there is no slab track structure for the gauge 1000mm. In Vietnam, in 2019 and 2020, Tran Anh Dung et al. designed track slabs at railroad crossings (1000 mm gauge), [3] and performed laboratory tests on this structure [4].

The track slab was made of a precast concrete structure. The principle of track slab design is not to appear cracks, but we sometimes see some cracks in the slab track due to load effect, environmental temperature, and concrete shrink. [5] In

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2014, Shengyang Zhu and Chengbiao Cai studied stress intensity factors for the through-transverse crack in the China Railway Track System (CRTS II) slab track system [6]. Then, in 2018, Chengbo Ai et al. researched a method to identify slab cracks by using a region-based active contour framework with the intensity cluster energy [7]. After that, in 2020, Zai-Wei Li et al. studied surface cracks in precasted track slabs for high-speedrailways. An infrared thermography-based method for the surface crack was proposed in the paper [8].

In this study, experimental measurements were implemented to determine the eccentricity of the gravity center point of the prestressed wires to the centroidal axis of the transformed area of the track slab at railroad crossings (1000mm gauge). The research results are used to optimize the arrangement of prestressed wires and limit cracking in the track slab. In addition, the authors studied tensile and compressive stresses in slabs under the effect of train and truck dynamic load. Based on the experimental results, it is shown that the slab structure meets the load-carrying requirements.

2 Calculation of the Center of Gravity of the Prestressed Wires

The dimension of the slab is designed with a length and width of 2.5 m and 1.0 m respectively. The height of the track slab is 0.176 m at the railseat section (A-A and C-C section), and 0.33 m at midslab section (B-B section). The geometric dimensions of the slab such as in Fig. 1.

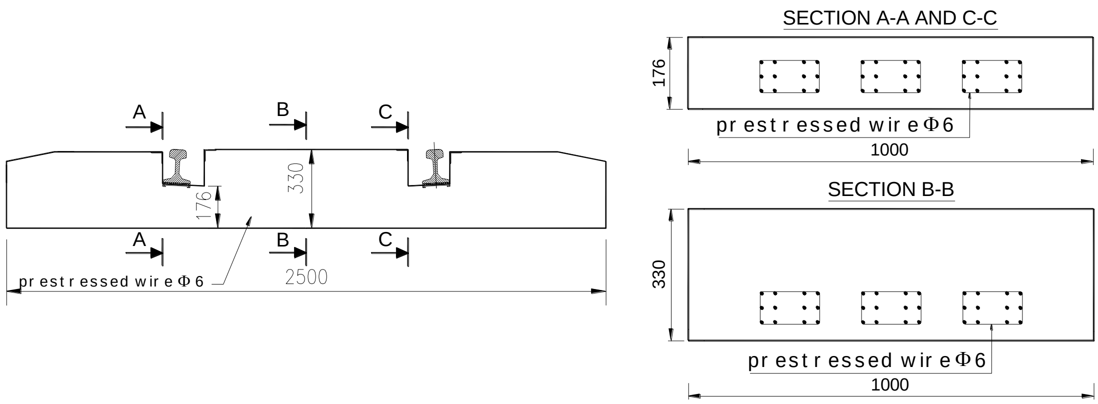


Fig. 1 – Cross-section of track slab (dimensions are in millimeters)

Technical characteristics of materials for track slabs are shown in Table 1.

Table 1 – Material properties for track slab [3]

	Specifications	**Symbol**	**Value**
Concrete	Concrete compressive strength	f_{cm}	58.0 MPa
	Concrete tensile strength	$f_{ct,\infty,dyn}$	3.0 MPa
	Elastic modulus	E_{cm}	37.0 GPa
Prestressed wire	Tensile strength	f_{pk}	1.470 MPa
	Elastic modulus	E_{ps}	200.0 GPa

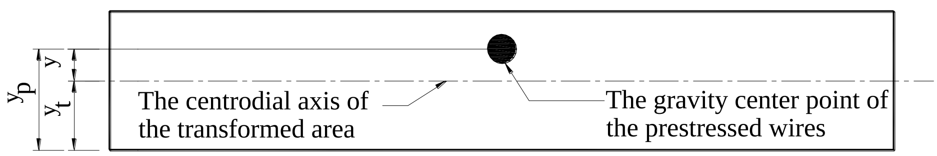


Fig. 2 – The eccentricity of the gravity center point

There are 36 prestressed wires in each section A-A and section C-C. Based on the arrangement of prestressed wires at sections A-A and section C-C such as Fig. 1., we calculate the eccentricity of the gravity center point of the prestressed wires to the centroidal axis of the transformed area at section A-A and C-C such as Fig. 2. and Table 2.

Table 2 – Calculating the eccentricity of the gravity center point of the prestressed wires to the centroidal axis of the transformed area at sections A-A and C-C

No.	Description	Formula	Unit	Value	
				Section A-A	Section C-C
1	The ratio of elasticity modulus of prestressed wire and concrete	$n_{sc} = E_{ps}/E_{cm}$		5.41	5.41
2	Area of a prestressed wire	A_{sps}	mm^2	28.27	28.27
3	Total areas of prestressed wires	$A_{ps} = n \cdot A_{sps}$	mm^2	1017.88	1017.88
4	Area of the concrete section	A_{cm}	mm^2	186,000	176,000
5	Distance from the bottom to the gravity center of the concrete section	y_{cm}	mm	93.0	88.0
6	Distance from the bottom to the gravity center of the prestressed wires	y_p	mm	80.0	80.0
7	Transformed area	$A_t = A_{cm} + (n_{sc} - 1) A_{ps}$	mm^2	190,484.1	180,484.1
8	First moment for the bottom prestressed wire	$S_t = A_{cm}.y_{cm} + (n_{sc} - 1).A_{ps}.y_p$	mm^3	17,656,732.5	15,846,732.5
9	Distance from the centroidal axis of the transformed area to the bottom	$y_t = S_t/A_t$	mm	92.69	87.80
10	Distance of the neutral axis to the gravity centerof the concrete	$y = y_p - y_t$	mm	-0.31	-0.20

3 Field Experiment

3.1 Experimental Equipment

We used strain gauges with a length of 60 mm to measure the deformation of the slab. Eight strain gauges were mounted at 3 sections on the slab such as in Fig. 3 and Fig. 4.

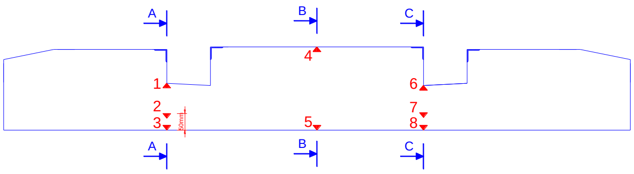
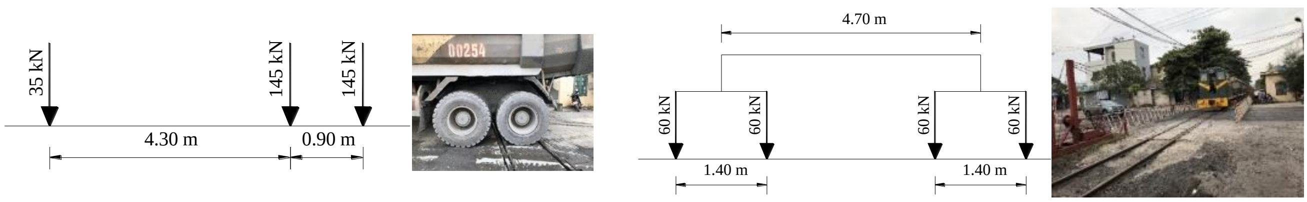


Fig. 3 - Set up for strain gauges on the slab

Fig. 4 - Set up for strain gauges on the slab at the site

3.2 Experimental Loads

The truck load used in the experiment is HL-93 (Fig. 5. (a)) [9]. The train load used in the experiment is TY-7E diesel locomotive (Fig. 5.(b)) [10].



(a) Track load

(b) Train load

Fig. 5 – Experimental loads

3.3 Results

Deformation of the slab when the truck acts on the slab at sections A-A, B-B, and C-C are shown in Fig. 6, Fig. 7, and Fig. 8.

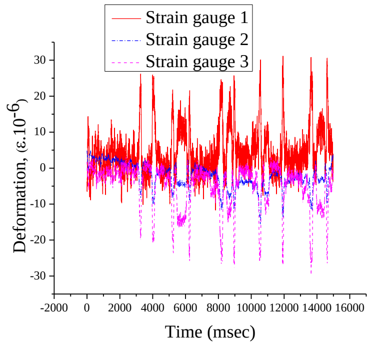


Fig. 6 – Chart of deformation of the slab at section A-A under the action of truck load

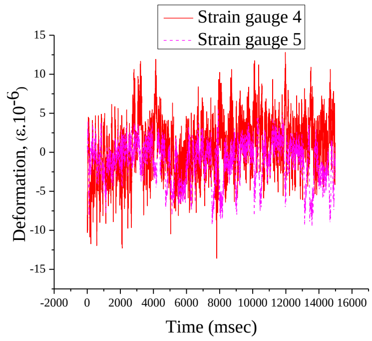


Fig. 7 – Chart of deformation of the slab at section B-B under the action of truck load

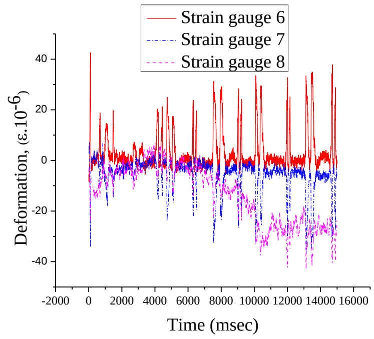


Fig. 8 – Chart of deformation of the slab at section C-C under the action of truck load

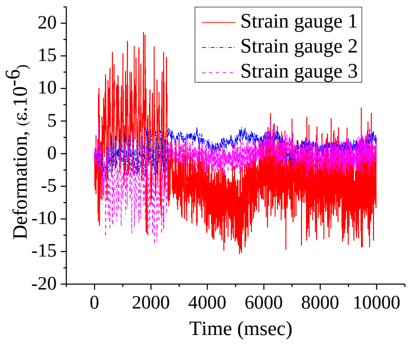


Fig. 9 – Chart of deformation of the slab at section A-A under the action of train load

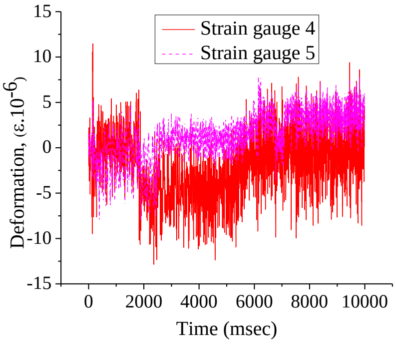


Fig. 10 – Chart of deformation of the slab at section B-B under the action of train load

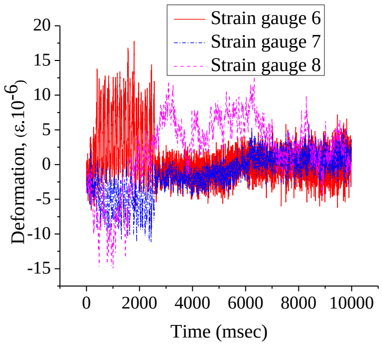


Fig. 11 – Chart of deformation of the slab at section C-C under the action of train load

Table 3 – Measurement results of slab deformation due to truck load

No.	Section	Strain gauges	Maximum strain $\varepsilon.10^{-6}$	Distance to the centroid of the section (cm)	Stress (MPa)
1	A-A	1	30.80	8.3	1.1
2		2	-11.68	-3.3	-0.4
3		3	-29.52	-8.3	-1.1
4	B-B	4	12.23	15.5	0.5
5		5	-9.28	-15.5	-0.3
6	C-C	6	33.00	7.8	1.2
7		7	-14.00	-2.8	-0.5
8		8	-31.52	-7.8	-1.2

Deformation of the slab when the train acts on the slab at sections A-A, B-B, and C-C are shown in Fig. 9, Fig. 10, and Fig. 11.

Table 4 – Measurement results of slab deformation due to train load

No.	Section	Strain gauges	Distance to the centroid of the section (cm)	Tensile strain $\varepsilon.10^{-6}$	Tensile stress (Mpa)	Compressive strain $\varepsilon.10^{-6}$	Compressive stress (Mpa)
1	A-A	1	8.3	18.2	0.7	12.28	0.5
2		2	-3.3	4.04	0.1	3.96	0.1
3		3	-8.3	4.4	0.2	13.92	0.5
4	B-B	4	15.5	0.0	0.0	5.00	0.2
5		5	-15.5	5.8	0.2	7.72	0.3
6	C-C	6	7.8	17.6	0.7	6.60	0.2
7		7	-2.8	0.0	0.0	6.60	0.2
8		8	-7.8	0.84	0.0	11.20	0.4

3.4 Discussion

Tensile and compressive stresses in slabs are compared with the characteristics of materials in Table 1. These results are smaller than the allowable values. This track slab meets the requirements of durability and strength under the action of train and truck dynamic load.

According to the distribution of stress caused by the truck load at the A-A and C-C sections, we can find the location of the center of gravity of prestressed wires such as in Fig. 12 and Fig. 13.

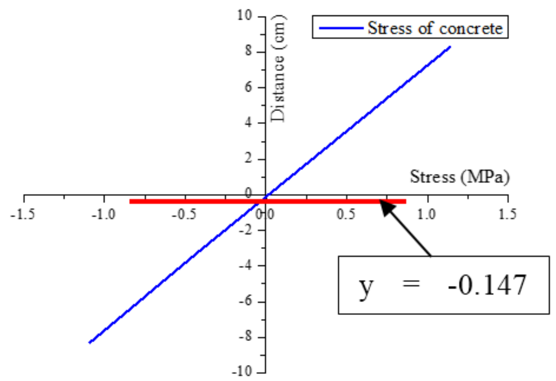


Fig. 12 – The gravity center of prestressed wires at section A-A

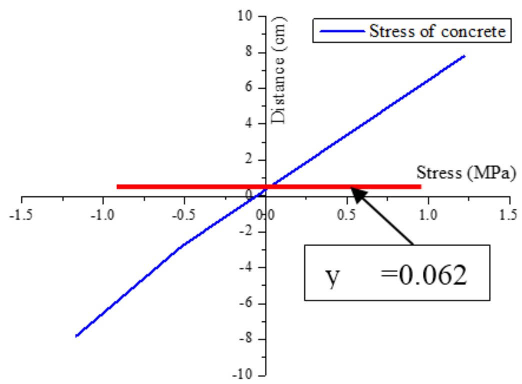


Fig. 13 – The gravity center of prestressed wires at section C-C

Table 5 – Comparison of the eccentricity of the gravity center point of the prestressed wires

No.	**Section**	**The eccentricity of the gravity center point of the prestressed wires (mm)**		**Deviation ratio**
		Experiment result	**Calculated result**	
1	A-A	-1.47	-0.31	1.25%
2	C-C	0.62	-0.20	0.88%

The results show that the arrangement of the wires is suitable between theory and experiment. The reasonable arrangement of prestressed wires plays an important role in the design process of track slabs. The arrangement of the prestressed wires is likely to reduce the phenomenon of cracking in the concrete. Due to the eccentricity of the gravity center point of the prestressed wires to the centroidal axis of the transformed area, the concrete of the slab often cracks at the tensile fiber. In order to limit this phenomenon, we should arrange the prestressed wires so that the gravity center point of the prestressed wires coincides with the centroidal axis of the transformed area.

4 Conclusions

In this paper, the author performed experiments at the site to measure the stresses of the track slab under the effect of truck and train loads. Based on the stresses of the concrete, authors calculate and determine the center of gravity of prestressed wires. Results are used to check the conformity in the arrangement of the prestressed wires. The arrangement of prestressed wires in the track slab is suitable because the gravity center point of the prestressed wires closely coincides with the centroidal axis of the transformed area.

In addition, the results show that the concrete stresses are within the allowable limit. Therefore, the arrangement of prestressed wires in the track slab is appropriate, and ensures the bearing capacity of the slab. The prestressed concrete slab track at railroad crossings is a suitable solution to replace the traditional crossings currently applied on Vietnam railways.

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