



Journal of Materials and Engineering Structures

Behavior of monolithic prestressed concrete slab track at highway-railway grade crossings

Tran Anh Dung ^{a,*}, Le Hai Ha ^a, Tran The Truyen ^a, Nguyen Hong Phong ^a

^a University of Transport and Communications, No.3 Cau Giay Street, Lang Thuong Ward, Dong Da District, Hanoi, Vietnam

ARTICLE INFO

Article history:

Received : 4 November 2020

Revised : 13 December 2020

Accepted : 13 December 2020

Keywords:

Slab track

Monolithic prestressed concrete

Highway-railway grade crossings

1000mm gauge

ABSTRACT

Highway-railway grade crossings are an important part of the transportation system. It allows two types of vehicles to operate in the same areas. Researchers have previously studied the grade crossings, but research on the monolithic prestressed concrete slab (PSCS) track at grade crossings for 1,000mm gauge is limited. At present, there are many types of grade crossing structures that are using in Vietnam. However, these structures still have many disadvantages in the operation process. A new structure type of grade crossing for PSCS is proposed to apply for the 1,000 mm gauge to overcome the main disadvantages of existing structural types. This paper presents test production and experimental measurements to analyze the behavior of PSCS. Test samples of monolithic PSCS were produced in factory. Measurement experiments were conducted in the laboratory. The results of the manufacturing and testing process presented in this paper show that this structure completely meets the criteria of stability and durability under the effect of test loads.

F. ASMA & H. HAMMOUM (Eds.) special issue, 3rd International Conference on Sustainability in Civil Engineering ICSCCE 2020, Hanoi, Vietnam, J. Mater. Eng. Struct. 7(4) (2020)

1 Introduction

For the purpose of optimizing performance and increasing the railway's crossroads longevity, scientists around the world have presented many design and solution proposals for crossroads railways with roads. In 2002, A.J. Lamanna and C.F. Scholer [1] conducted research on designing, manufacturing crossroads surfaces and assembling fiber reinforced concrete. After that, J.G. Rose [2] examined the application of an asphalt concrete mixture in the railway structure, hoping to replace the conventional macadam foundation. In 2014, Michigan University of Technology engaged in a study evaluating the performance of materials for crossroads surfaces structures [3], which empirical results showed the sub-surface layer has more impact on the mining performance than the surface paving material is in use. V. Markine et al., have also researched the application of embedded rail structure with the reinforced concrete slab [4]. For grade crossing using monolithic PSCS in the world today, they are mainly used for 1,067mm gauge (in Japan) or 1,435 mm gauge (in United States) without having monolithic PSCS for 1,000 mm gauge.

* Corresponding author. Tel.: +(84)983841175.

E-mail address: trananhdung@utc.edu.vn

In Vietnam, there are three types of grade crossing [5] in common use: sectional reinforced concrete slabs (panels) [6], asphalt [6] or rubber (panels) [6, 7]. Sectional reinforced concrete slabs (panels) are not smooth. The concrete slabs are often cracked, broken or deflected, causing danger for both trains and cars passing through intersections. The asphalt concrete crossroads have the disadvantage of being complicated when constructing because they have to use hot asphalt concrete to construct on the site, after a period of using, the surface of the crossroads sinks due to the insufficient tightness of the ballast and causing many difficulties for maintenance and repair. Disadvantages of the rubber (panels) are low longevity and durability.

Therefore, the authors propose a grade crossing structure with PSCS for railways (1,000 mm gauge) to overcome the disadvantages of the traditional crossroad structures currently in use in Vietnam.

2 Test production sample of prestressed concrete slab

2.1 Main material

Concrete: PSCS is used high strength concrete with some characteristics following:

- Concrete grade: $f_{ck} = 50 \text{ MPa}$
- Average compressive strength: $f_{cm} = 58 \text{ MPa}$
- Elastic modulus: $E_{cm} = 37.000 \text{ MPa}$
- Acceptance tensile strength: $f_{ct,\infty,dyn} = 3.0 \text{ MPa}$

Steel: PSCS is used prestressed steel with some characteristics following:

- Diameter: $\phi = 6 \text{ mm}$
- Characteristic tensile strength: $f_{pk} = 1.470 \text{ MPa}$
- Characteristic 0.1% absorb: $f_{PO,1k} = 1.290 \text{ MPa}$
- Elastic modulus: $E_p = 200.000 \text{ MPa}$

2.2 Geometry dimension

Base on design requirements for 1,000 mm gauge [8]. In this study, we produce pre-stressed concrete slab with some main parameters such as: 2,500 mm long, 1,000 mm wide and 320 mm high. There are four locations for fastening to link the rail to the slab. At the edges of the slab, the steel V is used to reinforce to reduce impact force to the slab.

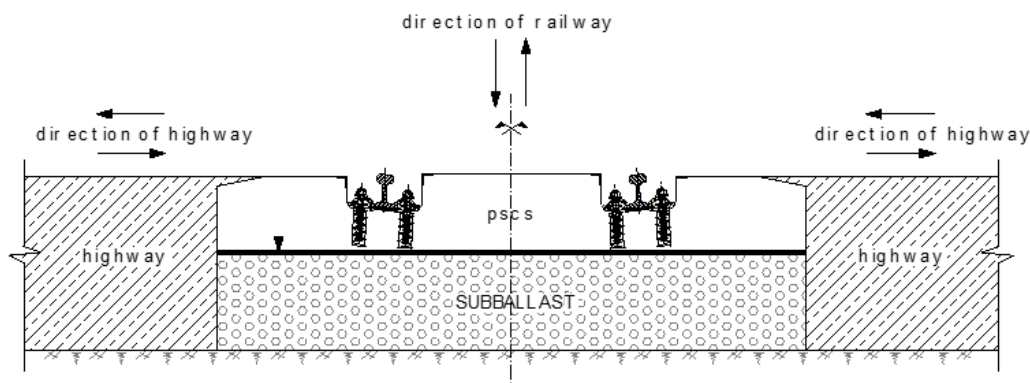


Fig. 1 – Cross section of PSCS at position of fastening

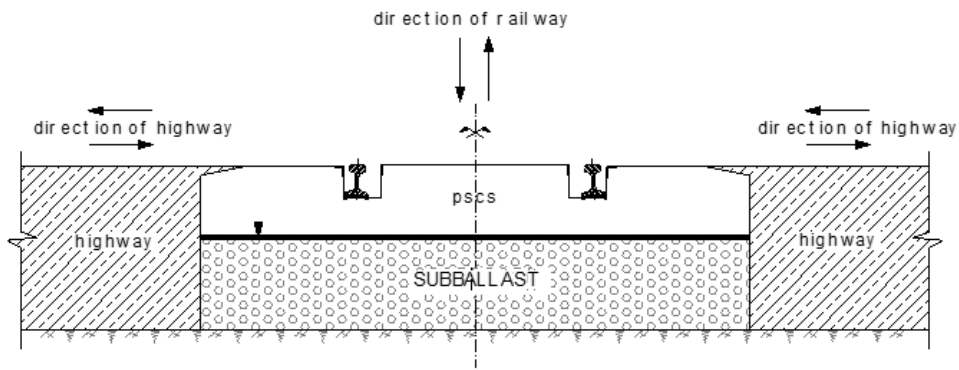


Fig. 2 – Cross section of PSCS at position without fastening

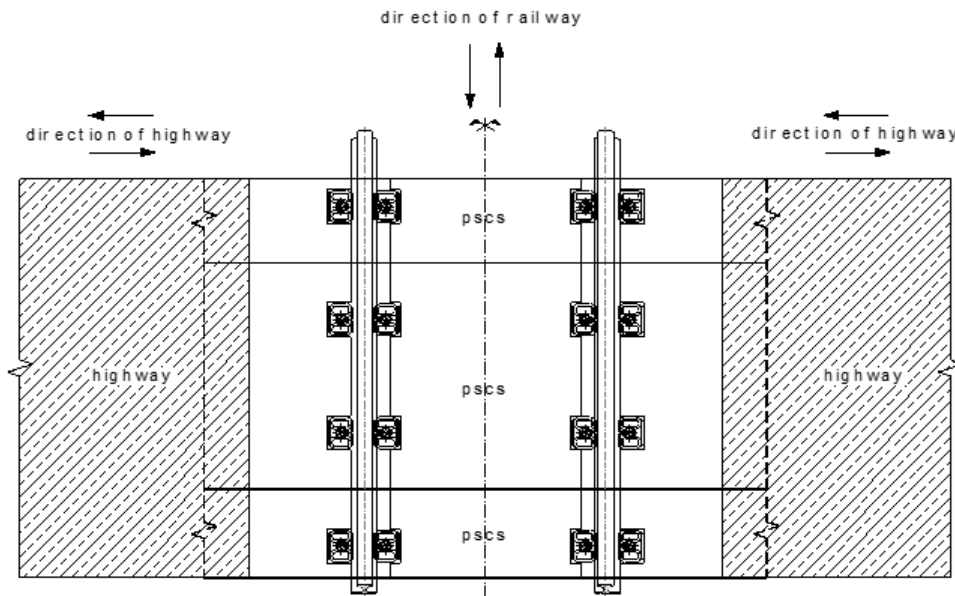


Fig. 3 – Plan of PSCS

2.3 Rail and fastener

Both type of rail used for main rail and guard rail is the P43 rail that made in China or Russia. Fastener is \emptyset elastic type that was permitted use in Vietnam railway by Ministry of Transport.

2.4 Test sample production

Model of PSCS is shown in Fig. 4 and Fig. 5.



Fig. 4 – Production of PSCS sample in the factory



Fig. 5 – Test sample production of PSCS

3 Sample test

3.1 Fatigue test

Test sample is conducted according to EN 13230 standard [9].

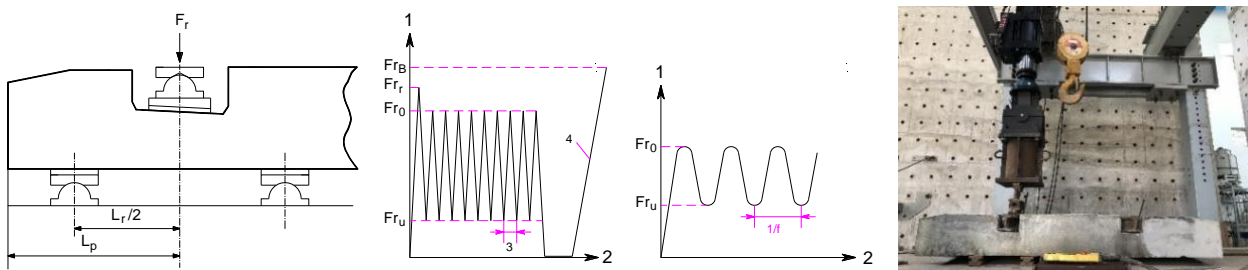


Fig. 6–Fatigue test procedure at the rail seat section of PSCS

1. Test load, 2. time, 3. frequency, 4. increasing of test load at 120 kN/min, L_p . distance from the centre line of the rail seat to the edge of the slab at the bottom, L_r . distance from the articulated supports centre lines to the rail seat section, F_{rB} . maximum positive test load at the rail seat section which cannot be increased, F_{rf} . positive test load which produces first crack formation at the bottom of the rail seat section, F_{r0} . positive initial reference test load for the rail seat section, F_{ru} . lower test load for the rail seat section dynamic test; $F_{ru}=50kN$

3.2 Negative load test

Test sample is conducted according to EN 13230 standard [9]. The linear variable differential transformer (LVDT) was mounted at the bottom centre of the PSCS to measure displacement.

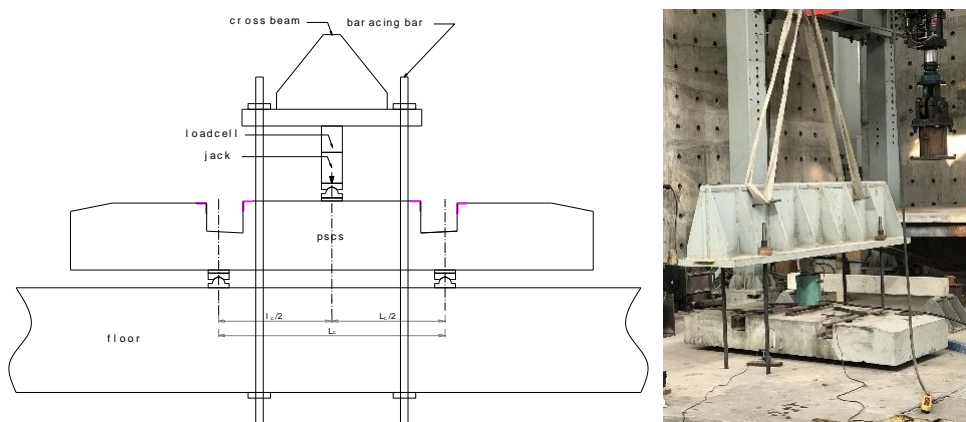


Fig. 7 – Negative load test procedure at the center section of PSCS

L_p . distance from the center line of the rail seat to the edge of the slab at the bottom, L_c . distance between center lines of the rail seat.

3.3 Test to determinate of clamping force

Test sample is conducted according to EN 13146 standard [10]. LVDT was mounted at the top centre of the rail to measure displacement.

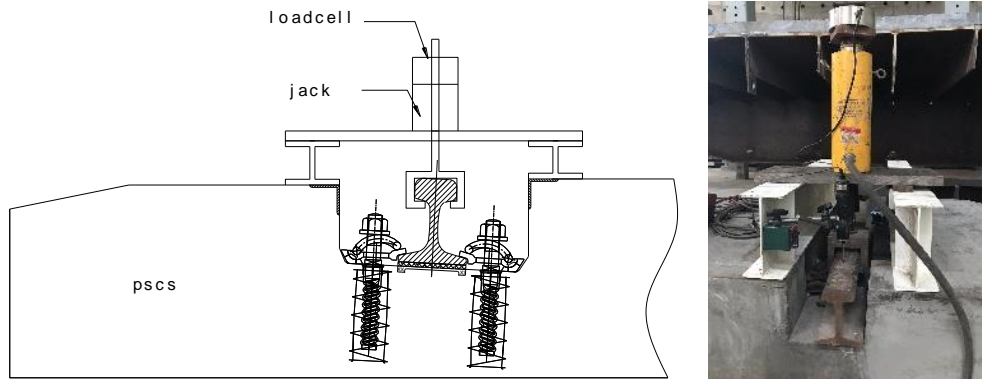


Fig. 8 – Clamping force test procedure at the rail seat section of PSCS

3.4 Test results

Fatigue test

Table 1 – Table of test result for fatigue test of the PSCS

| Test result after 2×10^6 cycles of application load | | | |
|--|--|--|---|
| Acceptance Criteria | Crack width is $\leq 0.1 \text{ mm}$ with load at Fr_0 | Crack width is $\leq 0.05 \text{ mm}$ with load at $Fr_0 = 0 \text{ kN}$ | $Fr_B > k_3 \times Fr_0 = 238.6 \text{ kN}$ |
| Results | No Crack | No Crack | 402 kN |
| Conclusion | OK | OK | OK |

Negative load test

The measured value of the crack load is 745.8 kN.

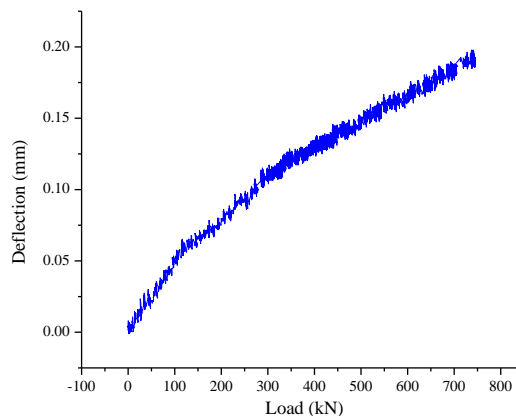


Fig. 9 – Deflection versus with load for PSCS at the center section

Clamping force test

The measured value of the clamping force is 19.32 kN. Maximum deflection of rail is 0.89mm.

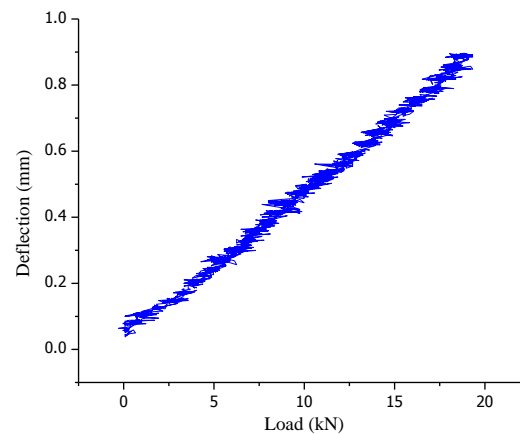


Fig. 10 – Rail deflection versus with clamping force for fastening.

4 Conclusion

This study had designed and proposed a new structure type at highway-railway grade crossings in Vietnam (gauge 1000 mm). The main purpose is developing a system of grade crossings to provide long serviceable life, smooth and minimizing maintenance costs. The model of monolithic PSCS at grade crossings was produced in the factory. Tests are carried out in a laboratory according to European standards. The experimental results have shown that PSCS is satisfied with test standards. The PSCS meets the requirements of the testing process.

In the future, the next development direction is field test installation. Field experiments need to be performed to assess fully for behavior of PSCS.

Acknowledgement

This research is funded by Ministry of Education and Training under grant number B2019-GHA-09.

REFERENCES

- [1]- A.J. Lamanna, C.F. Scholer, Design of Durable Concrete Railroad Crossings. Purdue University, 2002. doi:10.5703/1288284313173
- [2]- J.G. Rose, Highway-Railway At-Grade Crossing Structures: Optimum Design/Installation Practices and Management Program—An Overview. Research Report, Kentucky Transportation Center, 2009. doi:10.13023/KTC.RR.2009.04.
- [3]- C. Blessing, C. Fobbs, N. Jurmu, J. Klieber, A. Summers, Highway-rail grade crossing surface material performance, 2014.
- [4]- V. Markine, A. de Man, S. Jovanovic, C. Esveld, Modelling and optimisation of an embedded rail structure. Rail Int. 31(7) (2000) 15-23.
- [5]- P. Van Hung, T.A. Dung, D.B. Quoc, N.H. Phong, Design Proposal and Behavior Simulation of Prestressed Concrete Slab Track at Highway-Railway Grade Crossings, in CIGOS 2019, Innovation for Sustainable Infrastructure. Springer. (2020) 93-98. doi:10.1007/978-981-15-0802-8_11.
- [6]- Circular No.15/2018/TT-BGTVT : Regulations on crossroads and licensing of construction of essential works within the land area for railways. Transport Ministry of Vietnam, 2018.
- [7]- TCVN 12268:2018, Railway application - Rubber tile level crossings - Specifications and test methods. National Standard of Vietnam, 2018.
- [8]- TCVN 11793:2017, 1000mm gauge railway – Design requirements for track work. National Standard of Vietnam, 2017.
- [9]- UNE EN 13230-2: Railway applications - Track - Concrete sleepers and bearers - Part 2: Prestressed monoblock sleepers. European Standard, 2016.
- [10]- SIST EN 13146-7: Railway applications - Track - Test methods for fastening systems - Part 7: Determination of clamping force and uplift stiffness. European Standard, 2019.