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Experimental analysis of Perfonbond shear connection between steel and Pre-stressed concrete

*Xiaolong Hu[1)],Yun Lin[2)] and Qingyuan Wang[3)]

[1), 2),3)] *Key Laboratory of Energy Engineering Safety and Disaster Mechanics, Ministry of Education , Sichuan University, Chengdu, 610065, China*
[1)] *huxiaolongscu@foxmail.com*

ABSTRACT

Steel and concrete composite structure can give full play to the mechanical performance of steel and concrete materials, which can greatly improve the structural mechanics and economic performance because of high bearing capacity, good plasticity and toughness. In this type of composite structures, steel structures and concrete structures are implemented by shear connectors as a whole to work, so the design of the shear connector is very important. This paper describes the experimental tests carried out at the University of Sichuan using push-out specimens utilizing Perfobond[1] shear connectors and Pre-stressed concrete. The main objective of these tests is to understand the mechanics behavior and to analyse failure mechanism. Comparing the contribution of the different elements to the slip measured between the steel profile and the concrete slab, it is possible to define the connection ductility. The test follows some of the EC4[2] recommendations. The parameters under study are the diameter of holes, thickness of concrete flange plate and rebar perforated existence. Specimens in the process of test appeared the same failure mode and failure phenomenon. Shear pin occurred shear failure of concrete and the PBL connector failure is caused by concrete slab longitudinal splitting. Concrete block at the bottom grow cracks firstly from bottom to top. With the increase of load, longitudinal cracks along the specimen of concrete blocks developed and in the process of the steel plate and concrete block junction has concrete small block to exfoliate, finally through specimen with crack damage. Compared with the experimental results achieved and finite element calculation, the typical load-slip curve may be established.

1. INTRODUCTION

With the rapid development of economic and transportation, a new bridge structure of PC composite boxed girder bridge with span corrugated steel webs has been presented in recent years at home and abroad [3][4]. As a composite structure of steel and concrete, it makes full use of the material characteristics [5][6] and also begins being widely applied in the actual projects.

The key of this form of bridge structure is the transfer efficiency of shear stress on

[1),2)]Graduate Student
[3)]Professor

the steel and concrete joints. So a very high demand is required on the shear connectors[7][8][9][10]. The main traditional connectors are stud shear connectors and channel shear connectors. While the study of shear connectors at home and abroad has been mature. The shear connectors have some shortcomings in the mechanical properties and the application，while the new PBL shear connectors is a better solution for some of the shortcomings of the traditional connections. The studies at home and abroad on the new PBL shear connectors are not enough. The paper relies on the shear connectors used in the Shenzhen Nanshan Bridge, which has researched on PBL shear connectors from experimental and theoretical field. Designed and produced four PBL shear connectors specimens for static load test. The paper analyzs the load-slip curve of each specimen，then it obtains the relationship of its ultimate bearing capacity and the concrete strength of the specimen, the geometry of the connector and the connector holes diameter. These four specimens of the test is C25.The same experiment has showed in literature [11].One of the purposes of this test is comparative analysis of the test in literature [11]，the concrete strength grade of the latter is C30.Through the comparison of the two tests，it can further validation of the ultimate bearing capacity factors，and then analyzes the concrete strength. ANSYS finite element analysis software is used in paper，it analyzes this test and the test in literature [11]，and then obtains the load-slip curves of the specimens as well as the deformation and stress cloud picture before the specimens reach the elastic bearing capacity，and compares the test results with the finite element results.

2. Experimental Program

2.1 Material of Specimens

In this testing, ten specimens are tested, which consists of PBL shear connectors which are made of Q345qc steel and concrete. The main chemical composition of Q345qc steel is shown in Tab.1 and mechanical properties is shown in Tab.2. Ten concrete standard cubic block (150mm*150mm*150mm) are tested by 500T universal hydraulic testing machine to measure the compressive strength of testing concrete as shown in Tab.3

Tab.1 The main chemical composition of Q345qc steel [12]

C	Si	Mn	S	P	Al
0.15	0.38	1.36	0.00003	0.00012	0.00040

Tab.2 mechanical properties of Q345qc steel [12]

Elasticity modulus/Gpa	Yield strength/Mpa	Strength of extension/Mpa	Density/g/cm^3
201	420	570	7.85

Tab. 3 Cube compressive strength of concrete test samples test results

No.	1	2	3	4	5	6
Failure load （KN）	577	609	624	589	594	630
Compressive strength（Mpa）	25.6	27.1	27.7	26.2	26.4	28.0
Average of compressive strength（Mpa）	26.8					

2.2 Design and Preparation of Specimens

The size parameter of PBL shear connection are shown in Tab.4 and finished product is shown as Fig.1.

Tab.4 PBL shear connection parameter list

No.	Thickness of join key steel plate（mm）	Hole diameter （mm）	Strength grade of concrete	Number of opening holes
S-11A	10	25	C30	4
S-12A	12	25	C30	4
S-21A	10	30	C30	4
S-22A	12	30	C30	4
S1025	10	25	C25	4
S1225	12	25	C25	4
S1030	10	30	C25	4
S1230	12	30	C25	4

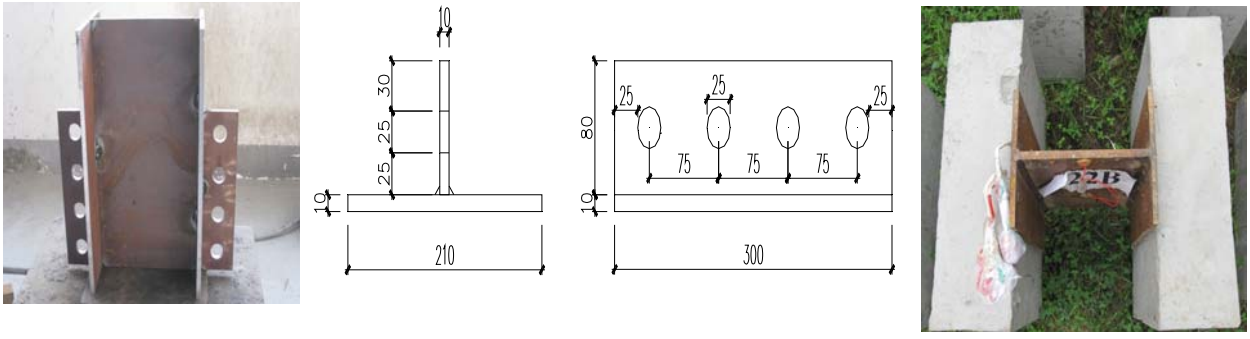


Fig.1 PBL shear connection diagram

Test loading plan uses the step by step loading, load increment is 10KN per level, with loading rate 0.2 KN/s. Testing machine will automatically stop until the specimen failure. In the whole test process, load values and the corresponding slip will be recorded. Test loading device schematic diagram is shown as Fig.2

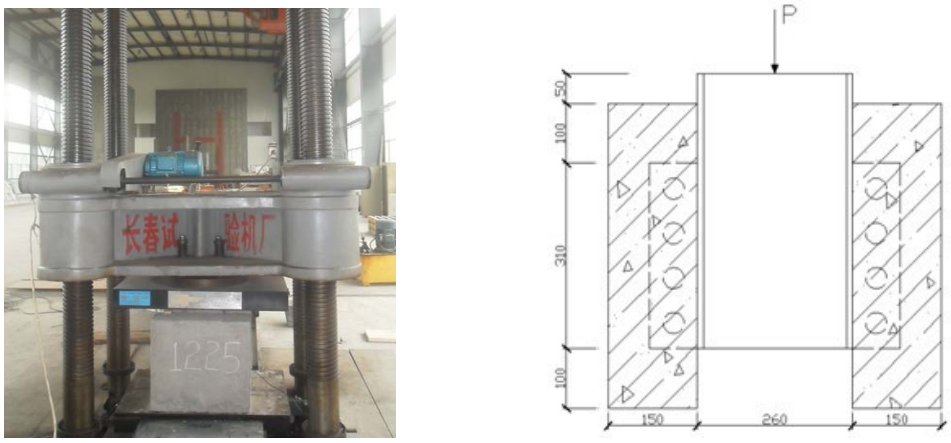
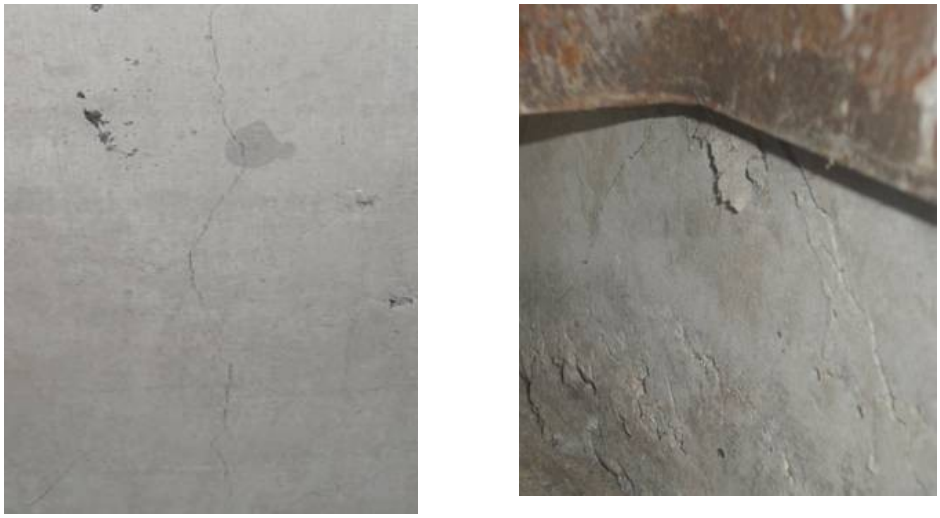


Fig.2 Test loading device schematic diagram

2.3 Analysis of test results

2.3.1 Test phenomenon

In the test process, all of specimens appear the same failure mode and phenomenon. Concrete pin shear occurred failure. Concrete slab happened longitudinal split leading the failure of PBL connector. There is phenomenon of concrete crushing on the bottom of flange plate with opening hole. Concrete cracks are shown as Fig.3.



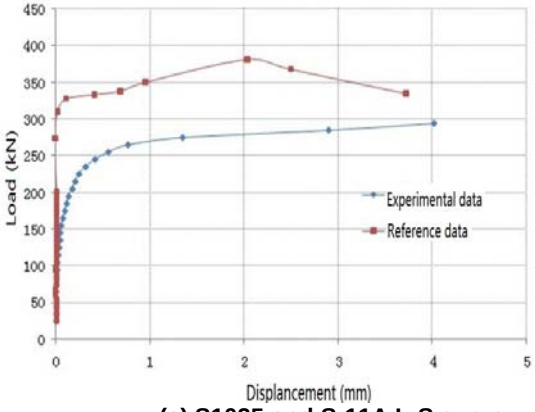
(a) Crack on the side **(b). Crack on the bottom**

(c). Concrete spalling on the bottom **(d).Vertical splitting cracks on the side**

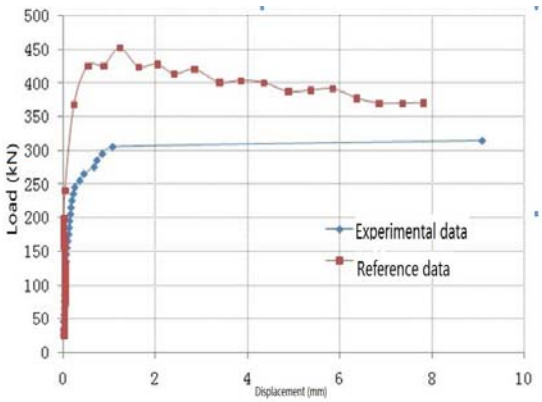
Fig.3 Concrete cracks form

2.3.2 Load-Slip curve (L-S)

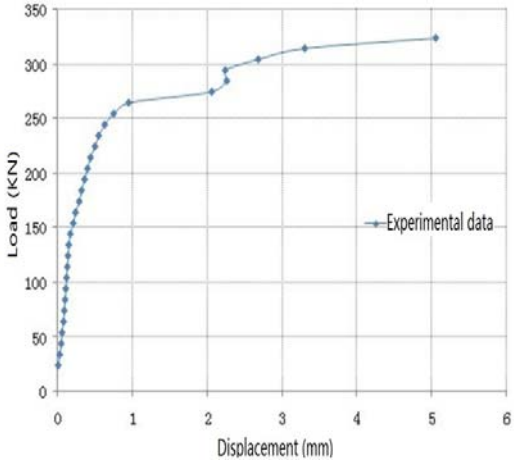
For the research method of PBL shear connectors, the relationship between load and slip is the foundation. It is very necessary to study on Load-Slip curve.



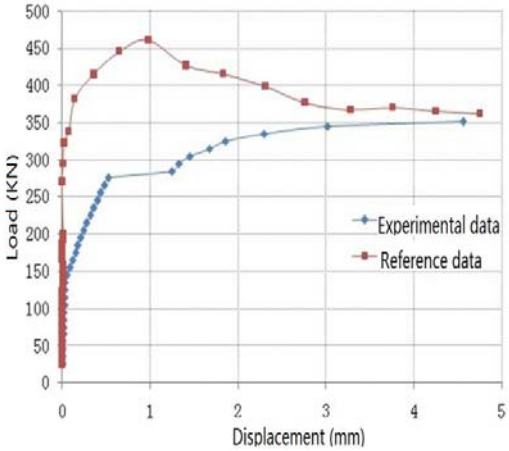
(a).S1025 and S-11A L-S curve



(b).S1030 and S-21A L-S curve



(c).S1225 and S-12A L-S curve



(d).S1230 and S-22A L-S curve

Fig.4 Load-Slip curve

According to the research on Load-Slip curve, it can certify that bearing capacity is mainly provide by bond force between shear connector and concrete. With the increasing load, slope of the curve is decrease. After that, it tends to be small constant value and a non-linear curve. So PBL shear connectors work stage is divided into elastic and elastic-plastic.

2.3.3 Analysis of PBL shear connector ultimate bearing capacity

There are many factors[13] that can influence ultimate bearing capacity of PBL connector. In this paper, concrete strength, diameter of hole and steel plate size are main factors. The result of PBL shear connector push-out test is shown in Tab.5.

Tab.5 The result of PBL shear connector push-out test

Specimen number		Thickness of join key steel plate（mm）	Hole diameter（mm）	Strength grade of concrete	Number of opening holes	Ultimate bearing capacity（KN）
Reference[11]	S-11A	10	25	C30	4	384
	S-12A	12	25	C30	4	/
	S-21A	10	30	C30	4	452.4
	S-22A	12	30	C30	4	461.4
Test of author	S1025	10	25	C25	4	294.2
	S1225	12	25	C25	4	324.4
	S1030	10	30	C25	4	314.2
	S1230	12	30	C25	4	351.4

According to the above Tab.5, compared with the strength of concrete for the C25, Thickness of join key steel plate for 10mm and hole diameter for 25mm, Ultimate bearing capacity of PBL shear connector improve by about 30%,10% and 10%, which used C30 concrete, thickness of join key steel plate for 12mm and hole diameter for 30mm respectively.

3. Finite element analysis

3.1 Finite element model

ANSYS software[14] is used to simulate the mechanics behavior and failure mechanism of PBL shear connectors. In this paper, steel members part adopts SOLID45 unit and concrete part adopts SOLID65 unit. This model adopts contact

element CONTACT175 and target unit TARGET170.Both of them are eight nodes. Defined for contact is shown as Fig.5 and finite element mode is shown as Fig.6.

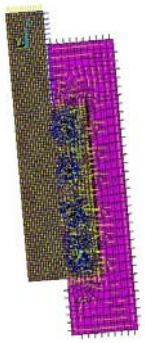


Fig.5 Defined for contact

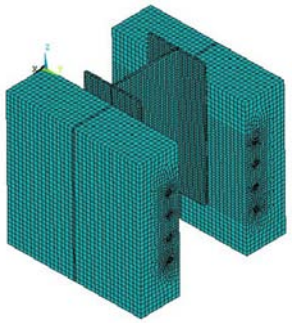
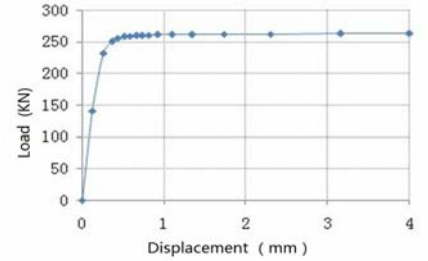
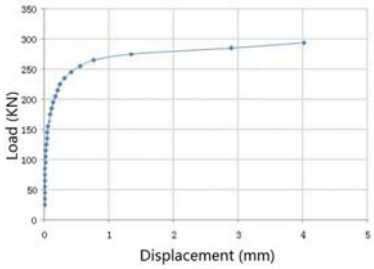


Fig.6 Finite element model

The applied load is controlled with the method of displacement. Through the finite element numerical simulation, load and sliding curve of the specimens can be achieved to contrast the results of experiment. One of specimens load and sliding curve is shown as Fig.7.



(a). Load-Sliding curve of finite element numerical simulation



(b). Load-Sliding curve of experiment

Fig.7 Load and sliding curve

3.2 Finite element analysis result

Through the analysis of the finite element results shown as Fig.8, the result of finite element analysis has same tend with experiment result that concrete strength grade and the diameter of the holes is bigger influence on the ultimate bearing capacity. So the finite element analysis has certain precision and guiding significance, and to supplement validation test results are very good.

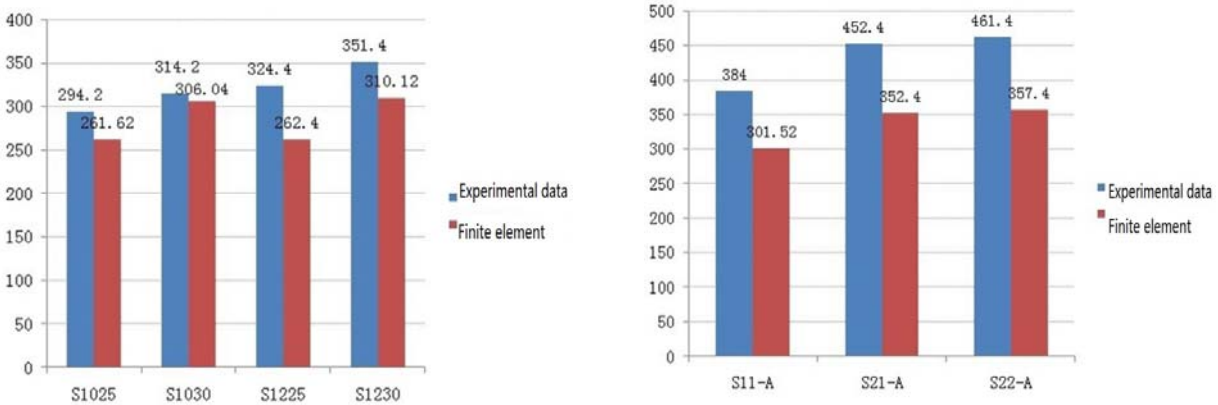


Fig.8 Compared finite element analysis results with experimental results

4. CONCLUSIONS

In fact, through the analysis of the experiment phenomena can be found that all the ultimate bearing capacity of the specimens are controlled by the concrete cracking, the intensity of concrete cracking has a direct influence to its, so the strength grade of concrete impacts on the ultimate bearing capacity of the specimens is larger.

For holes of PBL shear connectors without transfixion reinforced, Ultimate bearing capacity is determined by the shear capacity of concrete tenon. As hole diameter of plant increases, concrete shear resistance increased at the area of the concrete tenon and mortise.

Actually, the increase of steel plate thickness improved the strength and stiffness of steel component. But compared to the influence of concrete strength grade and hole diameter, this factor is not very obvious.

REFERENCES

[1] Leonhardt E F， Andrae W， Andrae H P,et al.Neues vorteilhaftes verbundmittel fur stahlverbundtragwerke mihoher Dauerfestirkeit [J]. Beton und Stahlbetonbau 1987，82(12)：325-331(in German)

[2] Eurocade 4,Design of Composite Steel and Concrete Structures[S]. BSI, London,1994.

[3] Nie Jianguo, Liu Ming, Ye Lieping. Composite structures of steel and concrete[M].Beijing: China Architecture & Building Press,2005

[4] Ling Huang, Hiroshi Hikosaka, Keizo Komine. Simulation of accordion effete in corrugated steel web with concrete flanges. Computers and Structures, 2004(82):2061-2069.

[5] Nie Jianguo. Composite structures of steel and concrete: theory and practice [M]. Beijing: Science Press,2005

[6] Zhao Hongtie. Composite structures of steel and concrete [M]. Beijing: Science Press,2001

[7] Ollgaard J Q，Slutter R G，Flsher J W. Shear strength of stud connectors in lightweight and normal-density concrete [J].Eng JAM Inst Steel Constr.1971，8（2）：55-64.

[8] Oehlers D J， Johnson R P. The strength of stud connectors in composite beams[J].The structure Engineering.1987，65B（2）：44-48.

[9] Johnson R P. Resistance of stud shear connectors to fatigue[J]. Journal of constructional steel research，2000，56（2）：101-116.

[10] Choi Sengkwan，Han Sanghoon，Kim Sungbae，et al. Performance of shear studs in fire[C]//Application of Structural Fire Engineering.2009：490-495.
[11] Ouyang Wenxin. Experimental Study of PBL Shear Connector in composite box girder with corrugated steel webs [D]. Sichuan: Sichuan university, master's degree thesis
[12] Fang Donghui. Liu Yongjie. Wang Qingyuan. etc . Super long life fatigue behaviors of Q345 bridge steel . Sciencepaper Online. 2009（4）：480-484(In Chinese)
[13] Oguejiofor E C， Hosain M U. Numerical analysis of push-out specimens with perfobond rib connectors [J]. Computer & Structures，1996，62(4):617-624.
[14]He Benguo, Chen Tianyu, Wang Yang. Application cases of civil engineering with ANSYS software [M]. Beijing: China WaterPower Press, 2011.