Experimental Study for Performance Evaluation of Large Double Head Studs in High Strength Concrete

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Abstract : A lot of push-out tests of shear studs embedded in normal and high strength concrete were conducted. It also appeared that the main factors affected to the behavior of shear connections are the strength of shear stud and concrete, diameter of shear stud, length of shear stud, connection method of H-beam and shear stud. But bearing strength of shear studs in connection part are not considered in push-out tests. So it is necessary to evaluate the load-slip behavior and the bearing strength effect of shear studs embedded in concrete. In this paper, it was performed push-out tests of large double head studs embedded in high strength concrete used in high-rise building.(double head stud means that head of stud is the above and the lower part.) and it was compared with resistance of horizontal load between concrete slabs. Experimental push-out tests were used to evaluate both the shear stud capacity and the load-slip curve of the connector considered bearing strength of shear studs and resistance of horizontal load between concrete slabs.

Introduction

Steel-concrete composite members have seen widespread use in high-rise building. Shear Studs are commonly used to transfer longitudinal shear forces across steel-concrete interface in composite member design. A lot of push-out tests of shear studs embedded in normal and high strength concrete were conducted. It was experimental study on stud shear connectors subjected to cyclic loading(N. Gattesco & E. Giuriani, 1996). Push-out tests on studs was in high Strength and normal strength concrete(Li An & Krister Cederwall, 1996). It was study of large shear studs for composite girders(Sameh S. Badie, 2002). It was study of composite shear stud strength at early concrete ages(Cem Topkaya, 2004). And it was introduced method of finite element modeling of push-out tests for large stud shear connectors(Huu Thanh Nguyen, Seung Eock Kim, 2009). But bearing strength of shear studs in connection part are not considered in push-out tests. So it is necessary to evaluate the load-slip behavior and the bearing strength effect of shear studs embedded in concrete. In this paper, it was performed push-out tests of large double head studs embedded in high strength concrete used in high-rise building.(double head stud means that head of stud is the above and the lower part.) and it was compared with resistance of horizontal load between concrete slabs. Experimental push-out tests were used to evaluate both the shear stud capacity and the load-slip curve of the connector considered bearing strength of shear studs and resistance of horizontal load between concrete slabs.

Description of tests

Test specimens

Eight push-out specimens were divided into three pairs, according to the strength of shear stud, the shape of shear stud and resistance of horizontal load between concrete slabs. Studs, 28 mm in diameter and 115 mm in height, were welded to the flange of the steel beam(size:400x280x18x18, SS400) in each concrete slab(thick:200mm). Concrete strength design was 80MPa. In this study, it was same at material properties of the concrete and shear stud. It was also equality to experimental setup and loading procedure. Specimens were tested in UTM machine with a capacity of 10000kN. The experiment was controlled by displacement result of LVDT. Displacement control was used for the monotonic tests. The monotonic tests were conducted at a displacement rate of 0.05mm/s. The setup used in the experiments is shown in Fig 1, 2, 3

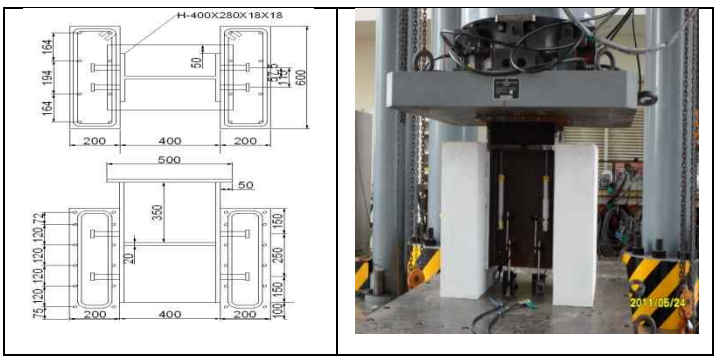


Fig. 1 Details of semi-resistance specimen

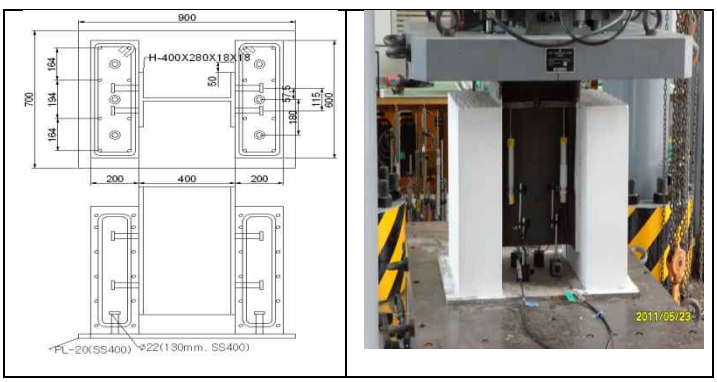


Fig. 2 Details of resistance specimen

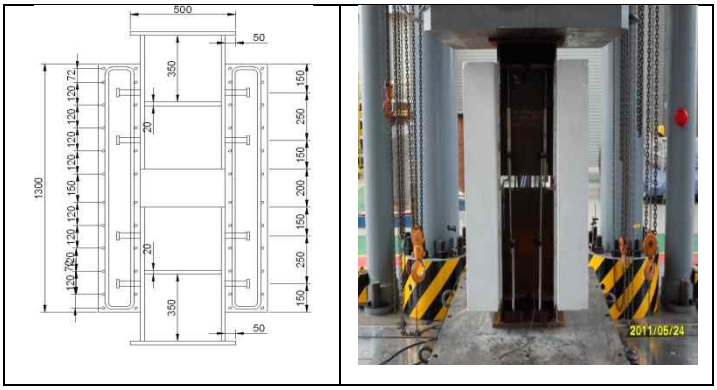
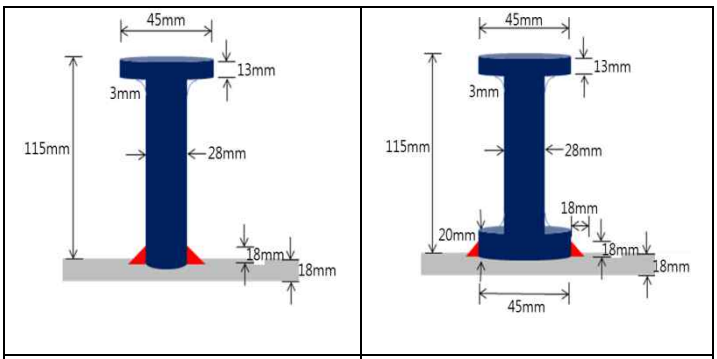


Fig. 3 Details of no-resistance specimen



Nomal shape stud	Double head Stud

Fig. 4 Details of nomal shape stud and double head stud

Concrete mix ingredient is shown in table 1. Mechanical properties of concrete is shown in table 2. And stud welding technique and dimension parameter is shown in table 3.

Table 1. Concrete mix ingredient

Specimens	W/B	S/a (%)	SP/C (%)	Weight Mix proportion (Kg/m3)						
				W	Binder				S	G
					OPC	BS	FA	SF		
80 MPa	22.5	43	1.8	152	507	0	135	34	660	882

S/a = fine-total aggregate ratio ; SP/C = Super Plasticizer/cement ratio; W = water; OPC = cement ; BS = blast-furnace slag ; FA = fly ash ; SF = silica fume; S = sand; G= aggregate

Age of concrete at testing was 28days. when compared with 80MPa design strength of concrete, compressive strength of concrete was differrent to 3.4MPa. Elastic modulus showed results from 31.3GPa.

Table 2. Mechanical Properties of Concrete

Specimens	Age of concrete at testing(days)	Concrete strength(design) (MPa)	Compressive strength of concrete (MPa)	Elastic modulus (GPa)
80MPa	28	80	76.6	31.3

Table 3. Stud welding technique and dimension parameters

specimen	Stud diameter (material)	Size of H-beam (material)	Sutd welding technique
Case 1	28 (400MPa)	400x280x18x18 (SS400)	Weld all around
Case 2	28 (520MPa)	350x350x12x19 (SS400)	Weld all around

Design code calculation methods

Korea building code

In the Korea building code(KBC), the stud shear bearing capacity is determined by

$$Pu = 0.5RaAs\sqrt{f'cEc} \leq AsFu \quad (1)$$

Ra=1.0 for reinforced concrete flat slab of the fixed thickness (resistance factor of shear stud connectors) ; As=cross-sectional area of a stud shear connector(mm2) ; $f'c$ = compressive strength of concrete cylinders ; Ec = elastic modulus of concrete

$$f'c \leq 29.4N/mm^2 : Ec = 4{,}700\sqrt{f'c}$$
$$f'c > 29.4N/mm^2 : : Ec = 3{,}300\ \sqrt{f'c} + 6{,}900$$

Fu = ultimate tensile strength of stud($\leq$ 440N/mm^2)

Eurocode4

In the latest proposal of Eurocode 4, the shear resistance of a headed stud is determined by

$$Pu = \frac{0.8Fu\pi d^2/4}{\gamma_v}, Pu = \frac{0.29\alpha d^2\sqrt{fEc}}{\gamma_v} \quad (2)$$

Whichever is smaller
Where the units are N, mm; d=diameter of the studs ; Fu = ultimate tensile strength of stud ; $f'c$ = compressive strength of concrete cylinders ; Ec = elastic modulus of concrete ; The partial safety factor γ_v should be taken as 1.25 ; $\alpha = 0.2(H/d+1) \leq 1$; and H=height of the studs.

AASHTO LRFD(2004)

In AASHTO LRFD(2004), the nominal shear resistance of one stud shear connector embedded in a concrete deck shall be taken as Eq.(3)

$$Pu = \phi 0.5As\sqrt{f'cEc} \leq \phi AsFu \quad (3)$$

Where Ø= resistance factor for shear connectors(=0.85)

Test results

Load-slip curve of specimens is shown in Fig. 5. And push-out test results is shown in table 4.

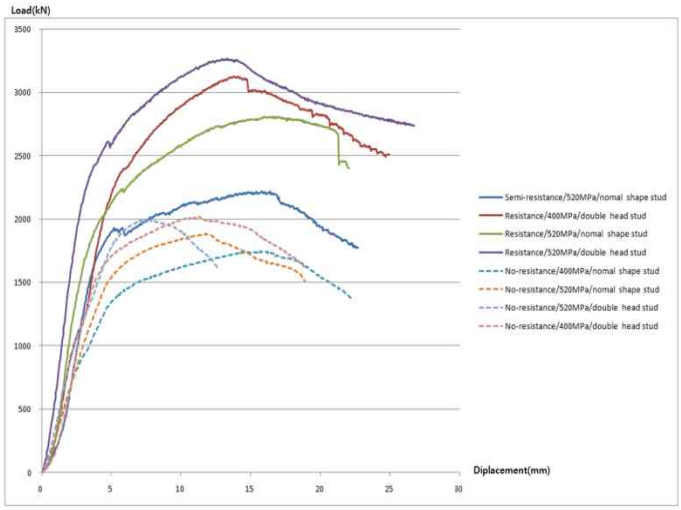


Fig. 5 Load-Slip curve of specimens

Throughout results obtained from the experimental push-out tests, maximum shear resistance was 3269.06kN and maximum slip at failure was 13.3mm in case of double head stud(520MPa, resistance of horizontal load) and minimum shear resistance was 1748.27kN and maximum slip at failure was 15.8mm in case of nomal shape stud(400MPa, no resistance of horizontal load)

Table 4. Experimental result of shear stud

No	Specimen			Maximum shear resistance (kN)	Maximum silp at failure(mm)	Kind of failure
	Resistance of horizontal load	Strength of stud	Shape of stud			
1	Semi-resistance	520 MPa	Nomal shape stud	2218.6	15.8	Stud failure
2	Resistance	400 MPa	Double head stud	3127.9	14.1	Stud failure
3	Resistance	520 MPa	Nomal shape stud	2812.3	16.6	Stud failure
4	Resistance	520 MPa	Double head stud	3269.1	13.3	Stud failure
5	No resistance	400 MPa	Nomal shape stud	1748.3	15.8	Stud failure
6	No resistance	520 MPa	Nomal shape stud	1881.4	11.7	Stud failure
7	No resistance	400 MPa	Double head stud	2015.8	11.2	Stud failure
8	No resistance	520 MPa	Double head stud	1997.9	7.9	Stud failure

Specimen substitutes a name from Resistance-520MPa- Double head stud to No 4

After maximum shear resistance force, The crack was appeared on the surface clearly. It also appeared a broken piece of concrete. Damage of the concrete was concentrated mainly around the studs. And it showed gap between H-beam and concrete after the experimental test. First of all, stud failure was occurred and concrete failure was occurred in afterwords. Comparisons of test and design code is shown in table 5. It was appear experimental test result was similar to result considered design code and Bearing Strength in the resistance of horizontal load(No 2,3,4). The shear strength of double head stud is larger than the shear strength of nomal shape stud in the same condition.(No 3,4 ; No 5,7 ; No 6,8). The shear strength of stud was appreared with increases in the resistance of horizontal load(No 1, 3, 6 ; No 2, 7 ; No 4, 8). But the material strength of shear stud does not interact with Maximum shear resistance shown in table 6.(No 2,4 ; No 5,6 ; No 7,8)

Table 5. Comparisons of test and design code

No	Maximum shear resistance(kN) by experimental test	Maximum shear resistance(kN) by Calculation result (Bearing Strength consideration)		
		KBC	Euro-code4	AASHTO LRFD
1	2218.6	2558.4 (3032.4)	1638.6 (2122.5)	2174.4 (2648.4)
2	3127.9	1968 (2689.3)	1260.4 (1981.7)	1672.8 (2394.1)
3	2812.3	2558.4 (3032.4)	1638.6 (2122.5)	2174.4 (2648.4)
4	3269.1	2558.4 (3279.7)	1638.6 (2359.8)	2174.4 (2895.7)
5	1748.3	1968 (2442)	1260.4 (1734.4)	1672.8 (2146.8)
6	1881.4	2558.4 (3032.4)	1638.6 (2122.5)	2174.4 (2648.4)
7	2015.8	1968 (2689.3)	1260.4 (1981.7)	1672.8 (2394.1)
8	1997.9	2558.4 (3279.7)	1638.6 (2359.8)	2174.4 (2895.7)

Table 6. Comparisons of shear resistance by variable

Case	Condition	No	variable		
			Semi-Resistance	Resistance	No Resistance
Case 1	The resistance effect of horizontal load	1,3,6	79%	100%	67%
		2,7	-	100%	64%
		4,8	-	100%	61%
Case 2	The shape of stud	No	Nomal shape stud		Double head Stud
		3,4	100%		116%
		5,7	100%		115%
		6,8	100%		106%
Case 3	the material strength of shear stud	No	400MPa(Stud)		520MPa(Stud)
		2,4	100%		105%
		5,6	100%		108%
		7,8	100%		99%

Conlusion

Eight push-out tests were carried out and the results obtained allow the following conclusions to be drawn:

1. It was appeared that experimental test result was similar to result considered design code and Bearing Strength in the resistance of horizontal load.
2. The shear strength of double head stud is larger than the shear strength of nomal shape stud in the same condition.
3. The shear strength of stud was appreared with increases in the resistance of horizontal load.
4. The material strength of shear stud does not interact with Maximum shear resistance.
5. The shear resistance of the stud calculated by the design code is determined separately by the concrete or by the stud. The interaction between the two materials has not also been applied in equations.
6. New design code is proposed for applying to high strength concrete and stud, new shape of stud.

Acknowledgments

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