論文 Study on the Bond Splitting Strength of Sheaths for A Precast Concrete System

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ABSTRACT: An experimental study on the bond strength of steel spiral sheaths for a precast concrete system was carried out. The specimens which represent a full scale section of beams or columns were tested with a constant bonded length. The influence of the height of the lug (rib) of sheath, sheath diameter, casting depth, thickness of the cover concrete, amount of the lateral reinforcement and size of the deformed bar on the bond strength are discussed in this paper.
KEYWORDS: precast concrete, spiral sheath, bond strength, lateral reinforcement, casting depth

1. INTRODUCTION

The bond characteristics of the proposed precast concrete system using spiral sheath [1, 2,] are assumed to be primarily governed by interlocking between concrete and lugs of the sheath. In the system conformed by main bar-mortar-sheath, the high strength mortar confined by the spiral sheath is assumed to be strong enough that bond failure will not occur between the lugs of main bars and the interior lugs of the sheath.

The proposed system uses steel sheaths with diameters more than 40 mm. The surface of concrete to resist the splitting forces become smaller, therefore it may be possible that the bond strength per unit of surface area decrease. Consequently it is necessary to study the bond characteristics of the spiral sheath.

2. TEST SPECIMEN AND TEST SET-UP

The specimens were designed to represent a confined section of precast concrete columns or beams, and were divided into six groups according to the following parameters: lug height of sheath, sheath diameter, casting depth, thickness of cover concrete, amount of lateral reinforcement (No. 1~ 15) and size of the bar (No. 19~ 22). Figure 1 shows the section of the typical specimens and Table 1 shows the differences among them. Two specimens were constructed for each parameter.

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Table 1 Characteristic of specimens

No	Parameter	b x D (mm)	Lug height (mm)	Sheath diam. (mm)	Lateral reinf. ratio (pw %) SD295A	Cover thickness (mm)	Casting depth (mm)	Deformed bars SD490
1	Lug		1.5					
2	Height		2.0	42				
3	(mm)		3.0		4-D10 @100 (0.63)			
4	Sheath			38				
2	diameter	450x600		42				
5	(mm)			46		40		
6					2-D10 @100 (0.32)			
7	Lateral				2-D13 @100 (0.56)		600	
2	reinf.				4-D10 @100 (0.63)			
8	ratio				4-D13 @100 (0.75)			
9				42	4-D13 @100 (1.13)			D25
10	Cover	410x560	2.0			20		
11	Thickness	430x580				30		
2	(mm)	450x600				40		
12		470x620				50		
13	Casting	450x300					300	
14	depth	450x450					450	
2	(mm)	450x600			4-D10 @100 (0.63)		600	
15		450x750				40	750	
19	deformed							D25
20	bars	450x600	without				600	D29
21	SD490		sheath					D35
22								D41

Table 4 Properties of steel

Bar	Grade	σ_y	σ_B	E
D10	SD295A	3.47	4.77	1934
D13	SD295A	3.38	5.00	2016
D25	SD490	5.16	6.99	2031
D29	SD390	4.48	6.39	2139
D35	SD390	4.61	6.37	1992
D41	SD390	4.52	6.29	1963

units:(tf/cm ^{2})

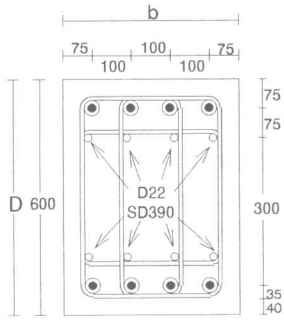


Fig. 1 section of specimens

Table 2 Properties of concrete

No	4 weeks	Exp day
3	277	314
1		
2		330
6	298	
10		
11		324
12		330
4		
5		323
7	277	
8		
9		311
14	280	310
15		323
13	277	308
19		
20	303	333
21		
22		

unit:(kgf/cm ^{2})

Table 3 Properties of mortar

Days	Strength
5	563
7	596
28	674

unit:(kgf/cm ^{2})

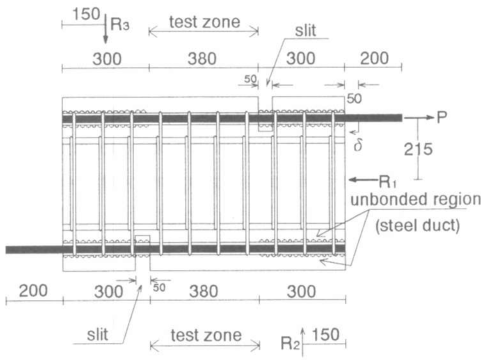


Fig. 2 Details of typical specimens

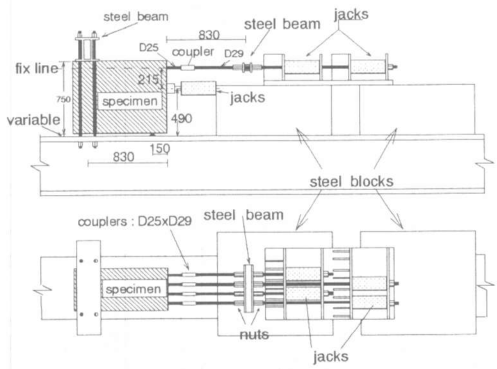


Fig. 3 Loading System

The typical specimens had a section of 450 mm x 600 mm with a distance between bars axes of 100 mm. The bonded part (test zone), was positioned in the middle of the specimen, with a length of 380 mm which is 20 times the diameter of the bars D19. The bond free length at either side was 300 mm, as shown in Fig. 2. A slit of 50 mm was provided at the end of the bonded region to prevent the concrete of the unbonded region from restraining the concrete at the test zone. The bond free end was obtained by placing a steel ducts concentrically around the bars and sealing the ends with plastic tape to prevent concrete from flowing in.

The concrete of the specimens was cast horizontally. The position of bars was the basis of naming the upper cast bars as "top bars" and the lower cast ones as "bottom bars". The specified concrete strength of specimens was Fc=300 kgf/cm^2 , and for the grout mortar it was 600 kgf/cm^2. The test results are shown in Tables 2 and 3, respectively. Main bars D25, SD390 were used as main bars to avoid the yielding of bars during the experiment. The properties of steel are shown in Table 4.

Tension force P was applied horizontally at the end of each main bar by four oil jacks controlled by a load cell as is shown in Fig. 3. Threaded type bars D29 were used to transmit the pulling forces from the oil jacks to the bars of specimens. The order adopted for the test was as follows: first the top bar was tested until the specimen was close to failure, then the bottom bar was tested until it failed. For the second specimen the bottom bar tested first and then the top bar was tested until failure. The displacements of the bars, from the end face of the concrete at the loading side were measured using linear voltage displacement transducers, attached to a rigid steel frame at the mid-height of the specimens.

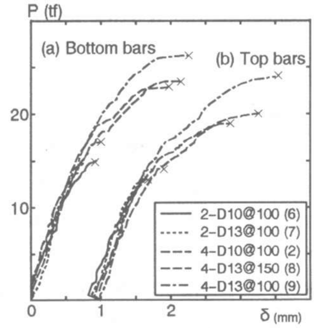


Fig. 4 Typical P-δ curves

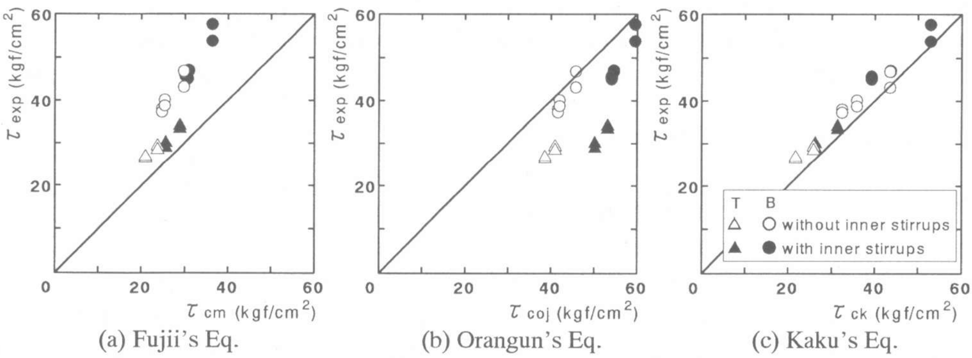
3. EXPERIMENTAL RESULTS

3.1 LOAD-DISPLACEMENT RELATIONSHIP

Typical load-displacement relationships for specimens where the parameter was p_w are presented in Fig. 4. The symbol "x" represents the point where each specimen reached the maximum load. For the top and bottom bars until approximately 12 tonf, a similar tendency of the load-displacement relationship is observed. However, as the lateral reinforcement ratio is increased the maximum load at which the specimen failed also increases. The main bar, mortar and sheath acted as a unit, and the bond failure took place not inside but outside the sheaths for all specimens.

3.2 COMPARISON WITH THE EXISTING EQUATIONS

To compare the test results of bond strength with those calculated using the existing equations, the measured maximum forces were converted into average bond stresses by $\tau_{exp}=P_{max}/(l_b\ \phi)$,



(a) Fujii's Eq. (b) Orangun's Eq. (c) Kaku's Eq.

Fig. 5 Experimental bond strength and calculated values where ϕ is the perimeter of the main bar or sheath and l_b is the bonded length. Also, bond splitting strengths calculated by Fujii's Eq. (τ_{cm}) [3], and Kaku's Eq. (τ_{ck})[4], for continuous bars, and Orangun's Eq. (τ_{coj}) [5]for bars with lap splices, are plotted in Fig. 5.

Specimens with inner stirrups (No. 2, 8, 9) are plotted with black circles ,and black triangles for bottom and top bars respectively. White marks were used for specimens without inner stirrups (No. 6, 7). In most of the equations the influence of the inner stirrup is not considered, however, Kaku's Eq. considered this effect. Therefore the test results from specimens both with and without inner stirrups present a good correlation with the values calculated using Kaku's Eq.

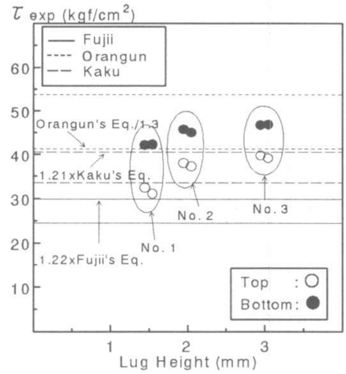


Fig. 6 Effect of the lug height of sheath

3.3 LUG HEIGHT OF SHEATH

The relationship between the lug height of the sheath and the bond strength is shown in Fig. 6. When the lug height is varied from 1.5 mm to 2.0 mm the bond strength increases. But when it is varied from 2.0 mm to 3.0 mm a slight increase on the bond strength is observed. None of the calculated values using Fujii's Eq., Orangun's Eq. and Kaku's Eq. fits with the tests results.

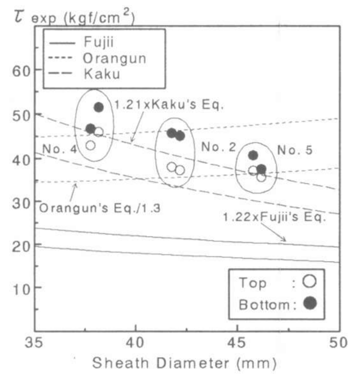


Fig. 7 Effect of the sheath diameter

3.4 SHEATH DIAMETER

The effect of the sheath diameter on the bond strength is shown in Fig. 7. As the diameter increases the bond strength decreases for either the top or bottom bars. It seems that the confinement effect due to the concrete between sheaths decreases when the sheath diameter becomes larger. The effect of the bar diameter is considered in each of the existing bond strength equations. Calculated values are obtained by using the sheath diameter instead of the bar diameter. Calculated values using Kaku's Eq. and Orangun's Eq. fit well with some of the test results. The calculated values using Fujii's Eq. give lower values than the test results.

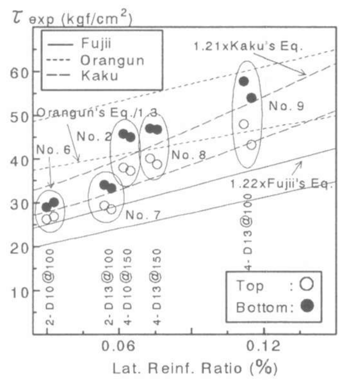


Fig. 8 Effect of the lateral reinforcement

3.5 LATERAL REINFORCEMENT RATIO

The effect of the variation of lateral reinforcement ratio is shown in Fig. 8. As the lateral reinforcement ratio increases the bond strength also increases. For specimens with inner stirrups (4-D10 or 4-D13), the increase of the strength became more evident than those for the specimens without inner stirrups (2-D10 or 2-D13), in which the bond strength increases slightly. It is found here that the amount of lateral reinforcement has a great influence on the bond strength.

The values obtained using Kaku's Eq. equation shows a quite good agreement with the test results for either the top or bottom bars. Orangun's Eq. gives a good approximation to the test results for the top bars, while for the bottom bars this equation gives higher values. Fujii's Eq. gives lower calculated values than the experimental.

3.6 THICKNESS OF COVER CONCRETE

The effect of the cover thickness of concrete on the bond strength is showed in Fig. 9. No remarkable effect on the bond strength is observed when the thickness of cover concrete is varied.

The calculated values using Orangun's Eq. showed a little higher values given by Kaku's Eq. On the other hand the calculated values using Fujii's Eq. gives lower values than the experimental values.

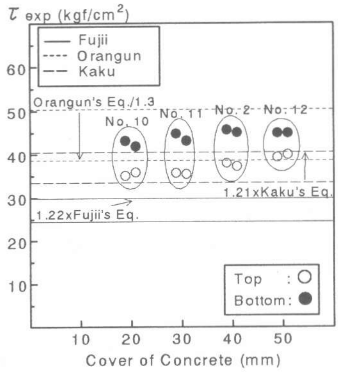


Fig. 9 Effect of the thickness of cover concrete

3.7 CASTING DEPTH

As the depth varied, the strength ratios of the bottom and top bars remained constant (1.22). Also, as the depth was increased the bond strengths for both the top and bottom bars remain constant, as it is shown in Fig. 10. This is because the specimens failed in side splitting mode. The calculated values from the three existing equations are plotted as horizontal lines. Only the values given by Kaku's Eq. have a good agreement with the values obtained in this test.

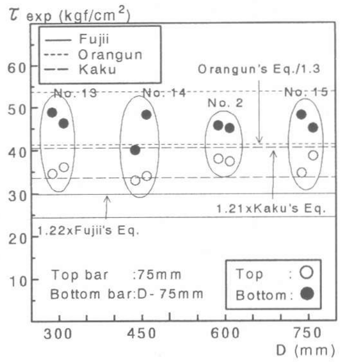


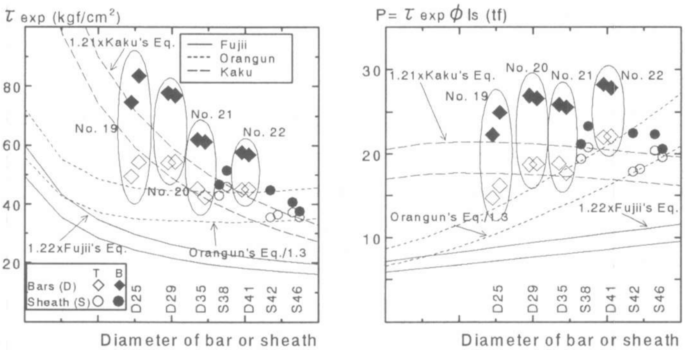
Fig. 10 Effect of the casting depth

3.8 COMPARISON OF THE BOND STRENGTH OF SHEATH WITH THOSE OF LARGE SIZE DEFORMED BARS

The comparison of the bond strengths of sheaths with those of large size deformed bars is shown in Figs. 11(a) and (b). As the diameter increases the bond strength per unit surface area decreases, as it is shown in Fig. 11(a). In case of the deformed bars placed at the bottom the strength decays considerably, while for the top bars the strength decays slightly. In case of the sheaths the strength decreases slightly for both the top and bottom bars.

In Fig. 11(b), the bond force for the bonded length is shown. For the experimental values, P is the bond force. As the diameter of bar increases the bond force also increases. The bond force of sheaths remains constant. Also, the bond forces of the top bars with diameters of 29, 35, and 41 mm are almost similar to hat of sheaths with diameters of 38, 42, and 46 mm. Therefore, it is possible to estimate roughly that the bond behavior of sheath is similar to that of the deformed bars with the same diameters to the sheath.

The calculated values using Kaku's equation fit with the experimental values of the deformed bars and sheaths placed at the bottom. Orangun's equation gives a good agreement with the test results of sheaths with diameters of 42 and 46 mm placed at the top.



(a) Bond strength (b) bond force

Fig. 11 Comparison between bond strength of sheath and those of large size deformed bars

4. CONCLUSIONS

The test results of the bond behavior of the spiral sheath for the precast concrete system are summarized as follows:

1. The system main bar-mortar-sheath behaves as one unit.
2. A slight increase on the bond strength is recognized when the lug height of the sheaths is increased.
3. When the diameter of the sheath is increased, the bond strength per unit surface area decreased.
4. For specimens with the same bar axis distance of 100 mm, as the diameter of bar increases the bond strength per unit length remains almost constant.
5. As the lateral reinforcement ratio increases the bond strength also increases.
6. The thickness of the cover concrete has no remarkable effect on the bond strength.
7. The casting depth has no remarkable effect on the bond strength.
8. The bond behavior of sheaths is almost similar to that of deformed bars with the same diameter of the sheath.

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