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ORIGINAL ARTICLE

Development of Post Shear Reinforcing Method "Spiral Anchor" for Existing Concrete Structures

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***Abstract*:** "Spiral Anchor" is the post shear reinforcing method for existing concrete structures. The seismic capacity of them is improved by inserting reinforcing bars with grout pouring in the drilled holes which are processed surface roughing of inside wall of holes, after core drilling from the surface of the existing concrete structures. The bonding strength, resistance against pullout force, and uniformity between anchors and existing concrete structure are improved by this roughing process and expanded shape of the both end of reinforcing bars. It is possible to reinforce existing basement or semi-basement structures from the inside of them which used to be difficult to reinforce in the past. Furthermore, it is the efficient seismic reinforcement method which can improve the ratio of shear capacity / flexural capacity.

Keywords: earthquake resistance, post shear reinforcing, core hole surface roughing, bonding strength

1. INTRODUCTION

It is well known that Japan is the country which has a large risk of mega earthquake, and the seismic design for RC structures had been revised several times after past mega earthquakes like Great Hanshin disaster (1995). A lot of old RC structures which had been constructed before Great Hanshin disaster don't have enough earthquake resistance because of less shear capacity and less ductility of old seismic design compared with latest design.

To reinforce the shear capacity and ductility of these old structures, cross section widening method is popularly used. However, this method will decrease the inner cross section of structure like a tunnel or water channel, therefore this method is not suitable when design inner capacity / flow of the structure is limited.

The authors have developed a shear reinforcing method for existing concrete structures which will improves the seismic capacity by inserting reinforcing bars with grout pouring in the drilled holes which are processed surface roughing of inside wall of holes, after core drilling from the surface of the existing concrete structures.

This paper describes the outline and the reinforcing effect of this method.

2. OUTLINE OF SPIRAL ANCHOR METHOD

Figure-1 shows the schematic of Spiral Anchor Method. The work procedure of Spiral Anchor Method is shown in Figure-2 and described as follows.

(1) Core drilling location is decided with avoiding the re-bar according to the rebar detection.

(2) Drilled holes are made by using core drilling machine to prevent the damages of existing concrete which will be caused by the micro-cracks when hammer drill machine is used.

(3) Roughing of inner hole surface are applied by roughing bit as shown in Figure-3. This roughing is increase the bonding capacity between existing

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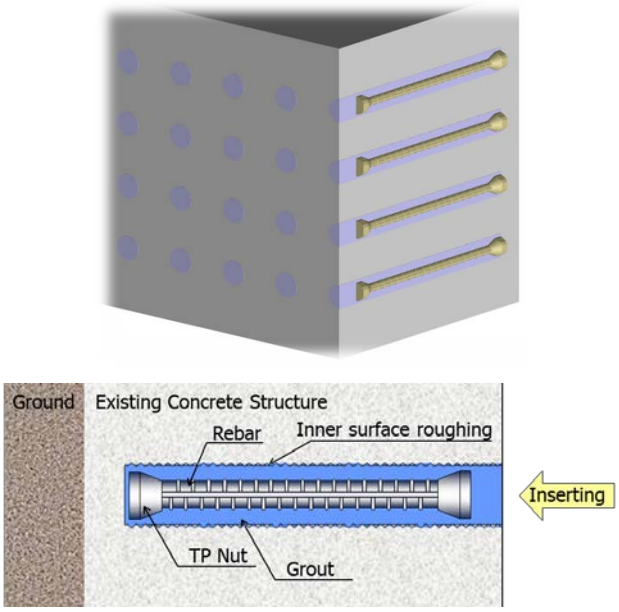

Figure-1 Schematic of Spiral Anchor Method

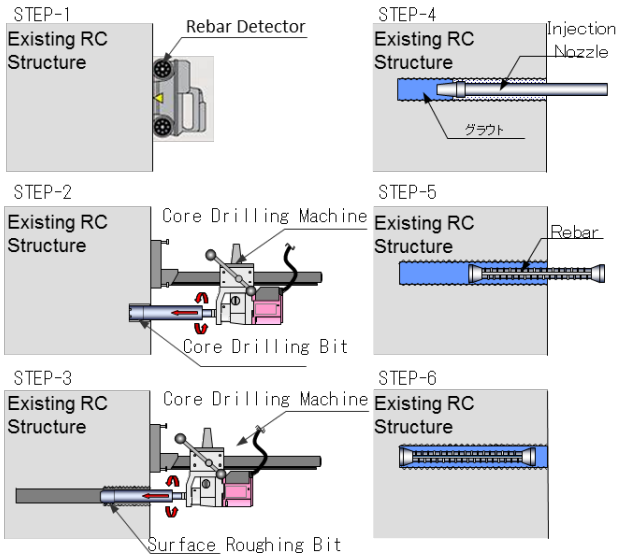

Figure-2 Procedure of Spiral Anchor Method

Figure-3 Inner surface roughing of drilled hole

concrete and grout, thus improve the effect of shear reinforcing capacity of anchor.

(4) High strength non-shrink grout material is injected into the drilled hole by using injection nozzle inserting to the bottom of drilled hole.

(5) Rebar with frustum shape nuts (named TP Nut Rebar) at both ends of rebar as shown in the Figure-4 is inserting into the grouted hole. These frustum shape nuts are fastened by the tapered screw mechanism as shown in Figure-5.

(6) Top surface of drilled hole is finished with finishing trowel.

As described above, Spiral Anchor Method is quite easy and rapid, furthermore, effective method of seismic reinforcing. Figure-6 and 7 show the actual situation of Spiral Anchor Method work.

Figure-4 Rebar with frustum shape nuts (TP Nut Rebar)

Figure-5 Taper shaped screw mechanism

Figure-6 Actual situation (core drilling)

Figure-7 Actual situation (rebar inserting)

3. EFFECT OF SPIRAL ANCHOR METHOD

3.1 Effect of inner surface roughing

Inner surface roughing of core drilled hole is very important to satisfy the required bonding capacity between existing concrete and grout. However, it is a cost increasing factor. Therefore the authors have developed a special roughing bit which is able to be attached to the core drilling machine. The workers can execute the drilling work and roughing work consecutively without changing or relocating the core drilling machine, but only changing the bit.

Figure-8 shows the relationship between pullout displacement and pullout stress in the rebar pullout test. The pullout stress was increased to approximately double when inner surface roughing was applied.

3.2 Effect of shear reinforcement by Spiral Anchor Method

A comparison test of beam bending was carried out to clarify the effect of shear reinforcing by the Spiral Anchor Method. Three cases of bending test were carried out for comparison as shown in Table-1. Figure-9 shows the detail of testing conditions. Figure-10 shows the loading system for beam bending test.

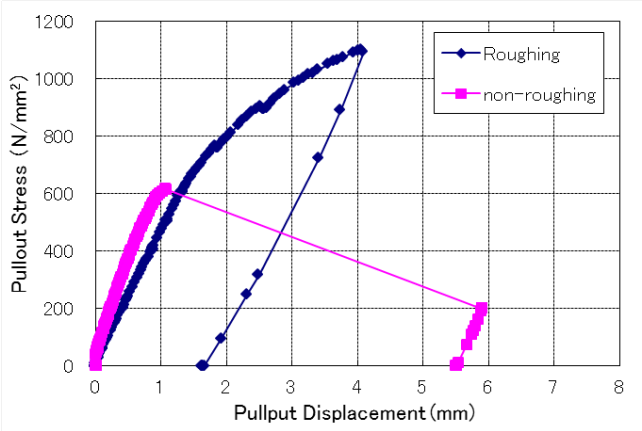

Figure-8 Pullout test result

Table-1 Experimental condition

Case		Case-1	Case-2	Case-3
Shear reinforcement		non	Post fit	Pre-fit+ Post fit
Section size of beam		400mm x 500mm		
Equivalent height		435mm		
Shear span length		1600mm		
Shear span ratio		2.87		
Compressive strength of concrete		32.2 N/mm^2	33.9 N/mm^2	35.0 N/mm^2
Size and pitch of Shear reinforcment	Pre-fit (fuck)	-	-	SD345 D16 @250mm
	Post-fit (Spiral Anchor)	-	SD345 D16 @250mm	SD345 D16 @250mm
Shear reinforcement ratio		-	0.40%	0.79%
Main Reinforcement		SD490 D41, 4nos		
Main reinforcement ratio		3.10%		
Loading condition		Reversed cyclic loading		

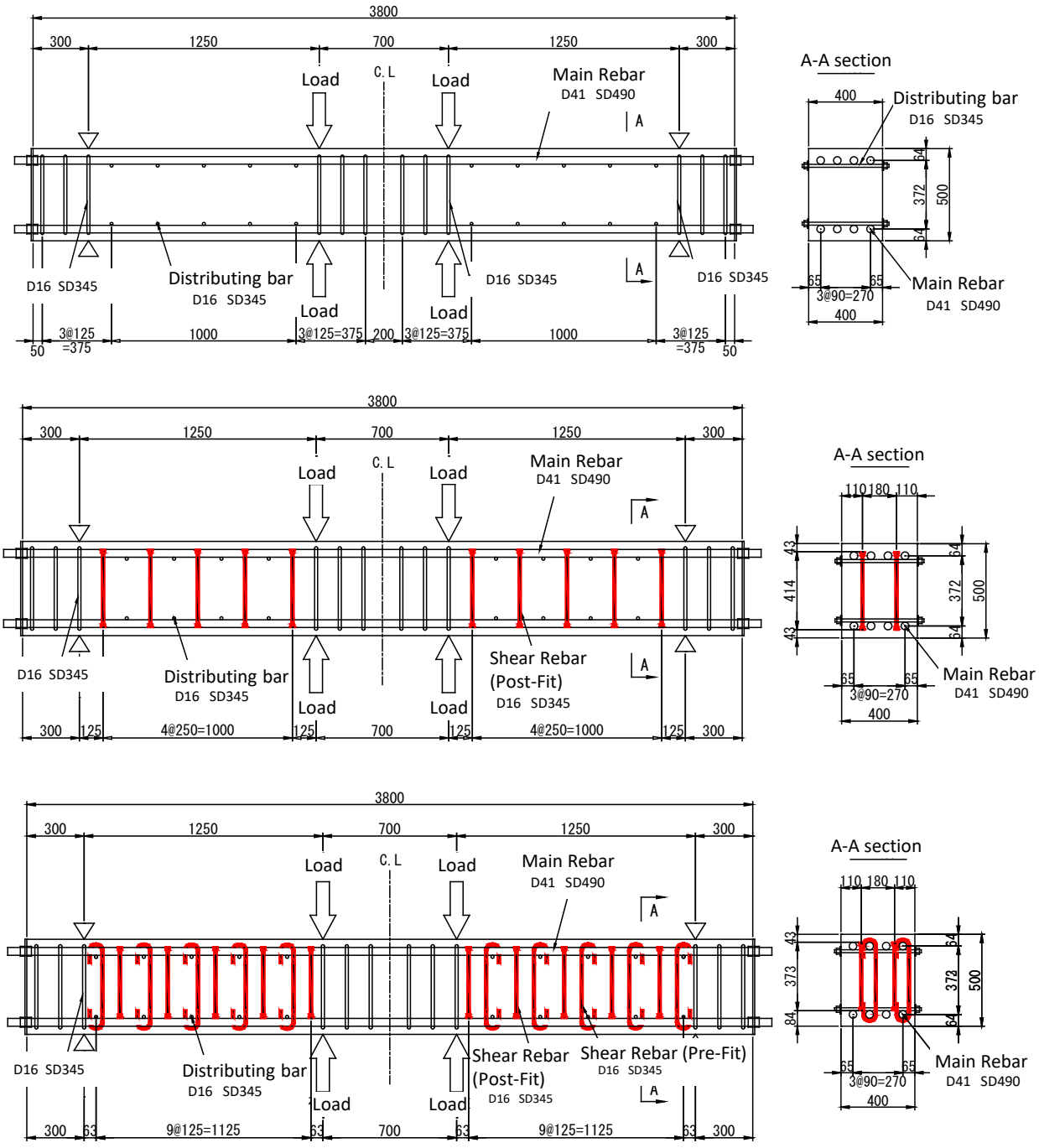

Figure-9 Detail of beam bending test conditions

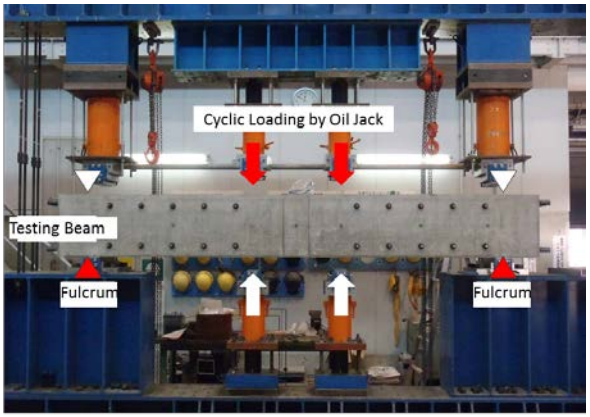

Figure-10 Loading system for beam bending test

Figure-11, 12 and 13 show the beam bending test results. In all cases, the beams were fractured in the shear failure mode. The shear capacity of the beam in case-1 which did not have shear reinforcement reached approximately 200kN in both foreword and reverse side. In case-2, which beam was shear reinforced with post fit rebar (Spiral Anchor), the shear capacity was increased to 406kN in foreword side and 442kN in reverse side respectively. In case-3, which beam was shear reinforced with pre-fit rebar and Spiral Anchor, the shear capacity was increased to 721kN in foreword side and 610kN in reverse side respectively.

The effectiveness of post fit shear reinforcing bars will be smaller than it of pre-fit reinforcing bars due to its bond characteristics. Therefore, the authors propose the calculation method of effectiveness ratio of post fit reinforcing bars (Spiral Anchor) as follows.

$$V_{spa} = V_{y\_\exp} - \left(V_{c\_\exp} + V_{s\_cal}\right) \quad [1]$$

$$\beta_{aw} = V_{spa} / V_{s'\_cal} \quad [2]$$

Where V_{spa} :shear capacity borne by post fit reinforcing bars

$V_{y\_\exp}$:shear capacity of testing beam obtained from experiment

$V_{c\_\exp}$:shear capacity of testing beam without shear reinforcement

V_{s_cal} :theoretical shear capacity of testing beam with pre-fit shear reinfocement

β_{aw} :the effectiveness ratio of shear capacity of Spiral Anchor

$V_{s'\_cal}$:theoretical shear capacity when post fit reinforcement has same effectiveness of pre-fit shear reinforcement

Table-2 shows the calculation result of shear reinforcement effectiveness by the Spiral Anchor Method. Table-3 shows the comparison result of shear capacity between calculation and experiment. Figure-14 shows the relationship between calculation result and experimental result.

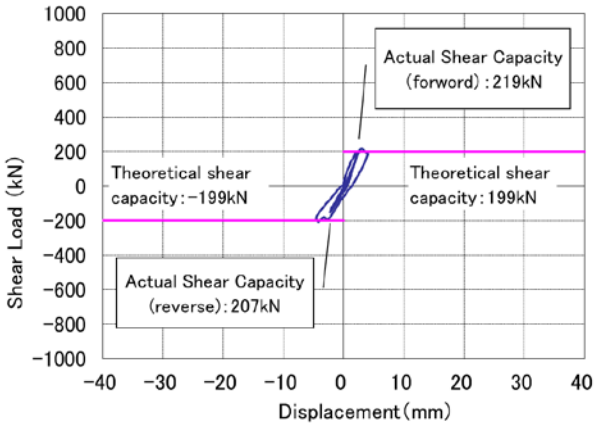

Figure-11 Relationship between displacement and shear load (Case-1)

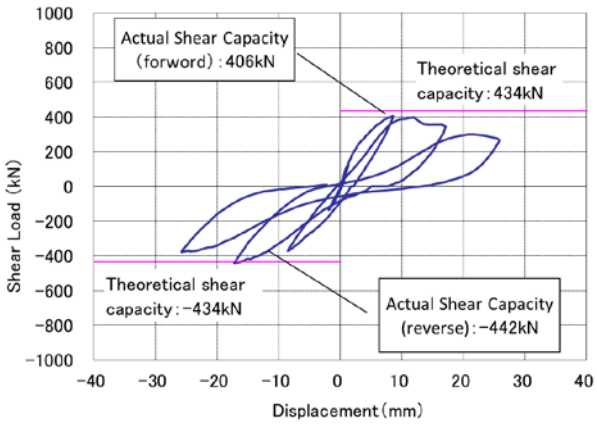

Figure-12 Relationship between displacement and shear load (Case-2)

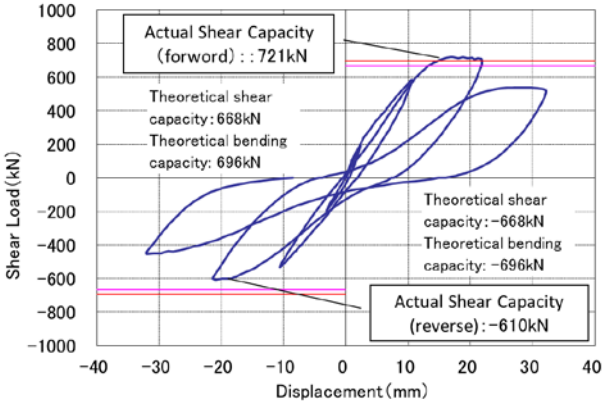

Figure-13 Relationship between displacement and shear load (Case-3)

Table-2 Calculation result of shear reinforcement effectiveness by the Spiral Anchor Method

CASE No.	Type of shear reinforcement	Theoretical Shear Capacity(kN)※1)				Experimental Result(kN)			Effectiveness Ratio	
		Vy_cal※2)	Vc_cal※3)	Vs_cal※4)	Vs'_cal※5)	Vy_exp	Vc_exp	Vspa※6)	Calculation βaw_cal	Experiment βaw_exp※7)
CASE1	no shear reinforcement	199	199	—	—	213	213	—	—	—
CASE2	Post-fit type (Spiral Anchor) SD345 D16	434	202	—	232	424	213	211	0.81	0.91
CASE3	Pre-fit + Post fit SD345 D16	668	204	232	232	666	213	220		0.95
Notes	※1) Theoretical value calculated according to the JSCE recommendation ※2) Vy_cal＝Vc_cal＋Vs_cal＋Vs'_cal ※3) Calculated from the compressive strength test result of concrete which was used for testing beam ※4) Calculated from the tensile strength of rebar which was used for testing beam ※5) theoretical shear capacity when post fit reinforcement has same effectiveness of pre-fit shear reinforcement ※6) Vspa＝Vy_exp－Vc_exp－Vs_cal ※7) βaw_exp＝Vspa／Vs'_cal									

Table-3 Comparison result of Shear Reinfocement Capacity between Calculation and Experiment

CASE No.	Type of shear reinforcement	Theoretical Shear Capacity(kN)※1)						Experimental Result(kN)	
		Vy_cal※2)	Vc_cal※3)	Vs_cal※4)	Vs'_cal※5)	βaw_cal	γb	Foreword Vy_exp	Reverse Vy_exp
CASE1	no shear reinforcement	199	199	—	—	—	1.1	219	207
CASE2	Post-fit type (Spiral Anchor) SD345 D16	372	202	—	170	0.81	1.1	442	406
CASE3	Pre-fit + Post fit SD345 D16	606	204	232	170	0.81	1.1	721	610
Notes	※1) Theoretical value calculated according to the JSCE recommendation ※2) Vy_cal＝Vc_cal＋Vs_cal＋Vs'_cal ※3) Calculated from the compressive strength test result of concrete which was used for testing beam ※4) Calculated from the tensile strength of rebar which was used for testing beam ※5) Vs'_cal＝βaw_cal×Vs_cal／γb　(γb：safety factor)								

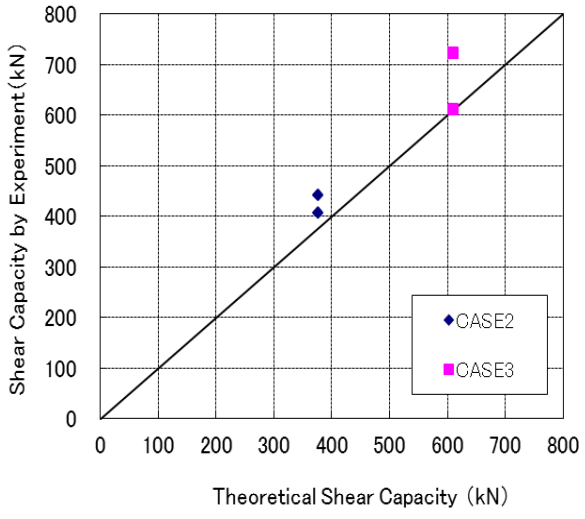

Figure-14 Relationship between calculation result and experimental result

4. CONCLUSION

Spiral Anchor Method is a post reinforcing method for the existing RC structure. The authors have developed it to be an easy, rapid and further effective method. In this paper, detail of the method of reinforcement was described, and the effect of this method was clarified.

REFERENCE

Public Work Research Center, *Certificate report of technical evaluation No.1402, "Spiral Anchor"; post reinforcing method with surface roughing of inside wall of drilled holes*, March 2014