Conference Poster

Fracture Behavior of Multiple Adhesive Post-Installed Anchors Subjected to Shear Force

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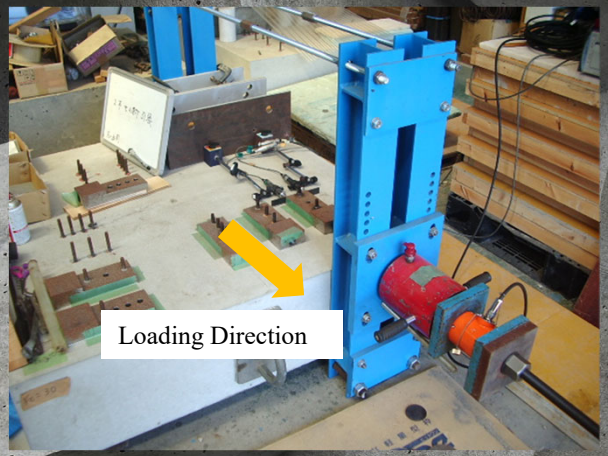

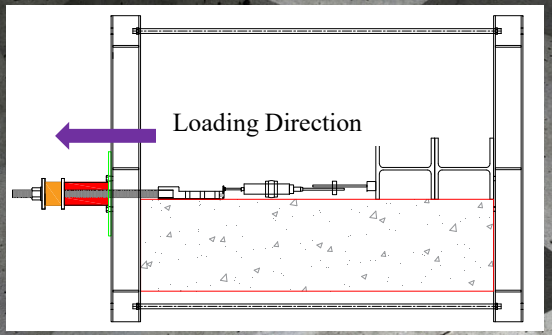

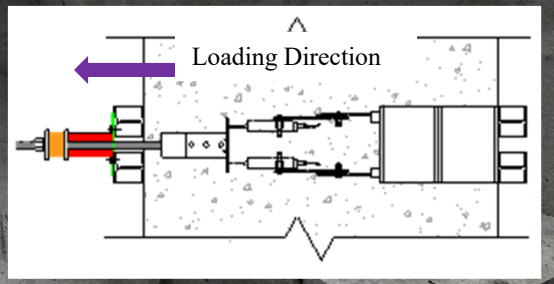

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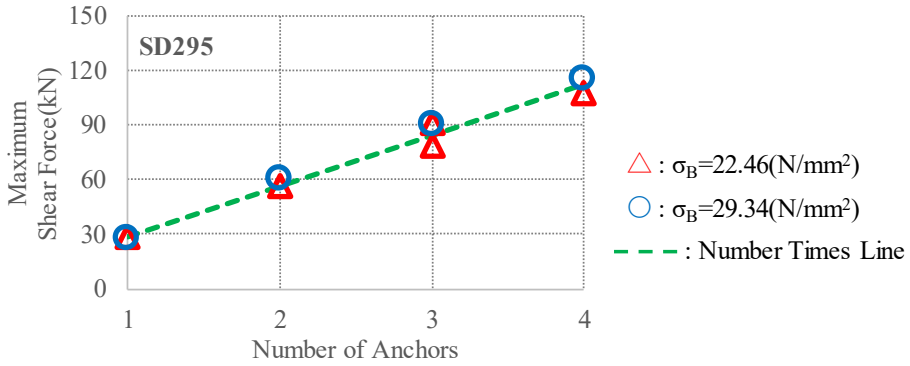
Specimens

Table 1. Properties of Specimens.

Serial number	Material of Anchor	σ_y	σ_u	E_s	n	D_p	σ_B	E_c	Quantity
		MPa	MPa	GPa		(mm)	MPa	GPa	
1	SD390 D10	428	590	209	1	—	29.34	26.9	1
2					2	100			
3					3	50			
4					4	30			
5					1	—	25.12	23.1	1
6					2	100			
7					3	50			
8					4	30			
9					1	—	23.12	24.6	1
10-1,2					2	100			2*
11					3	50			1
12-1,2					4	30			2*
13	SD295 D10	345	479	183	1	—	29.34	26.9	1
14					2	100			
15					3	50			
16					4	30			
17					1	—	22.46	31.4	1
18					2	100			1
19-1,2					3	50			2*
20					4	30			1

Properties of specimens were summarized in Table 1. There were 23 specimens in total. The anchor was used deformed bar of nominal diameter of 10mm(D10). The post-installed anchor arrangement was made such that only one anchor is arranged, two anchors are arranged along loading direction (D_p = 100mm, D_p/d_a = 10, d_a: nominal diameter), three anchors are arranged (D_p = 50mm, D_p/d_a = 5), and four anchors are arranged (D_p = 30mm, D_p/d_a = 3). In other words, pitches of two, three and four anchors were arranged along loading direction at 100, 50 and 30mm, respectively. The compressive strengths of concrete were 3 types of 23.12, 25.12 and 29.34 (N/mm^2). Materials of anchors were used SD390 and SD295. The embedded depth was constant 70mm ($7d_a$). An epoxy resin was used as a fixing agent for the post-installed anchor.

Maximum Shear Force – Number of Anchors Relations



- Maximum shear force-number of anchors relations used with SD295 were shown. Maximum shear forces with the compressive concrete strengths of 22.46 and 29.34 (N/mm^2) were shown by triangles and circles respectively. When the average of the maximum shear force for one anchor was calculated without considering the concrete strength, it was 28.04 (kN). The value obtained by multiplying that by the number of anchors was shown by a dotted line in Figure 3. Maximum shear forces with a concrete strength of 22.46 (N/mm^2) tended to be lower than the dotted line. On the other hand, Maximum shear forces with a concrete strength of 29.34 (N/mm^2) tended to be larger than the dotted line.

Photo :Serial Number 20 (four anchors)

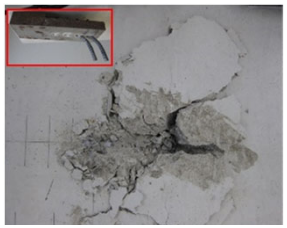
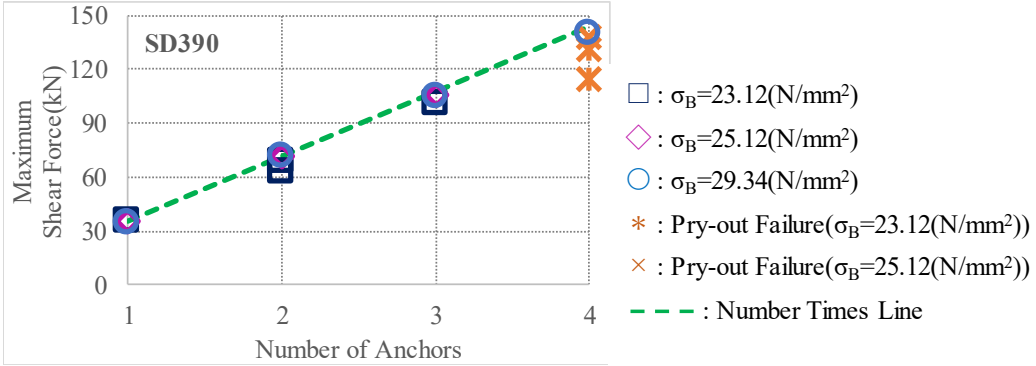
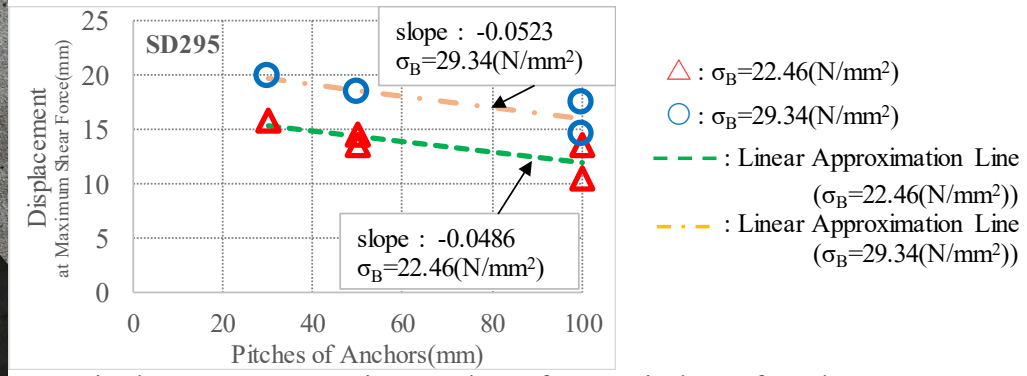


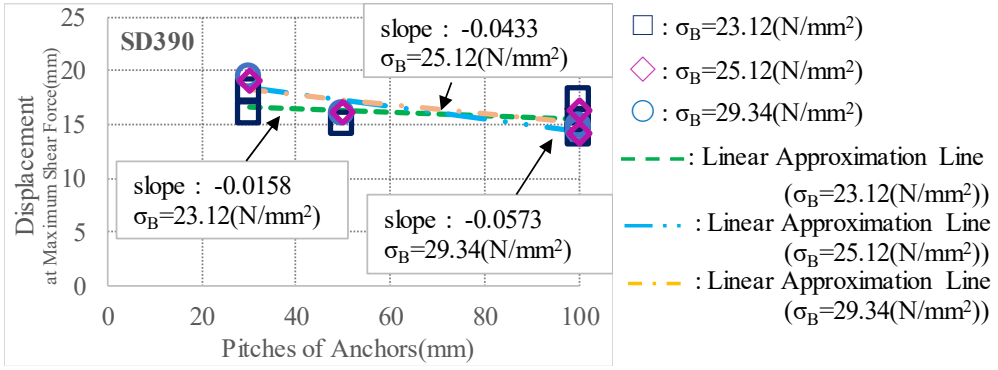
Photo :Serial Number 12-1 (four anchors) at pry-out failure



- Maximum shear force-number of anchors relations used with SD390 were shown. The maximum shear forces with the compressive concrete strengths of 23.12 and 25.12 (N/mm^2) for specimens failed in pry-out were shown by asterisks and a cross respectively. When the average of the maximum shear force for one anchor was calculated without considering the concrete strength, it was 35.96 (kN). The value obtained by multiplying that by the number of anchors was shown by a dotted line. Maximum shear forces with a concrete strength of 23.12 (N/mm^2) tended to be lower than the dotted line. Maximum shear forces with a concrete strength of 29.34 (N/mm^2) were almost on the dotted line. Considering these results, the boundary condition between anchor shear rupture and pry-out failure was found that concrete compressive strength was 25.12 (N/mm^2) or less and anchor pitch was 30 to 50mm, and anchor was tensile strength over SD390. In this study, since the embedded depth of the anchor was constant 70mm ($7d_a$), the embedded depth was not considered. When the hysteresis of the four anchors and that of the three anchors in Figure 2 were compared again from the above viewpoint, signs could be confirmed that the second stiffness was almost the same. Furthermore, by examining the boundary conditions precisely hereafter, it would be possible to install the anchor at a shorter pitch than the current standards in Japan when using the anchor for seismic reinforcement.

Displacement at Maximum Shear Force – Pitches of Anchors Relations





- Displacement at maximum shear force–pitches of anchors relations used with SD295 were shown. Displacements at maximum shear force with the compressive concrete strengths of 22.46 and 29.34 (N/mm^2) were shown by triangles and circles respectively. Linea approximation lines with the compressive concrete strengths of 22.46 and 29.34 (N/mm^2) were shown by a dotted and one-dot chain line respectively in Figure 5. The anchor pitch was considered appropriate for the horizontal axis when evaluating shear displacement, but one anchor did not have a pitch. Therefore, the crack pattern for the two anchors was referred to in Photo 2(b). The pitch for the two anchors was 100 (mm), the cracks did not interfere each other. Consequently, the pitch of one anchor was considered as 100mm and discussed afterwards. The slopes of the linear approximation line for each concrete strength were shown. These slopes tended to increase the displacement at maximum shear force as the pitch became shorter.

- Displacement at maximum shear force–pitches of anchors relations used with SD390 were shown. Displacements at maximum shear force with the compressive concrete strengths of 23.12, 25.12 and 29.34 (N/mm^2) were shown by squares, diamonds and circles respectively. Linea approximation lines with the compressive concrete strengths of 23.12, 25.12 and 29.34 (N/mm^2) were shown by a dotted, two-dot chain and one-dot chain line respectively in figure. With the same idea as above, the pitch of one anchor was considered as 100mm and discussed afterwards. In Figure 6, the slopes of the linear approximation line for each concrete strength were shown. Although the slope with SD390 was lower than the slope with SD295, the displacement at maximum shear force tended to increase as the anchor pitch became shorter.

- These meant that as the anchor pitch became shorter, the compressive failure zone for the concrete was expected deeper from the surface

Conclusions

- The following conclusions can be drawn from the present study about multiple adhesive post-installed anchors subjected to shear force:

1. Except for two specimens, the anchors of the other specimens failed in shear rupture. The two specimens with four D10(SD390) anchors and a concrete compressive strength of 23.12 (MPa) failed in pry-out. For the specimen with four D10(SD390) anchors and a concrete compressive strength of 25.12 (MPa), although the anchors eventually failed in shear rupture, diagonal cracks occurred on the back in the loading direction. This could be judged as a sign of a pry-out failure.
2. Maximum shear forces with a concrete strength of 22.46 (N/mm^2) tended to be lower than the line obtained by multiplying the maximum shear force for one anchor by the number. In other words, in case of 22.46 (N/mm^2) for concrete compressive strength, shear strength of anchors was not double, triple, and quadruple as number of those increased to 2, 3, and 4, and that gradually decreased as number of those increased.

- Considering these results, the boundary condition between anchor shear rupture and pry-out failure was found that concrete compressive strength was 25.12 (N/mm^2) or less and anchor pitch was 30 to 50mm, and anchor was tensile strength over SD390.

3. Considering the pitch of one anchor as 100 mm, the slopes of the linear approximation line for each concrete strength tended to increase the displacement at maximum shear force as the pitch became shorter.