

Evaluation on Anchorage Capacity of Headed Bars with Large Diameter in TTC Node

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ABSTRACT

Headed bars were developed to address the problems that arise from the use of conventional anchorage. Previous researchers evaluated anchorage capacity of headed bars in lap splice region and CCT node. However, anchorage tests in TTC node have not been conducted. TTC Node exists in an anchorage region of cut-off tensile bars. For a wide use of headed bar, anchorage tests in TTC node should be conducted. Therefore, in this research, anchorage capacity of headed bar in TTC node was evaluated. For this TTC node tests, which consider cut-off region, were conducted. The transverse reinforcement was considered as variables. Test results present that each specimen show different failure mode according to transverse bar. Failure of specimen without transverse bar is determined by tensile failure of concrete around the head. Failure of specimen with transverse bars is determined by yield of transverse bars. The transverse bars show effect on increase of anchorage capacity. Specimens with transverse bars present the greater anchorage capacity than specimens without transverse bars.

1. INTRODUCTION

Headed bars were able to shorten the development length by using the bearing plate. To evaluate the anchorage capacity of headed bars, previous researchers performed various tests as follows; the CCT node test, the lap splice test, the concrete block test etc. (DeVries 1996). The lap splice test was generally known as conservative test method that was considered the flexure deformation of beam member. However, for a wide use of headed bar, it needed the evaluation of anchorage capacity in cut-off region of beam member. In this study, the TTC node tests were planned to describe the Cut-off region that was worked the bending moment and shear forces.

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The anchorage capacity of headed bars was affected the various reason as follows; the diameter of bars, the size of head, the thickness of clear cover, the clear bar spacing, and the transverse bars index. (Thompson 2006). Among them, the transverse bars in development region were expected to be effective to increase the anchorage capacity of headed bars at TTC node. In this reason, the TTC node tests were performed for the headed bars with large diameter to evaluate on effect of the transverse bars.

2. TEST PROGRAM

Table 1. Properties of Test Specimens

Specimens ID	f'_c [MPa]	b [mm]	h [mm]	l_{dt} [mm]	Rebar			Cover and bar spacing			Transverse bar		$(c + K_{tr}) d_b$
					f_y [MPa]	d_b [mm]	A_b [mm ²]	C_b [mm]	C_{so} [mm]	C_{si} [mm]	K_{tr} [mm]	S [mm]	
#14-15db-0db	42	344	400	645 (15 d_b)	500	43	1,452	86 (2 d_b)	86 (2 d_b)	43 (1 d_b)	-	-	1.5
#14-15db-1db											43	186	2.5
#14-15db-2db											86	93	3.5
#18-15db-0db	42	456	520	855 (15 d_b)	500	57	2581	114 (2 d_b)	114 (2 d_b)	57 (1 d_b)	-	-	1.5
#18-15db-1db											57	200	2.5
#18-15db-2db											114	100	3.5

f'_c : measured concrete strength, b: width, h: height, l_{dt} : development length, f_y : headed bar yield strength, d_b : headed bar diameter, c_b : clear bottom cover, c_{so} : clear side cover, c_{si} : half of clear spacing K_{tr} : transverse reinforcement index, s: spacing of transverse bar

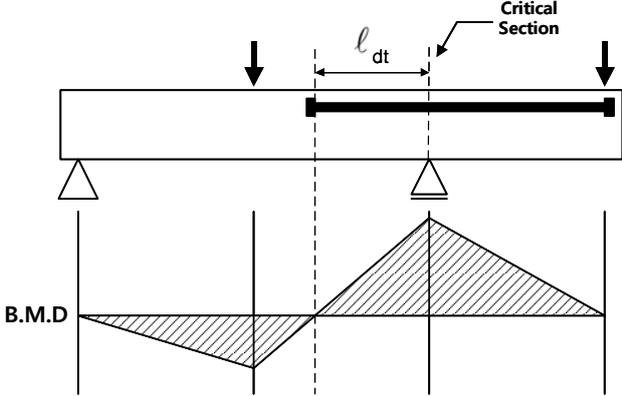


Fig. 1 Concept of TTC Node Tests

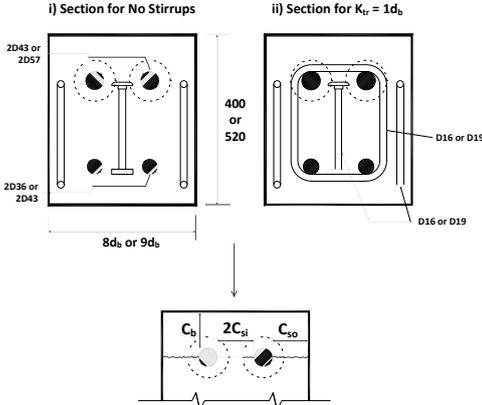


Fig. 2 Sections and Splitting Crack

2.1 Test Specimens.

To evaluate the anchorage capacity of headed bars, six specimens are planned. Details of test specimens were presented in the Table 1. All specimen, two bars ($f_y = 500\text{MPa}$) are used as headed bar. Based on the ASTM A970M, diameter of obstruction was 1.5 bar diameter and Net bearing area of the head was four times area of the bar. The development length of all specimens was designed in accordance with the recommendation of the ACI Building code (ACI 318-08). Applying the yield strength ($f_y = 500\text{ MPa}$) and the compressive strength of concrete ($f'_c = 42\text{ MPa}$) to Eq. 1, the development length was designed to $15d_b$.

$$l_{dt} = 0.19 \left(f_y / \sqrt{f'_c} \right) d_b \tag{1}$$

To prevent the shear failure, the shear reinforcements were arranged along to full-length of specimens. To investigate the effect the transverse bars in development region, the shear reinforcements in the anchorage region are arranged under the center of headed bar for the specimens without transverse bars. The section of specimens was shown in Fig. 2

2.2 Test Setup and instrumentation.

For all specimens, end support and loading point are respectively located 240mm and 280mm from end of specimens. The two rollers were used as support to eliminate any horizontal force development at the bearing plate. For the four point loading test, two actuators are used. In this test, load was controlled to maintain center load to end load constant ratio so inflection point was located on the bearing face of head. The concept of TTC node test was shown in Fig. 1

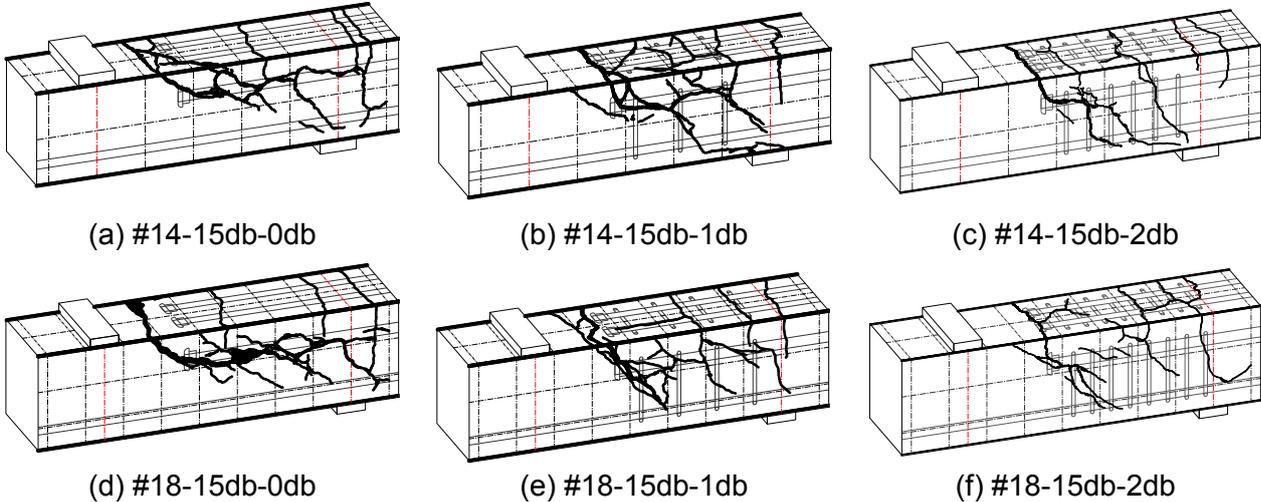


Fig.3. Failure Modes of Test Specimens

3. TEST RESULTS

3.1 Failure mode.

Each specimen show different failure mode especially according to transverse bar and each failure mode is presented in the Fig. 3. Specimens without transverse rebar show in Fig. 3 (a), (d). First crack occurred in the maximum moment region and flexural crack continually increased. And then horizontal crack around headed bar occurred and as soon as diagonal crack around the head occurred, concrete upper cover was lifted by headed bar and specimen was failure. This failure mode was very sudden and brittle. For specimens with transverse rebar (Fig.3 b, c, e, f) appeared the similar behavior until the horizontal crack occurred. However, for these specimens after diagonal crack around the head occurred, concrete upper cover was not lifted and load continually increased. At ultimate load, crack width around the head highly increased and specimen was failure.

3.2 Anchorage Capacity of headed bar.

The anchorage capacity of headed bar was estimated with the wire strain gauge in critical section of beam member and was verified by section analysis with Hognestad's concrete model. The result of test was presented in the Table 2. As being increased the transverse bar index, the anchorage capacity of headed bar was increased. Specimens with transverse bar were increased by 63% ~ 97% than specimens without transverse bar. This was affected with the transverse bar that was restrained the prying action due to bending moment. The prying action acted as the headed bar pushed the cover concrete above headed bar. This work with splitting stresses due to bar under tension at the same time. In this reason, the specimen without transverse bar was reached earlier the failure state than the specimen with transverse bar.

Table 2. Test result and comparisons with design codes

Specimen ID	Anchorage capacity			Bearing contribution			Bond contribution		
	$f_{an.Test}$ [MPa]	$f_{an.ACI}$ [MPa]	$f_{an.ACI} / f_{an.Test}$	$f_{be.Test}$ [MPa]	$f_{be.ACI}$ [MPa]	$f_{be.ACI} / f_{be.Test}$	$f_{bo.Test}$ [MPa]	$f_{bo.ACI}$ [MPa]	$f_{bo.ACI} / f_{bo.Test}$
#14-15db-0db	202	512	0.40	93	187	0.50	109	144	0.76
#14-15db-1db	326		0.64	118		0.63	208	241	0.86
#14-15db-2db	397		0.78	131		0.70	266		1.10
#18-15db-0db	197		0.39	91	183	0.50	106	144	0.73
#18-15db-1db	331		0.67	103		0.56	228	241	0.95
#18-15db-2db	390		0.77	122		0.67	268		1.11

4. CONCLUSIONS

In this study, the TTC node tests, which consider cut-off region, were conducted on the effect of transverse reinforcement. Test results present that each specimen show different failure mode according to transverse bar. The transverse bars show the effect on increase of anchorage capacity. Specimens with transverse bars present the greater anchorage capacity than specimens without transverse bars. And, as compared with the ACI 318-08, it was confirmed that the codes overestimated the anchorage capacity of headed bar. So, it needed the consideration with effect of transverse bar.

ACKNOWLEDGEMENTS

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