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Suggestion to evaluate accurate shear capacity of cast-in-place anchor by ACI 349 Code

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1. Introduction

The Cast-In-Place(CIP) anchor is widely used as fastening system to fix the mechanical and electrical equipment and piping system, etc. to concrete structure at Korean Nuclear Power Plants and ACI 349 Code is being applied as design code for the design of the CIP anchor in Korea. But, ACI 349 Code revised in 2001, is only available for the anchor with diameter not exceeding 2 in., tensile embedment not exceeding 25 in. in depth and load-bearing length of anchor for shear not exceeding 8 times of anchor diameter and ACI 349 Code can't be applied to the design of the large sized anchors. So, influence of some design factors to shear capacity of CIP anchor is investigated using the verified numerical analysis model with an intent to expand applicable range of ACI 349 Code.

2. ACI 349 Code

The basic concrete breakout strength V_b in shear of a single anchor in cracked concrete shall not exceed [1]:

$$V_b = 7\left(\frac{l}{d_0}\right)^{0.2}\sqrt{d_0}\sqrt{f_c}\,c_1^{1.5} \text{ (unit : lb)} \qquad (1)$$

Where,

c_1 : distance from the center of an anchor shaft to the edge of concrete in one direction

l : load-bearing length of anchor for shear, not to exceed $8d_0$

d_0 : outside diameter of anchor

f_c : compressive strength of concrete

3. Influence of design factors to shear capacity

3.1 Analytical Condition

The influence of some design factors to shear capacity of CIP anchor is investigated using the verified numerical analysis model [2, 4]. In order to consider the cases which exceed the applicable range of ACI 349 Code, the anchors with diameter exceeding 2 in., tensile embedment exceeding 25 in. in depth and the l/d_0 exceeding 8 times are considered. Table 1 shows all analytical conditions and Figure 1 shows the typical numerical analysis model for shear capacity evaluation of CIP anchor in Table 1.

Table 1. Analytical conditions

Analytical condition	d_0 (cm)	l (cm)	c_1 (cm)	l/d_0	c_1/l
1	5.0	27	30	5.3	1.1
2	5.1	30	30	6.0	1.0
3	2.5	30	30	12.0	1.0
4	5.0	30	15	6.0	0.5
5	5.0	30	30	6.0	1.0
6	5.0	30	45	6.0	1.5
7	5.0	30	60	6.0	2.0
8	9.0	64	114	7.0	1.8

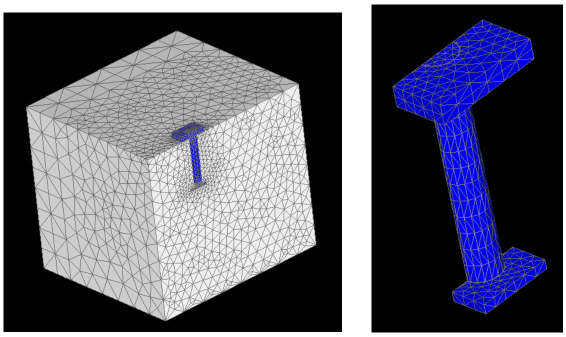

Figure 1. Numerical analysis model

3.2 Influence of l/d_0

In order to investigate the influence of l/d_0 to shear capacity of CIP anchor, analytical condition 1 to 3 are considered. Figure 2 shows the typical failure shape of CIP anchor under shear load by numerical analysis and is same with failure shape by test [1]. Figure 3 shows the load-displacement curve to the analytical condition 1 to 3. As shown in Figure 3, l/d_0 has no influence on the concrete breakout strength of CIP anchor in shear but CIP anchor approaches fast to the peak point of concrete breakout strength in inverse proportion to l/d_0.

3.3 Influence of c_1/l

As known in Eq. 1, c_1 has the largest influence on the concrete breakout strength of CIP anchor in shear among the design variables. In order to investigate the influence of c_1/l to shear capacity of CIP anchor,

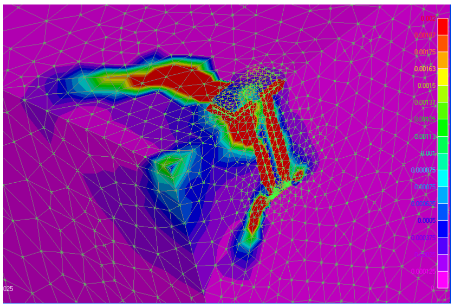

Figure 2. Failure shape by numerical analysis

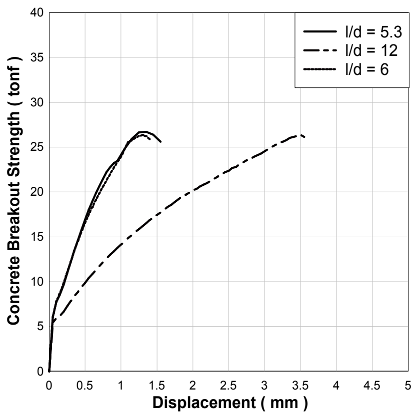

Figure 3. Influence of l/d_0

analytical condition 4 to 8 are considered in Table 1. Figure 4 shows the comparison of numerical analysis results with design results by ACI 349 Code to all analytical conditions in Table 1. As shown in Figure 4, ACI 349 Code over-estimates shear capacity of CIP anchor compared with the numerical analysis results of the analytical condition 7 and 8. Representing Figure 4 to 5, ACI 349 Code gives a non-conservative result in case that c_1/l is larger than 1.5. That means that the stiffness ratio of anchor bolt to concrete has a large influence on the shear capacity of CIP anchor. Therefore, if c_1/l doesn't be considered in Eq. 1 of ACI 349 Code, ACI 349 Code may over-estimate real shear capacity of CIP anchor in some cases.

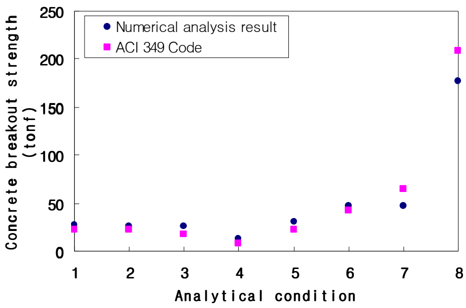

Figure 4. Comparison of concrete breakout strength

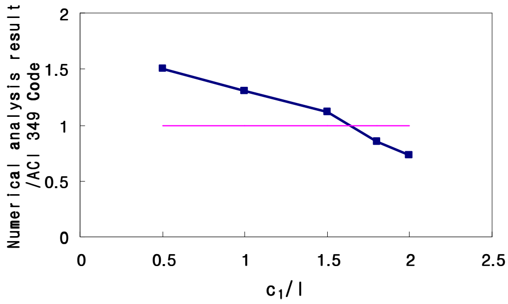

Figure 5. Ratio of ACI 349 Code to numerical analysis result

4. Conclusion

Influence of some design factors to shear capacity of CIP anchor is investigated using the verified numerical analysis model with an intent to expand applicable range of ACI 349 Code in this study. As a result, l/d_0 has no influence on the concrete breakout strength in shear and CIP anchor approaches fast to the peak point of concrete breakout strength in inverse proportion to l/d_0. But, in case that c_1/l not considered in ACI 349 Code, is larger than 1.5, ACI 349 Code may give a non-conservative results compared with real shear capacity of CIP anchor. Therefore, the application of ACI 349 Code is necessary to be limited to CIP anchor with c_1/l lesser than 1.5 and in reverse, the limitation of l/d_0 is necessary to be relaxed.

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