Experimental Plan for Tensile Behavior of Cast-in-Place Anchors with Surface and Anchor Reinforcement

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***Keywords :** anchor, surface reinforcement, anchor reinforcement, concrete breakout failure

1. Introduction

In nuclear power plants, anchors connecting safety-related equipment to concrete structures play a critical role in seismic safety, and their tensile capacity is often governed by concrete breakout failure. Current design provisions for concrete breakout strength are primarily based on tests on unreinforced concrete, whereas anchors in actual structures are commonly installed in reinforced concrete members containing surface reinforcement. Although surface and anchor reinforcement may influence breakout behavior, their effects are not explicitly considered in current design codes, which may lead to conservative estimates of tensile capacity. To address these limitations, an experimental study is planned to investigate the tensile behavior of cast-in-place anchors with surface and anchor reinforcement and to assess the applicability of current design provisions for anchors installed in reinforced concrete members.

2. Test Plan

2.1 Test Specimens and Material Properties

Table 1 summarizes the key parameters of the anchor tensile tests planned in this study. The experimental program consists of cast-in-place anchors with effective embedment depths (h_{ef}) of 200, 300, and 400 mm, referred to as the H2, H3, and H4 series, respectively. A single anchor will be installed at the center of each concrete block, and surface reinforcement and anchor reinforcement will be selectively provided depending on the specimen configuration.

The target compressive strength of concrete is planned to be 30 MPa. To ensure that anchor tensile failure does not govern the test results, high-strength anchor steel will be used, with nominal yield and ultimate strengths of 720 MPa and 860 MPa, respectively. The yield strength of the surface reinforcement and anchor reinforcement will be 400 MPa. The anchor diameters are planned to be 44.5 mm, 57.2 mm, and 63.5 mm for the H2, H3, and H4 series, respectively. To prevent pullout failure, a circular anchor head will be installed at the embedded end of the anchor, with head diameters of 100 mm, 120 mm, and 130 mm for the H2, H3, and H4 series, respectively.

To investigate the effect of surface reinforcement, specimens with and without surface reinforcement were prepared for each embedment depth, designated as S0 and S1, respectively (H2-S0, H2-S1, H3-S0, H3-S1, H4-S0, and H4-S1). Deformed reinforcing bars with a diameter of 19 mm (D19) will be used as surface reinforcement and arranged in a grid pattern with a spacing of 170 mm. The concrete cover to the upper surface reinforcement will be maintained at 30 mm for all specimens. For the S0 specimens, a grid of reinforcement will be placed at the bottom of the concrete block to prevent cracking due to drying shrinkage and self-weight during handling and transportation. In addition, local reinforcement will be provided near the specimen edges to prevent bearing failure caused by the steel rods used to fix the concrete block during testing.

Table I: Test Variables

Specimen	Embedment depth (mm)	Surface reinforcement		Anchor reinforcement	
		Diameter (mm)	Spacing (mm)	Diameter (mm)	Distance from anchor (mm)
H2-S0	200	-	-	-	-
H2-S1		19.05	170	-	-
H2-D19		19.05	170	19.05	94.0 (0.47h_{ef})
H3-S0	300	-	-	-	-
H3-S1		19.05	170	-	-
H4-S0	400	-	-	-	
H4-S1		19.05	170	-	-
H4-D22		19.05	170	22.23	200.0 (0.5h_{ef})

To evaluate the influence of anchor reinforcement, additional reinforcement will be provided for selected specimens (H2-D19 and H4-D22). Deformed reinforcing bars with diameters of 19 mm (D19) and 22 mm (D22) will be used as anchor reinforcement for the H2 and H4 series, respectively. The anchor reinforcement will be configured with a U-shaped hook at the top and anchored at the bottom by bearing against the internal reinforcement to ensure adequate force transfer. Design guidelines such as ACI 318 [1] and Eurocode 2 [2] indicate that anchor reinforcement should preferably enclose surface reinforcement, although this is not a mandatory requirement. In the planned specimens, the surface reinforcement will be intentionally arranged outside the anchor reinforcement to allow for a conservative evaluation of tensile capacity.

2.2 Test Setup and Instrumentation

Figure 1 shows the planned test setup for the anchor tensile tests. A hydraulic actuator with a capacity of 1000 kN will be installed above the specimen and connected to the anchor to apply tensile loading. For the H2 series specimens, a single actuator will be used, whereas for the H3 and H4 series, two actuators will be connected in parallel to apply the required load. A custom-designed steel jig will be fabricated to connect the actuator(s) to the anchor. To minimize unintended deformation of the jig during testing, the jig will be constructed using steel plates with thicknesses of 80 mm and 100 mm, connected by webs with a thickness of 50 mm.

During the tests, the actuator will be operated under displacement control. In the initial loading stage, a displacement rate of 0.02 mm/s will be applied to prevent brittle failure caused by rapid loading. After reaching the peak load, once a load reduction is observed and the response becomes relatively stable, the displacement rate will be increased to 0.1 mm/s to continue loading.

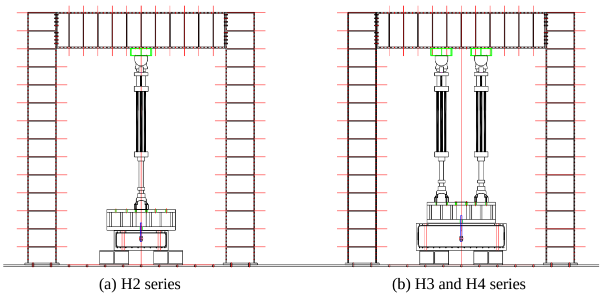

Fig. 1. Test setup for anchor tensile tests.

Figure 2 shows the planned locations of strain gauges installed to monitor the deformation of the reinforcement. For all specimens, a strain gauge will be attached at the mid-depth of the anchor embedment to measure the deformation of the anchor under tensile loading. For the H2-S1, H3-S1, and H4-S1 specimens, strain gauges will be installed on the surface reinforcement along the anchor centerline and in the vicinity of the expected concrete breakout cone. For the H2-D19 and H4-D22 specimens, additional strain gauges will be attached to the anchor reinforcement at multiple embedment depths to measure the tensile forces carried by the reinforcement during loading.

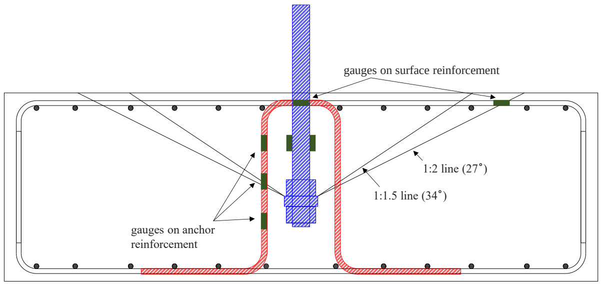

Fig. 2. Planned locations of strain gauges.

3. Conclusions

An experimental program is planned to investigate the tensile behavior of cast-in-place anchors with surface and anchor reinforcement. The study will evaluate the effects of embedment depth, surface reinforcement, and anchor reinforcement on concrete breakout behavior and tensile capacity. The planned tests are expected to provide useful data for assessing the applicability of current design provisions and for improving the evaluation of anchor tensile capacity in reinforced concrete members.

Acknowledgement

This work was supported by the National Research Foundation of Korea(NRF) grant funded by the Korea government(MSIT) (No. RS-2022-00144425).

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