Experiment on the Shear Capacity of M12 Concrete Expansion Anchors Installed in Low Strength Uncracked Concrete with various Torque

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1. Introduction

Numerous concrete expansion anchors (CEAs) are used to secure equipment to concrete structures in the nuclear power plants. The CEA must be installed with the correct torque recommended by the manufacturers. CEA installed with a different torque than the values specified in the design document may not perform as expected in the design. This study experimentally investigated the performance of M12 CEA installed with torque values different from the manufacturer's recommendations. The test was carried out according to ACI 355.2 [1] and ASTM E488 [3]. The test results were compared to the strength calculated with the design equations in ACI 349 [2].

2. Experiment

In this study, the most commonly used M12 anchors in NPPs were selected for testing. Anchors were tested in five different torque cases ranging from 0.5 to 3.0 times the standard torque. The minimum number of anchor specimens for each test case was set to 5.

2.1 Test Anchor

The dimensions of and installation conditions of the anchors tested are shown in Table 1.

Table 1. Installation conditions of M12 CEA

Type	T (Nm)	Min. H_{ef} (mm)	Min. D_h (mm)	T_{pull} (mm)	T_{conc} (mm)
M12	60	80	105	25	160

T: Installation Torque
H_{ef}: Embedment Depth
D_h: Hole Depth
T_{pull}: Pulling Fixture Thickness
T_{conc}: Thickness of Concrete Member

2.2 Test Cases

The test cases are shown in Table 2. The shear tests were conducted for five installation torques.

Table 2. Installation conditions of M12 CEA

Case	Case 1	Case 2	Case 3	Case 4	Case 5
Torque (N m)	30	60	90	120	180
Ratio (%)	50	100	150	200	300

2.2 Test Method

For testing, the methods of ACI 355.2 and ASTM E488 [3] were applied. The test follows the testing program as shown in Figure 1. Loading was applied by a hydraulic cylinder. The displacement was recorded by using a linear variable displacement transducers (LVDTs), and loads were measured using a load cell. The loading was applied until concrete failure.

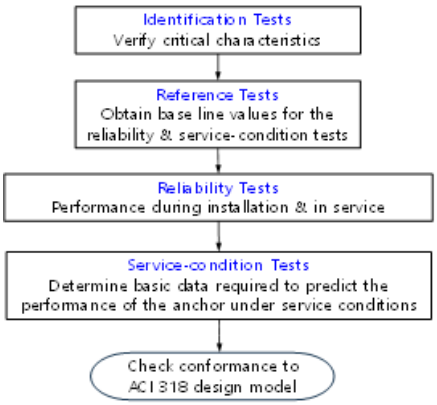

Fig. 1. Testing program for post-installed mechanical anchors in concrete (ACI 355.2, 2001)

2.3 Concrete Block

The concrete blocks were prepared to install the anchors before the test. The concrete block has a size of 1,840 x 480 mm and a thickness of 300mm. The test was carried out after 62 days of concrete curing. The blocks are low strength without reinforcing bars, and non-cracked concrete. The required average compressive concrete strength was designed to be 21MPa. The

compressive strength of the standard concrete specimen was measured from 17 MPa to 28 MPa.

2.4 Test Setup

The test set-up is shown in Figure 2. The test fixture on the concrete blocks was fabricated according to ASTM E488 [3]. The jig size was determined to be sufficient to prevent interference with adjacent failure circles. Three anchors were installed on a single concrete block.

Fig. 2. Test set-up for shear test

3. Test Results

The test results were summarized in Table 3. The coefficient of variation (COV) ranged from 4.3% to 8.8%, indicating low variability among the five test specimens. The standard installation torque case produced the highest mean peak load. The shear capacity shows no noticeable change depending on the torque value. Figure 3 shows the load-displacement curve recorded in the standard torque case test. The failure mode is mostly concrete breakout. Figure 4 shows the failure mode of concrete breakout.

Table 3. CEA shear test results

Torque (N·m)	Mean Peak Load (kN)	Standard Deviation (kN)	COV (%)	Failure Mode
30	39.9	1.5	3.7	CB then CP
60 (standard)	42.7	2.5	5.8	CB then CP
90	41.2	1.8	4.3	CB then CP
120	41.0	1.4	3.4	CB then CP
180	41.3	3.3	8.0	CB then CP

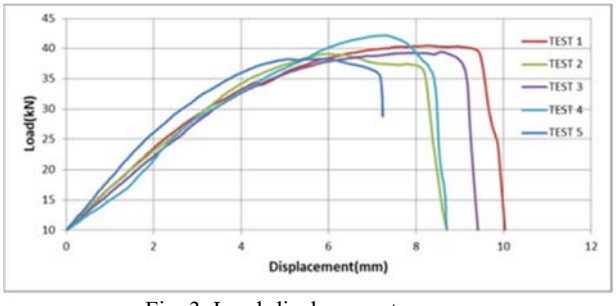

Fig. 3. Load-displacement curves

4. Conclusions

This study experimentally investigated the shear performance of CEA installed with different torque. The test results show that the magnitude of the installation torque does not significantly affect the shear performance of CEA, which is tightened with a force up to 200% of the standard torque. After concrete breakout occurred in the shear test, a continuous load caused the concrete pry-out in the opposite direction of the loading direction. Excessive tightening can cause sleeve rupture when installing anchor bolts.

Fig. 4. Concrete breakout failure

ACKNOWLEDGEMENTS

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