Transactions of the Korean Nuclear Society Virtual spring Meeting
May 13-14, 2021

Evaluation of Tensile Behavior for Large-Diameter CIP Anchor Bolts with Embedded Plate

Junhee, Park [a*]
[a]*Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong, Daejeon, 305-353*
[*]Corresponding author: jhpark78@kaeri.re.kr

1. Introduction

From the spectrum of the Gyeongju and Pohang earthquake that occurred in South Korea, it was found that the spectrum exceeds the design spectrum in the high-frequency range. This characteristic of the spectrum can affect the response of the component.

In the previous seismic analysis, the ductility of the components anchorage was ignored and conservatively evaluated. If the seismic load exceeds the design load, anchorage damage can occur, which causes nonlinear behavior of the components. Therefore, it is necessary to properly reflect the characteristics of the anchorage in order to accurately evaluate the seismic performance of a components.

In nuclear power plants, the anchorage is widely used as a bolts or welding method, but since the behavior of the anchorage is very complex and difficult to predict, analyzing the behavior of component during earthquakes by relying on analysis cannot show realistic behavior. Therefore, the behavior test of anchorage can be used as important data in the seismic performance evaluation of the components.

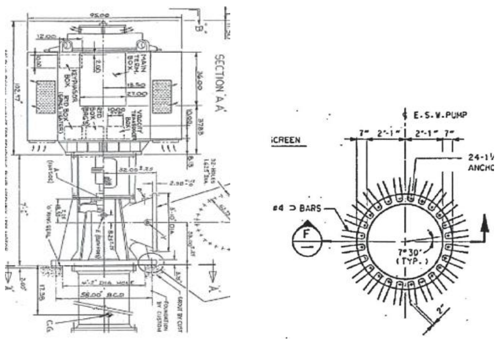
The anchorage test has been mainly conducted on a small-diameter bolts due to the capacity limitation of the experimental equipment. However, for some components in nuclear power plant, large-diameter anchor bolts exceeding 30mm were used. Since the behavior of components with large-diameter anchor bolts cannot be judged to be similar to that of a component with a small-diameter bolts, the tensile and shear behavior tests of a large-dimeter bolts are required to analyze the ultimate capacity and failure mode. In this study, the tensile behavior of large-diameter anchor bolts was experimentally analyzed for component with a concrete cone breakout failure.

2. Prediction of tensile strength for test specimens

2.1 Test specimens

The ESW pump of the OPR (Optimized Power Reactor) 1000 nuclear power plant was selected as the target component among the components dominated by the failure of the anchorage by referring to the Ulchin 3&4 PSA report [1]. The ESW pump is connect to the floor of ESW pump building by total of 24 bolts with a diameter of 30 mm as shown in figure 1.

It was found that the dominant failure of ESW pump was concrete cone breakout according to the past seismic fragility assessment result. In this study, the material properties of concrete and anchor bolts was defined considering the material properties of the actual ESW pump.



(a) ESW pump (b) Layout of anchor bolts
Fig. 1. Detail of ESW pump

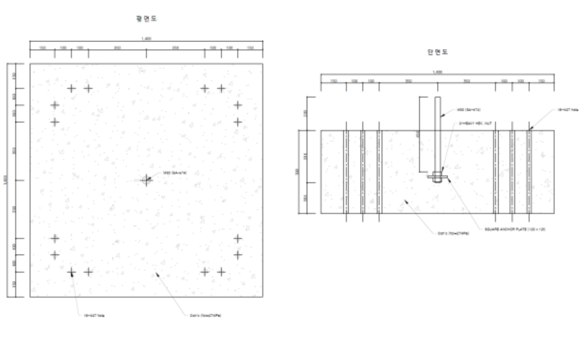
2.2 Prediction of tensile strength

The diameter and embedded depth of the bolts were defined by reflecting the actual condition. A rectangular embedded plate was connected to the end of the anchor bolt.

The test specimens used in this study were cast in place (CIP) anchor bolts and were designed to cause concrete cone breakout failure according to the "Concrete Anchor Design Criteria" (KDS 14 20 54 : 2016). The prediction tensile strength of anchor bolts was to be 316kN.

Table I: Design specification of test specimens

Anchor type	Dia. (mm)	Embedded depth (mm)	Conc. Strength (Mpa)	Bolt strength (N)
CIP	30	250	27	482460



(a) Plan (b) Section
Fig. 2. Plan and section of test specimens

3. Test method

3.1 Test setup

For the tensile test of the specimens, a tensile test jig was connected to the reaction floor and the concrete block was fixed to the jig. The 1,000kN actuator was used for the tensile test. The load cell and LVDTs (linear variable differential transformers) were installed to measure the tensile load and displacement.

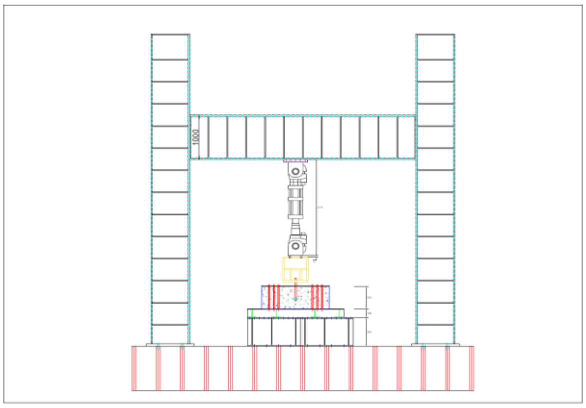


Fig. 3. Test setup

3.2 Input motion

Monotonic and cyclic load tests were performed to evaluate the ultimate tensile strength of the specimens.

The loading speed used in this test was to 1 mm/min and 5 mm/min. In order to evaluate the ultimate capacity of anchor bolts, the test was carried out while increasing the load until the specimens was failure as shown in figure 4.

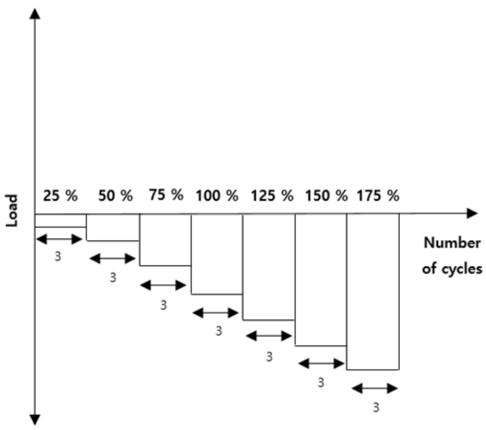


Fig. 4. Cyclic loading pattern

4. Test results

3.1 Load-displacement curves

The tests were conducted on one monotonic test specimen and three cyclic test specimens. From the test, the tensile strength was to be 490 kN for the monotonic test, and the maximum tensile strength was to be 520kN for the cyclic test.

It was found that the actual strength increased by about 39% from the predicted strength. The previous predicted strength for the concrete cone breakout strength of CIP anchor bolts not take into account the effect on the embedded plate. For this reason, it is judged that there is a difference between the actual and the predicted strengths.

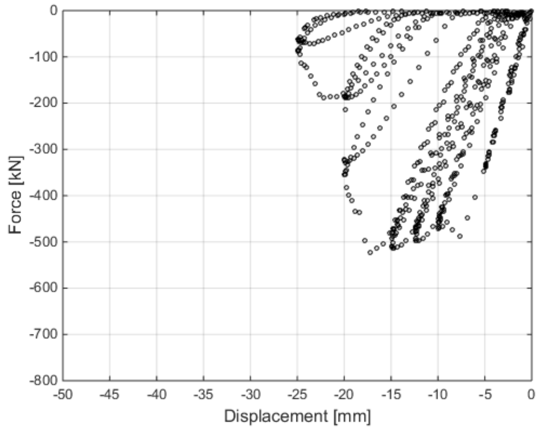


Fig. 5. Force-displacement curves

5. Conclusions

The monotonic and cyclic test were performed to evaluate the tensile strength of the CIP anchor bolt with embedded plate used in NPPs,. Due to the influence of the embedded plate, it was found the actual tensile strength was to be about 39% higher than the predicted value. For components connected with CIP anchor bolts, it is judged that the effect of increasing the tensile strength by the embedded plate should be considered for realistic seismic performance evaluation.

6. Acknowledgement

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20181510102410).

REFERENCES

[1] KHNP (2004), Probabilistic Safety Assessment for Ulchin 3&4 [Level 1 PSA for External Events : Main Report].

[2] Korean Design Standard. (2016). "Concrete Anchor Design Criteria." Ministry of Land, Infrastructure and Transport.