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PULL-OUT PROPERTIES OF GYPSUM BOARD ANCHORS

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In this study, pull-out properties of various anchors embedded in gypsum board were investigated. Tensile tests for anchors embedded in 200mm square size gypsum board were conducted to measure the load - load displacement curves. Strength of gypsum board was changed for three conditions and twelve kinds of anchors were selected which were ordinary used for gypsum board anchoring. The loading conditions were a monotonous loading and a repeating loading controlled by a servo-controlled hydraulic loading system to achieve accurate measurement. The fracture energy for each anchors were estimated by the analysis of consumed energy calculated by the load - load displacement curve. The effect of the strength of gypsum board and the types of anchors on the pull-out properties of gypsum board anchors was cleared. A numerical model to predict the load-unload curve of pull-out deformation of gypsum board anchors caused by such as the earthquake load was proposed and the validity on the model was proved.

Keywords: Gypsum board, Anchor, Tensile test, Pull-out property, Repeating loading, Load-unload curve.

1 INTRODUCTION

Gypsum boards have been used as an interior material for numerous buildings, with various interior fixtures and anti-seismic devices being fitted to them. However, screws directly driven into gypsum boards are prone to pullout, due to insufficient load-bearing capacity of the boards, making it difficult to safely secure such fixtures and devices to the boards. The use of gypsum board anchors (hereafter simply referred to as “anchors”) is effective in securing such devices on the boards and complementing the load-bearing capacity. While anchors come in wide ranges of shapes and materials, few studies have compared their pull-out properties (Takahashi and Okamoto 2013) with no quantitative indices having been provided for their selection. This paper reports on a study in which tension tests were conducted on various types of anchors by monotonic and cyclic loading to investigate the characteristics of each type and proposes a method of estimating a unidirectional history curve, which is necessary for evaluating the load-bearing capacity under cyclic seismic loads.

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2 EXPERIMENT OVERVIEW

Figure 1 shows the anchors used in the tests. The symbol JN represents a self-drilling screw type; JU, a self-drilling drive type; SO, a drilling insert type; and SN, a drilling screw type.

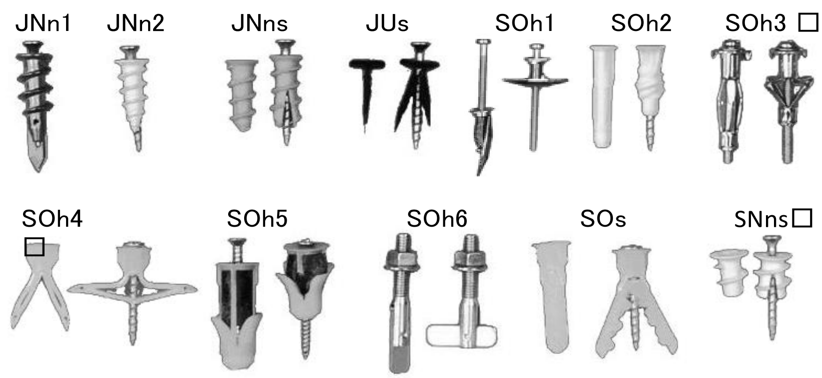

Figure 1. Anchor bolts use in this study.

The gypsum boards were regular gypsum boards 12.5 mm in thickness. An anchor was fixed to the center of each gypsum board 200 mm by 200 mm in size, which was fixed to a steel reaction board, and subjected to unidirectional cyclic tensile displacement using a displacement-controlled fatigue testing machine shown in Figure 2.

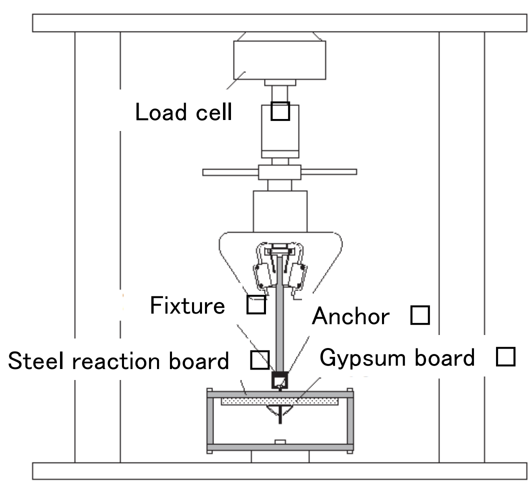

Figure 2. Overview of tensile test.

The displacement rate was 1 mm/min under repeating conditions shown in Figure 3 conforming to the test method specified in the standard test method for metal fastenings and fasteners “Test method of metal fastenings and fasteners for wood frame construction, Chapter 4” (HOWTEC 2015). Monotonic loading tests were also conducted for comparison.

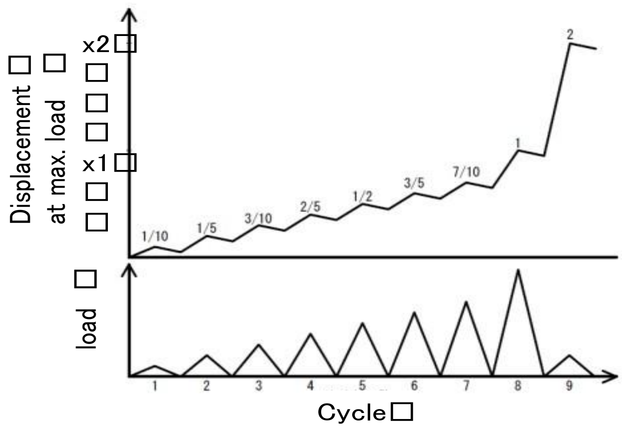

Figure 3. Displacement repeating conditions.

3 ESTIMATION OF LOAD-UNLOAD CURVES BY CYCLIC LOADING TESTS

Figure 4(a) shows a conceptual drawing of a load-displacement curve and unloading-reloading curves at arbitrary deformations and energy changes (Kitsutaka 1997). The unloading curves at C and D are linearly approximated to CA and DB. The elastic strain energy (Ue) at C and D is expressed as the area of ∆CAF and ∆DBE, respectively. The energy externally given to the specimen from C to D (dUw) is expressed as the area of □CFED, and the energy consumed for pullout (dUf) is dUw – dUe. Therefore, dUf = □CFED – (∆DBE - ∆CAF) = □CAED - ∆DBE =□CABD, which is the gray part of Figure 4(a). As to the accumulated change in the energy to the anchor pull-out length (a), the energy given from the outside (Uw) is the sum of the energy consumed for pullout (Uf) and the elastic strain energy (Ue). This relationship is illustrated as Figure 4(b). Figure 4(b) is determined by determining dUf, dUe, and dUw from the cyclic loading test results of each anchor. Ue is determined from *P* at an unloading point on the load-displacement curve, where estimation is desired, and the pull-out length (a) in Figure 4(b). Linearly approximated unloading-reloading curves are then evaluated, and history curves under various cyclic tensile loads can be estimated (Figure 5).

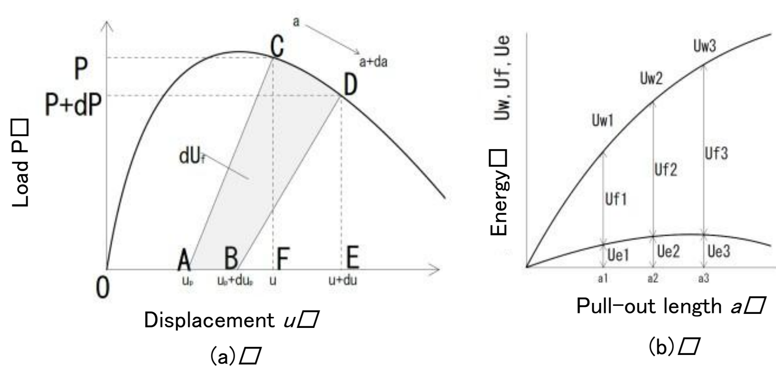

Figure 4. Unloading-reloading curves and energy changes.

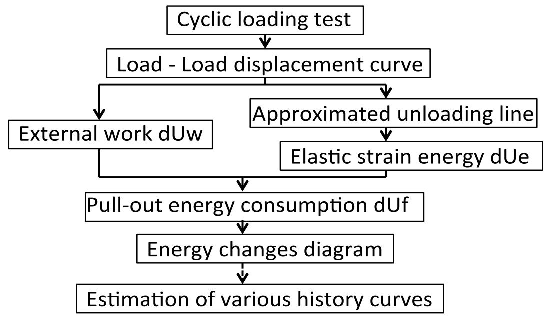

Figure 5. Flowchart of estimating historic curves.

4 TEST RESULTS AND DISCUSSION

Figure 6 shows the test results. The pull-out properties widely vary depending on the anchor type.

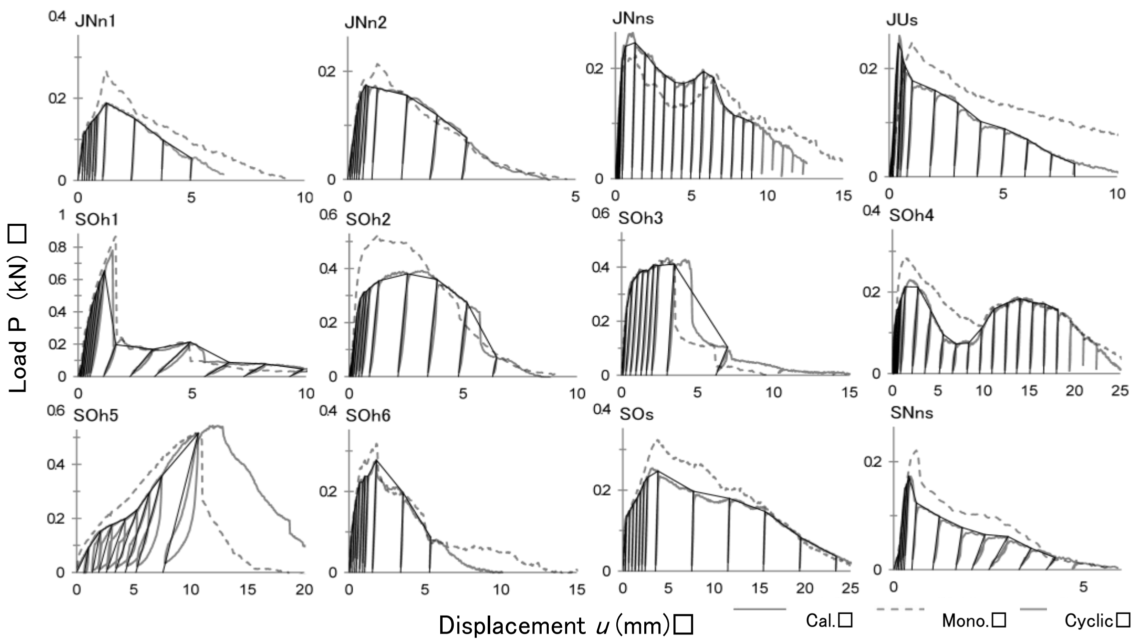

Figure 6. Load – load displacement curves.

4.1 Self-drilling Anchors

Specimens JNn1 and JNn2 lead to small maximum loads and small displacements to 0 kN. JNns lead to a small maximum load and a post-peak increase in the load at around a displacement of 5 mm, due to friction fixing by the expanded end. Also, reductions in the load are relatively slow. JUs lead to a small maximum load, with slow reductions after reaching the peak. Also, self-drilling anchors are characterized by the relatively small effect of the gypsum board type on the pull-out capacity.

4.2 Anchors Requiring a Pilot Hole

As to SOh1, failure of the anchor was observed in the regular-hard gypsum board. This led to rapid increases and reductions in the load, attaining the largest pull-out capacity of all anchors. SOh2 shows a relatively large maximum load, with anchor failure in the regular-hard gypsum board. However, the load did not increase after the peak, as the gypsum board did not break. SOh3 leads to anchor failure associated with rapid increases and reductions in the load. SOh4 leads to anchor failure, but the reductions in the load are very slow, presumably due to the shape of the anchor after failure resembling the type of friction fixing by an expanded end. SOh5, which was made of a soft anchor material, shows increases in the load slower than the other anchors, but the post-peak reductions are rapid. The maximum loads of anchors that grip the board from behind other than SOh4 are very large when being placed into regular-hard gypsum boards. The increases and reductions in the load on SOs are both very slow. SNns shows a small maximum load, with the displacement to 0 kN being small. It was therefore confirmed that the load-displacement curves are clearly characterized by the methods of fixing.

4.3 Differences among Fixing Methods

Figure 7 shows a conceptual drawing illustrating the differences in the pull-out resistance and characteristics among the fixing methods. Anchors fixed by screw friction show small maximum loads at pullout and subsequent slow reductions in proportion to the displacement. These anchors are mostly self-drilling, being impossible to drive into high strength gypsum boards. The type of gypsum board scarcely affected the pull-out capacity. Anchors fixed by friction of expanded ends show moderate curves of increases and reductions in the load, with the type of gypsum board slightly affecting the pull-out capacity. As to anchors that grip the board from behind, the effect of the gypsum board type was significantly observed on the pull-out capacity. These anchors are characterized by the rapid increases in the load to large maximum loads followed by rapid reductions with the failure of the gypsum board. The anchors that grip the board from behind also include specimens in which the anchor fractured, causing re-increases in the load after reductions. SOh4 is a characteristic example in which the expanded end re-resisted the tensile forces after pull-out.

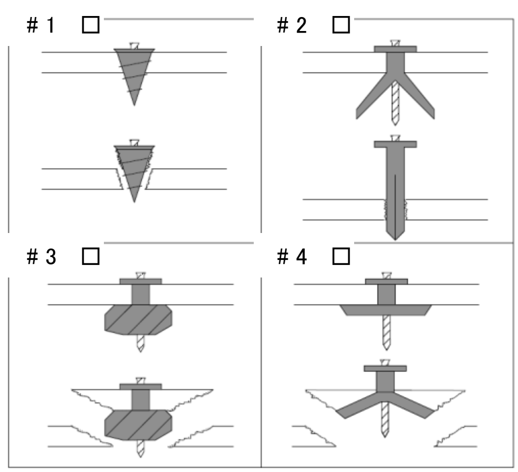

Figure 7. Conceptual drawing illustrating the pull-out fracture.

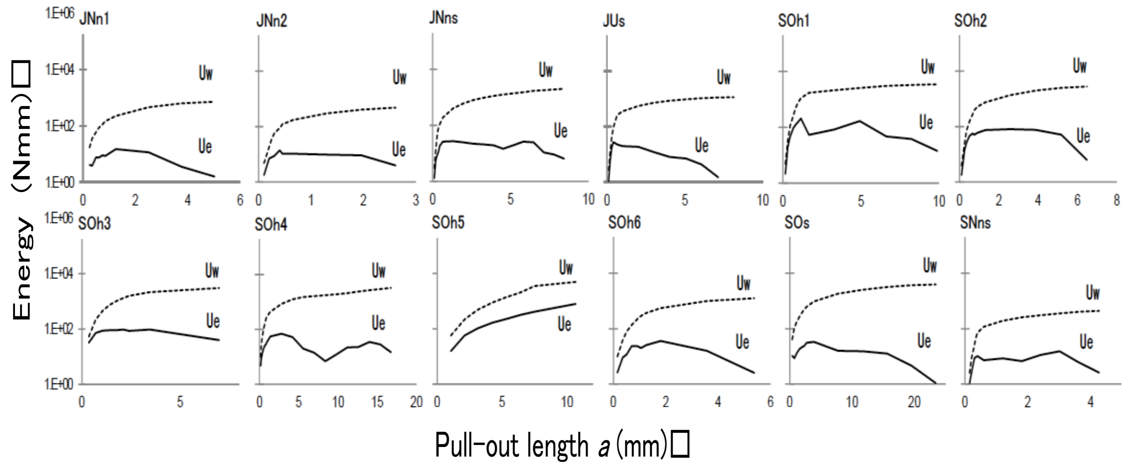

Figure 8. Energy changes in pull-out test.

4.4 Results of Cyclic Loading Tests

In Figure 8, the load-displacement curves under cyclic tensile loads as well as those under monotonic loading were shown. The envelope curves of anchors under monotonic and cyclic loading nearly agree with each other. Figure 8 shows the results of determining changes in the energy on the assumption that the unloading-reloading curves obtained from cyclic tension tests are straight lines. The unloading-reloading curve of each anchor assumed from the energy changes shown in Figure 8 following the estimation flow shown in Figure 7 is also superimposed in Figure 8. The estimations nearly agree with the test results, proving the validity of the estimation method.

5 CONCLUSIONS

Major conclusions of this study are as follows:

(1) Tension tests were conducted on various types of gypsum board anchors by applying monotonic and cyclic loads to grasp the characteristics of each type.

(2) Differences in the pull-out resistance and characteristics among the fixing methods of anchors were cleared.

(3) A method of estimating unidirectional unloading-reloading curves under cyclic loads, such as seismic loads was proposed and the results of estimation by the proposed method agreed with the test results, verifying the validity of the estimation method.

References

Kitsutaka, Y., Fracture Parameters by Poly-linear Tension Softening Analysis, *Journal of Engineering Mechanics,* ASCE, Vol.123, No.5, pp.444-450, (1997).

Standard Test Method of HOWTEC, Test method of metal fastenings and fasteners for wood frame construction, *Japan Housing & Wood Technology Center,* (2015).

Takahashi, H. and Okamoto, H., et al., Pull-out Strength of Tilted Screw from Furring Channel, *Summaries of Technical Papers of Annual Meeting, Architectural Institute of Japan,* A-1, 1109-1110, (2013).