ON-SITE ANCHOR TESTING UNDER TENSILE LOADS

Tips and tricks for engineers

Version 1.0
March 2023

TABLE OF CONTENTS

1. INTRODUCTION

As a structural engineer, you may not have enough data available to determine the resistance of an anchor for a safe, efficient and cost-effective design. Approval documents or technical manuals may not cover the base material. You're most likely to encounter this when working on reinforcement or restoration projects with older, possibly damaged, concrete or masonry, and also with natural stone or porous materials, etc.

As a project manager, you may need to validate the installation quality of post-installed anchors or rebar and document the executed proof load tests as reference for the quality manager, project owner or an external inspector.

For both scenarios, Hilti offers anchor on-site testing services.

2. BENEFITS OF ON-SITE ANCHOR TESTING

Hilti's on-site anchor testing provides you with a test report and an optional evaluation report, based on an official guideline, for one of the two following purposes:

- As a basis for you to determine the resistance of a post-installed anchor in an unknown / uncertain base material
- As an adjunct to help you to control and potentially verify the installation quality

3. BOUNDARIES OF ON-SITE ANCHOR TESTING

On-site anchor testing has its limitations. Tests of post-installed anchors on the jobsite can **never** serve:

- As a substitution for an approval document
- To overrule an existing approval document
- To conclude which is a "better" product by comparison
- As a substitution for proper anchor design

Hilti can support you by preparing the test, executing the test on the jobsite and providing an evaluation report.

The decisions on the test parameters and further usage of the results must always be taken by the responsible engineer, because only the responsible engineer has the full project overview and knowledge.

4. QUESTIONS TO ASK ABOUT THE TESTED FASTENING POINT AND THE INSTALLATION OF THE ANCHOR

1. Is the location representative for the test purpose?
2. Is the test location properly documented and traceable?
3. Is the base material on the jobsite identical to the one specified (concrete, brick, hollow brick, others)?
4. Is the tested anchor's item number, name, diameter, length, material, coating, etc. as specified?
5. Is proof of purchase available for anchors and the needed accessories (e.g., brushes, etc.)?
6. Was the installation done by a qualified installer (i.e., certified with Hilti installer training)?
7. Is the protruding part of the anchor not cut or modified?

8. Are all needed accessories and parts in place (e.g., filling washer)?
9. Is the anchor installed at 90° +/–3° to the surface?
10. Was the installation process documented (drilling method, diameter, depth, cleaning, installation torque, etc.)?
11. Are obvious setting criteria from IFU fulfilled (e.g., red ring of HST3, ring marks on HKD, etc.)?
12. Chemical anchors only: is the mortar visible in the angular gap on the substrate's surface?

This list is not exhaustive. Additional important and / or project specific points must be added by the responsible engineer.

5. QUESTIONS TO ASK ABOUT THE TEST EXECUTION AND RESULT

1. Is the number of tests sufficient for the chosen evaluation method?
2. Could the expected test loads be achieved?
3. Are the failure modes as anticipated?
4. Are the displacement curves similar to each other?
5. Is the total displacement in the expected range?

This list is not exhaustive. Additional important and / or project specific points must be added by the responsible engineer.

6. EVALUATION OF TEST RESULTS

A test report states what has been tested and where and how the tests were executed. It also gives the results of the measured load and displacement values. A test report is therefore one piece of the puzzle.

7. WHAT DO YOU DO WITH THE RESULTS?

Different official guidelines are available to help determine the test parameters and to evaluate results from anchor tests on the jobsite.

Hilti can perform an evaluation for you and provide an evaluation report based on your input, along with an official guideline. The evaluation report gives you a sound foundation for your assessment of the available anchor resistance or your assessment of the installation quality.

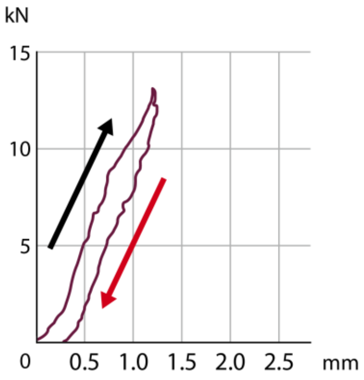
Please contact Hilti when planning the tests to help you determine which evaluation method you want to use and to align the test program with your specific requirements, e.g., number of tests needed.

8. LOAD OVER DISPLACEMENT AND LOAD OVER TIME GRAPH

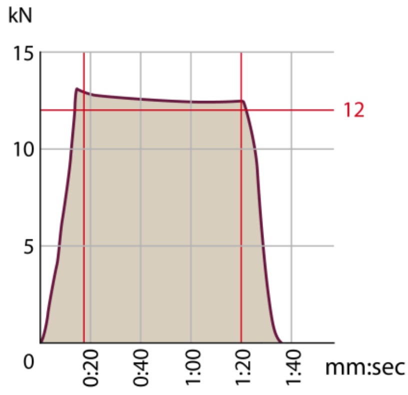
The graphs below (examples 1 & 2) show how the anchor was loaded.

Example 1 shows a typical hysteresis for a stud anchor installed according to the instructions for use. The anchor gets loaded with a 12 kN target proof-load. The loading and unloading curves (example 1, left side) are parallel to each other and the residual displacement is neglectable.

Example 1



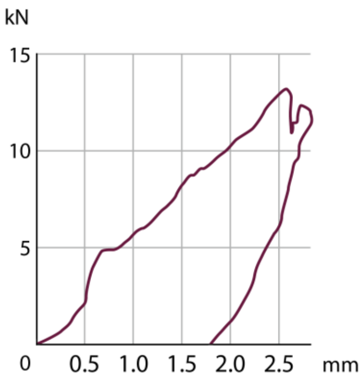
Load over displacement



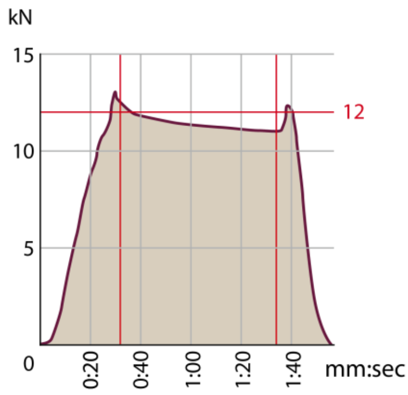
Load over time

Example 2 shows a typical picture of a stud anchor which was installed with only 25% of the recommended installation torque.

Example 2



Load over displacement



Load over time

On the one hand, the 12 kN target proof-load could be reached. On the other hand, the total displacement was much higher than in the first example and the load-drop was much more significant when the loading was halted for at least one minute.

After the one-minute holding time, the test load was again increased to 12 kN which caused incremental movement of the anchor. The loading and unloading curves are not parallel to each other and the residual displacement is considerable. This displacement behaviour can be a strong hint that the anchor was not installed as instructed and that it could not perform as designed.

9. LOAD-DROP

A load-drop is always visible when loading is halted. There are two main reasons:

1. Imperfections in the hydraulic testing system (e.g., small internal oil leakages) can cause loss of pressure.

2. Relaxation takes place in the anchorage as stresses are distributed into the base material.

The degree of the load-drop varies between anchor types and is the smallest with chemical anchors, in general.

Both effects together result in reduction of the indicated load which is visible in the load over time graph. Depending on the tested system, the influence coming from the hydraulic system can have the bigger impact.

If the target load can be reached again after the one-minute holding time without significant incremental displacement, the load-drop was most probably caused by the hydraulic system.

If the target load can only be reached again with significant incremental displacement, the anchor doesn’t behave as designed.

10. HILTI ON-SITE TESTING TESTER TOOLS AND MEASUREMENT OF DISPLACEMENT CONCEPT

HAT 30 & 50

- Compact, hydraulic tester tool.
- 30 kN maximum load.
- Standard load spreading bridge (as shown in picture) with 300 mm longitudinal clearing between supports.
- Measurement of displacement sensor in the body of the tool (see arrow in the picture).
- Due to technical reasons, shown measurement includes deflection of load spreading bridge, its legs and feet. Depending on the set-up, this deflection is roughly about 1mm per 10 kN.

HAT 180 & 370

- Hydraulic tester tool with separate cylinder and pump, connected with a hose.
- 180 kN maximum load for HAT 180.
- 370 kN maximum load for the HAT 370.
- Standard load spreading bridge (as shown in picture) with 400 mm longitudinal clearing between supports (equal for both tester tools).
- Measurement of displacement sensor attached to the loading adapter (see arrow in the picture on the left) references directly on the substrate’s surface.
- Due to the position of the sensor, the measured value is close to the displacement of the anchor.

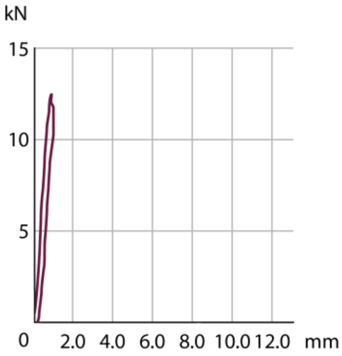
11. HINTS ON THE INTERPRETATION OF THE LOAD OVER DISPLACEMENT GRAPHS

On-site anchor tests cannot be compared with tests done under laboratory conditions. Hilti on-site testing can only provide an indication how the anchor behaves under load.

For calculation purposes please refer to the published displacement values in the ETA. These values also consider effects which tests on the jobsite can't factor in (e.g., cracked concrete, aging, sustained loading etc.).

We show loading and unloading of the anchor in our graphs (examples 3 to 5). These help you to determine if the deformation of the anchor was elastic or plastic. Each anchor in examples 3 to 5 reached 12 kN maximum loading.

Designed behaviour
Example 3

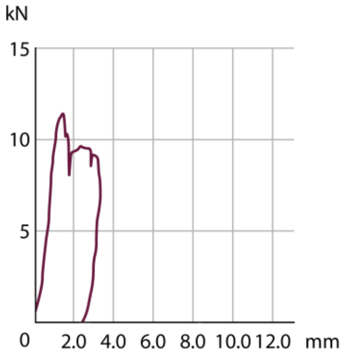


Load over displacement

Target load reached. Loading and unloading is linear with very little, neglectable residual displacement.

Anchor performs as designed

Slipping on high load level
Example 4

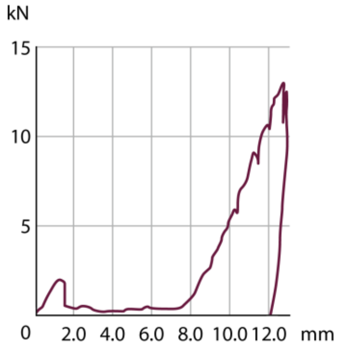


Load over displacement

Target load reached. However, the anchor pulls out, indicated by displacement at maximum load level and high residual displacement of approximately 2 mm.

Anchor doesn't perform as designed

Initial slip
Example 5



Load over displacement

Target load reached. However, high initial displacement phase on low load level and very high residual displacement of approximately 12 mm. Potential reason: installation torque not correctly applied.

Anchor doesn't perform as designed

If you simply consider the maximum loads in examples 3, 4 and 5 all trials appear to be equal, and all anchors seem to perform as designed. Only the load vs. displacement graphs show the critical differences between the trials.

Anchor behaviour should be predictable and repeatable.

Check all load over displacement graphs of all test trials within a test series (same jobsite, same application, same anchor, same base material, same geometrical conditions, etc.). Scatter in results as normal, depending on anchor type and base material. Look for tests which are obviously deviating from others and look for potential explanations.

Data from different jobsites, applications, anchors, base materials, etc. are not comparable.

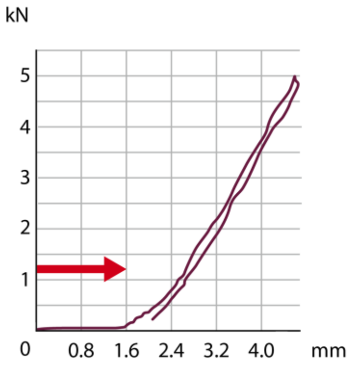
12. TEST EXECUTION MISTAKE

The behaviour as shown in example 6 is most probably either caused by a forgotten installation torque or a handling mistake during test execution (initial slip, indicated by the red arrow in the graph).

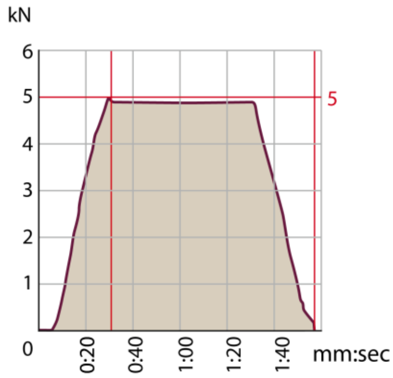
Compare with the graphs of the other test trials in the same test series.

If the inclination of the curve matches the ones of the other trials, and is just set off by a few millimeters, it was most probably forgotten to eliminate the backlash in the test set-up before starting the test.

Example 6



Load over displacement



Load over time

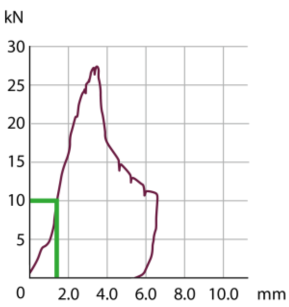
13. SPECIAL CASE DESTRUCTIVE TESTING

If you order destructive anchor testing (i.e., test to failure of the anchoring system), you will be interested in the failure load and most probably the displacement at the serviceability load level.

For the HAT 30 you need to deduct approximately 1 mm per 10 kN to consider the elastic deflection of the testing system.

For the HAT 180 & 370 you can read this value directly from the load over displacement graph. The measurement of displacement of these two tester tools references directly on the substrate's surface.

Example 7



Load over displacement

HAT 30 with standard load spreading bridge.
Recorded displacement at serviceability level of 10 kN ≈ 1,5 mm
Subtract ≈ 1 mm per 10 kN

→ the anchor displacement at serviceability level was in this specific case about 0.5 mm.

Check if all displacement values are in the same range and within acceptable limits.

DON'T GUESS. TEST. INTERPRET CORRECTLY.

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