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LONG-TERM PERFORMANCE OF POST-INSTALLED CONCRETE SCREWS

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Abstract
Concrete screws are a type of anchor used in structural and non-structural applications in uncracked and cracked concrete. The load transfer is based on mechanical interlock between the threads and concrete. Like all anchor products, they undergo rigorous testing during product assessment which at the moment does not cover the sustained load behavior. This investigation aims at studying the sustained-load behaviour of concrete screws by performing a series of tensile tests. Short-term tests were first performed from which the ultimate load capacity of the screws was determined. Long-term tests were then performed at different load levels, selected as a function of the short-term capacity. The time to failure and displacements were recorded throughout each test. The resulting experimental data was used to generate time-to-failure curves and fit the regression models that are currently used for the long-term assessment of chemically bonded anchors. Finally, the predicted long-term capacity for a 50-year lifetime is presented and compared to adhesive anchors.

1. Introduction
Concrete screws are hardened steel anchors typically equipped with cutting surfaces at the tip to facilitate installation. They are installed in drilled holes of a larger diameter than the core of the screw. The threads cut the concrete during the process. The load transfer mechanism is provided by the threads bearing against the concrete along the connected length and, similar to headed studs, the load capacity is proportional to the embedment depth. Concrete screws are currently designed according to ACI 318 or EN 1992-4. In many cases concrete cone breakout is the critical failure mechanism, although also pull-out failure or mixed failure modes occur depending on the anchor geometry, concrete strength and embedment depth.

Because of their increasingly frequent use, concrete screws follow approvals for the evaluation of their properties. Normally, their performance is assessed under ideal and under adverse conditions, e.g. fire or seismic loads. Unlike the case of bonded anchors, these approval standards do not include the long-term performance assessment of concrete screws under any condition. However, sustained loads induce creep deformations that might exceed the deformation capacity of the structure leading to failure. The sustained-load assessment of bonded anchors has been intensively discussed, especially after an accident in the Interstate Boston Tunnel (2006), while the long-term performance of concrete screws, post-installed mechanical anchor or cast-in elements has not been considered.

In this investigation, the stress vs. time to failure method for the assessment of bonded anchors was used to study the long-term performance of concrete screws in a confined setup. This method consists in performing a series of short-term pull-out tests to determine the ultimate capacity of the anchor and a series of long-term tests at different load levels. The load levels are selected based on the short-term capacity. The time to failure t_f is recorded throughout the test and plotted against the relative load level in a semi-logarithmic plot (time-to-failure-curve). The experimental data set is then used for fitting different models. Typically, a logarithmic model or a power law is used in the regression analysis. However, different models may be used, like a Sigmoid function based on concrete creep rate analysis. Other models are based on creep rate theory and result from combining a failure criterium and a functional form for the effect of creep rate in concrete.

2. Results
An experimental campaign was performed on post-installed concrete screws. A total of three sets with varying diameters and embedment depths were tested: two sets with core diameters of 8 mm and 14 mm, both with an embedment depth of 40 mm (set S01 and S02 respectively), and one set with a core diameter of 14 mm and 65 mm embedment depth. Each set consisted of a minimum of five short-term tests, from

which the load capacity of the screw was determined. A minimum of 10 long-term tests at different load levels were performed. The measured times-to-failure were then used to construct the time-to-failure curves based on four different regression models to predict the load level for a 50-year service life.

Fig. 1 illustrates the resulting curves corresponding to set S01. It is observed that sustained-load failure occurs even for load levels below 80% of the ultimate capacity of the anchor. At relatively high load levels (for t_f<30 days), a linear behaviour in a semi-logarithmic time-to-failure plot is observed. This is represented accurately by all regression models. These models yield similar results for a 50-year load level, with differences smaller than 5%

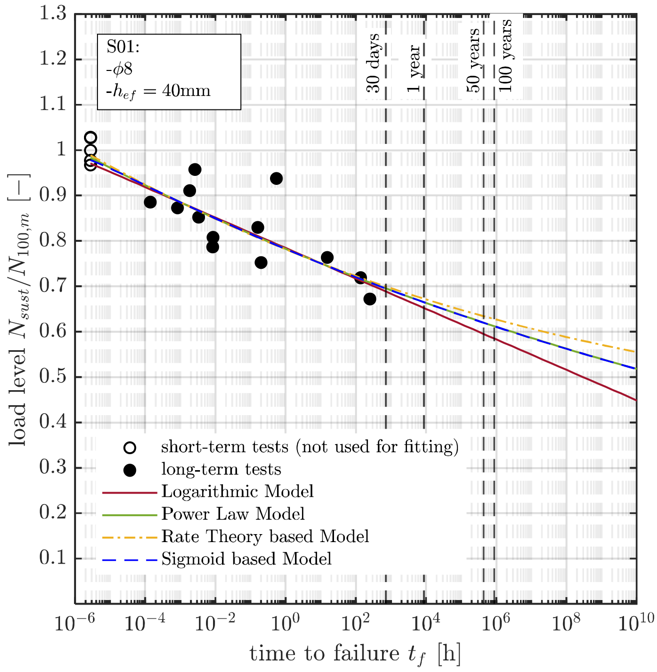

Fig.1 – Time to failure curve for configuration S01 and fitted models

3. Conclusions

Despite their frequent use in construction, post-installed concrete screws are not assessed for their long-term performance. However, these types of anchors exhibit sustained-load failure at load levels noticeably below their ultimate capacity. While the anchor design values are quite conservative owing to a number of reduction factors that are determined during product assessment, the exact long-term safety level remains unknown. A more in-depth analysis should be performed of the long-term performance of concrete screws for different configurations. A comparison to established procedures for adhesive anchors could create a level playing field and allow a fair comparison of long-term performance between different anchor types.

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