Required thickness for flexurally rigid base plate

Background and Design Proposal

in the software Anchor Profi 2.5.0

Dr. Li Anchor Profi GmbH

Background

The test results of university Stuttgart show that the assumption of flexurally rigid base plate for design of multiple anchor fastenings may lead to huge safety deficit, if the base plate thickness is determined only by stress condition under design actions.

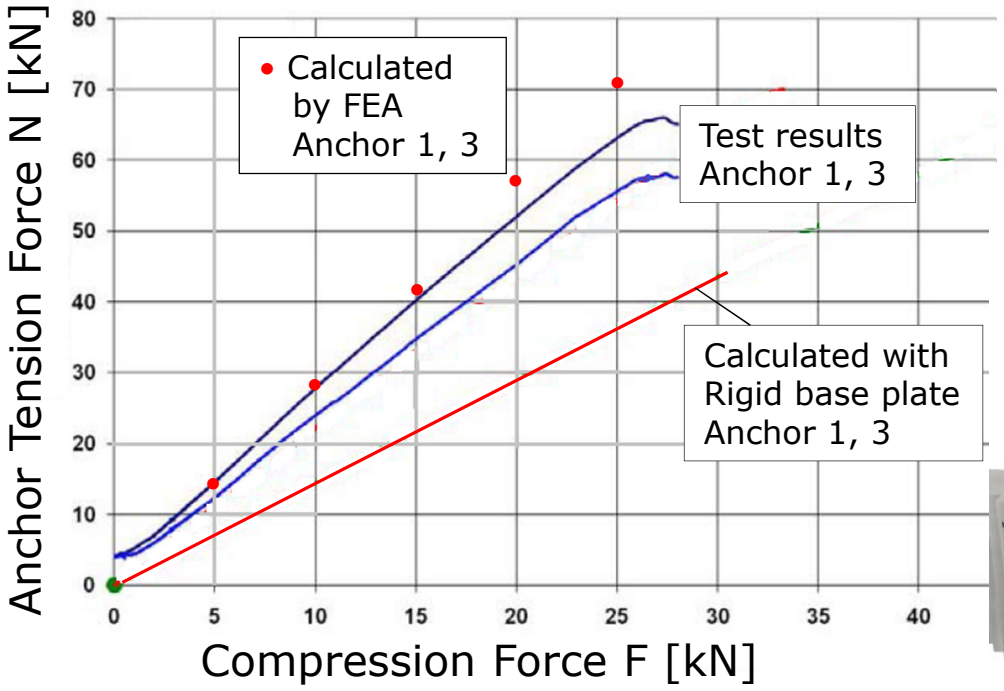
In the following slides the test results are compared with the calculation results to show the importance of using the finite element method to consider the deformations of the base plate, the anchors and the concrete in the anchorage design.

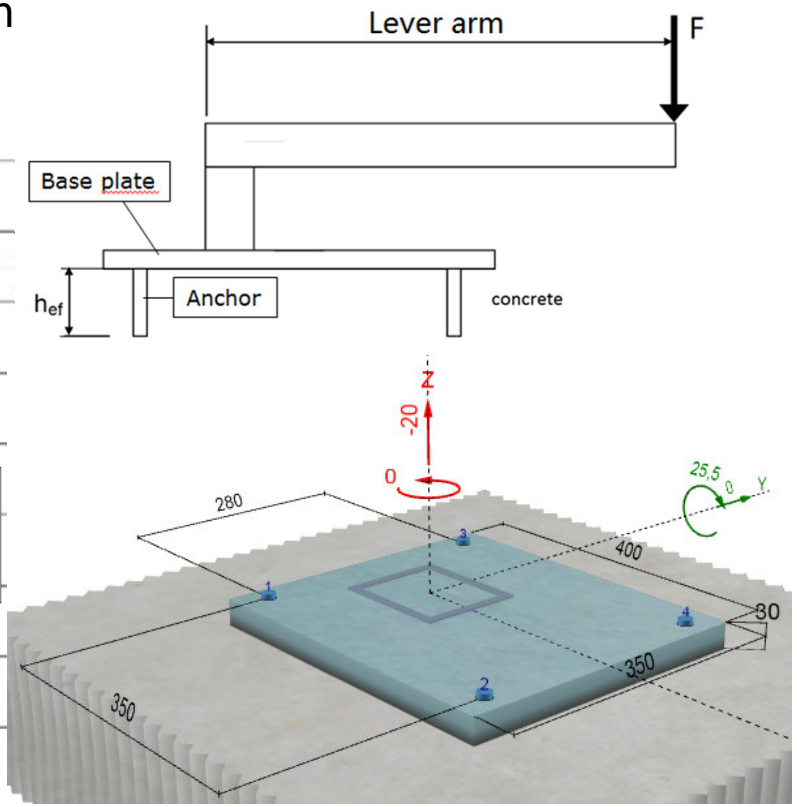
After that a stiffness condition for the flexurally rigid base plate is defined and **illustrated by examples**.

This stiffness condition for calculating the required thickness of the flexurally rigid base plate is implemented in the new version of **Anchor Profi** 2.5.0.

Test 1 investigated by Fichtner/Eligehausen

FEA=Finite Element Analysis

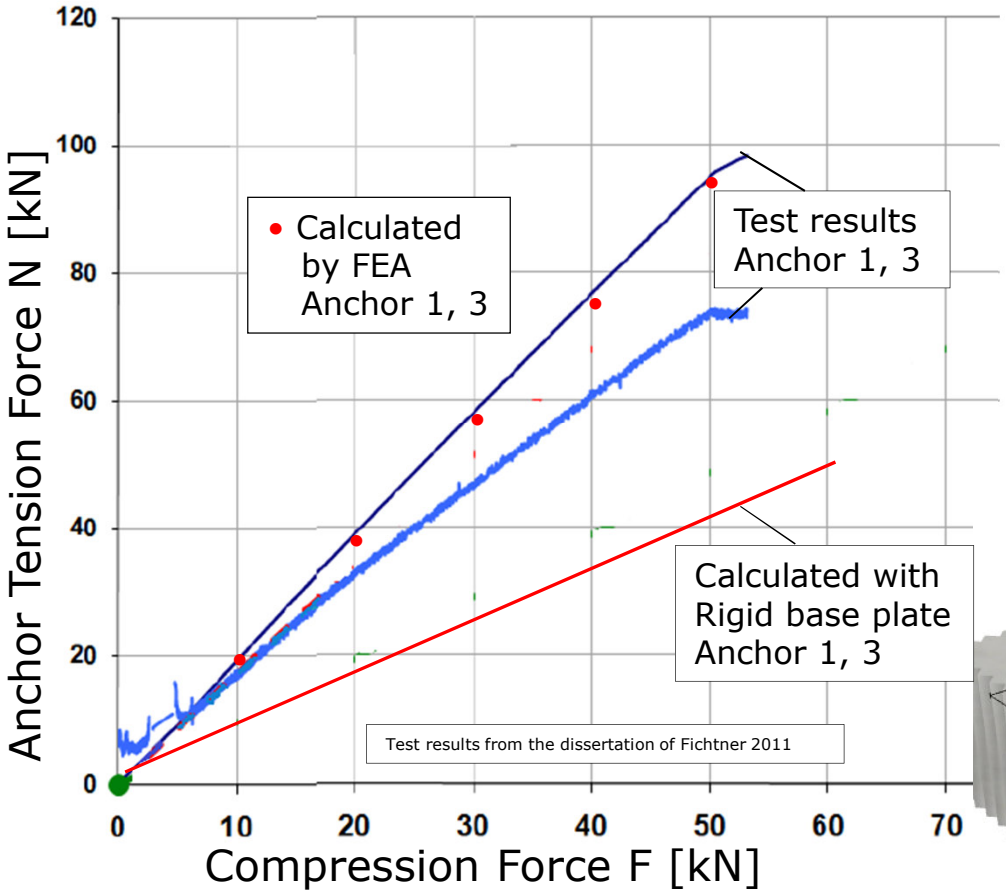


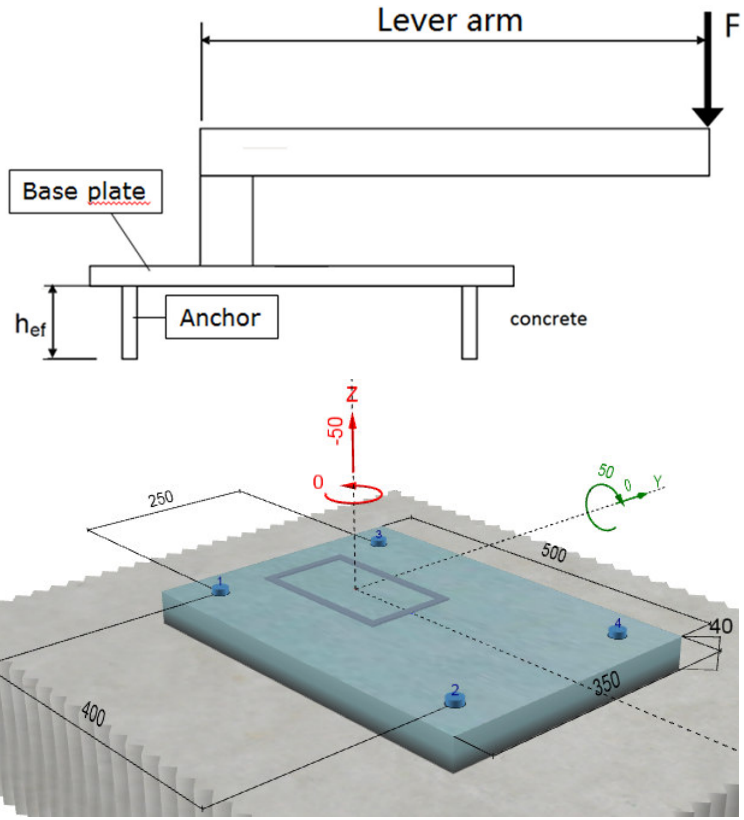


Test results from the dissertation of Fichtner 2011

Figure from the design software **Anchor Profi** of Dr. Li Anchor Profi GmbH

Test 2 investigated by Fichtner/Eligehausen

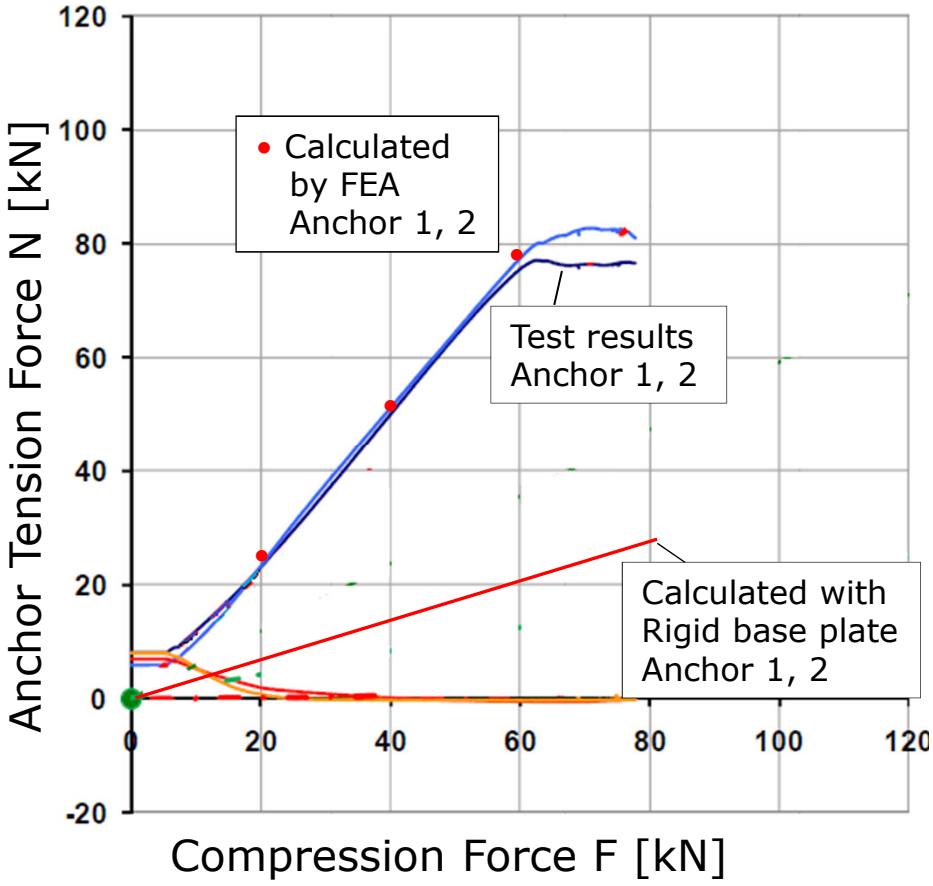


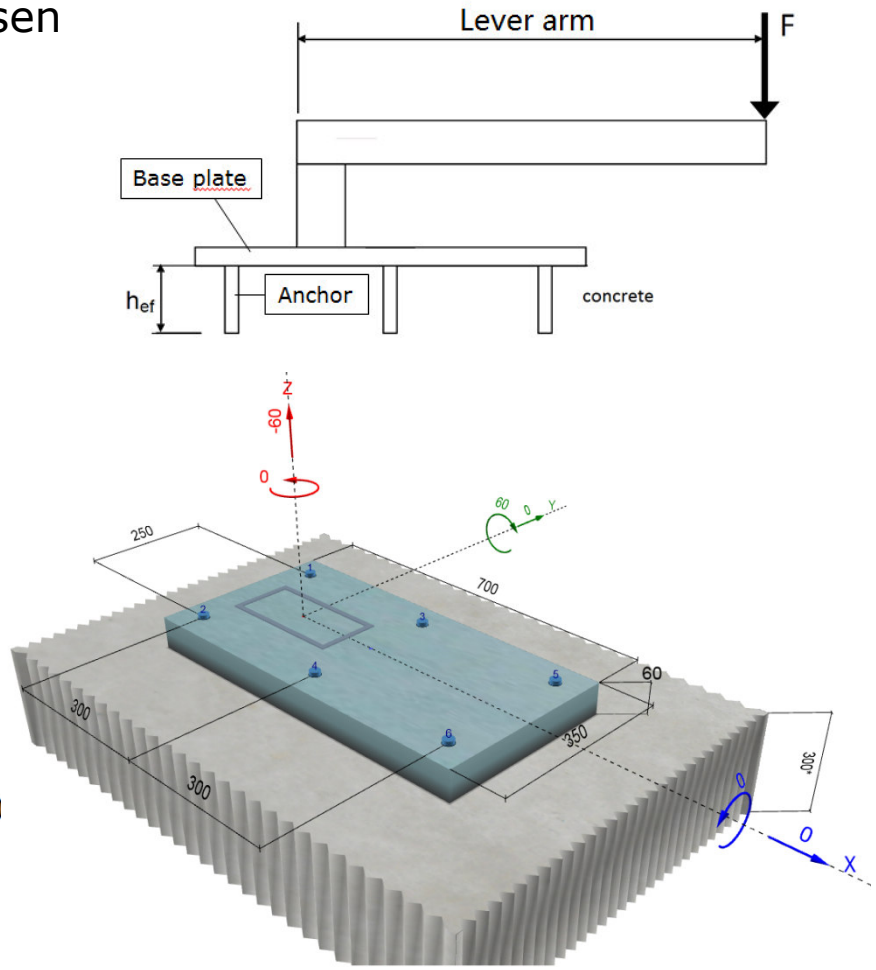


Test results from the dissertation of Fichtner 2011

Figure from the design software **Anchor Profi** of Dr. Li Anchor Profi GmbH

Test 3 investigated by Fichtner/Eligehausen





Test results from the dissertation of Fichtner 2011

Figure from the design software **Anchor Profi** of Dr. Li Anchor Profi GmbH

Conditions for flexurally rigid base plate

1. The base plate remains elastic under design actions

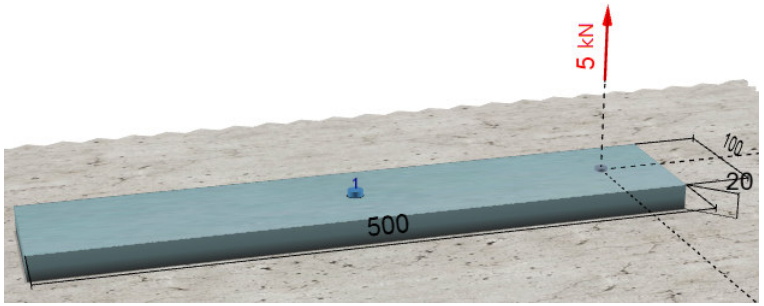
   $\sigma_{Ed} \leq \sigma_{Rd} = f_{yk} / \gamma_M$

   and

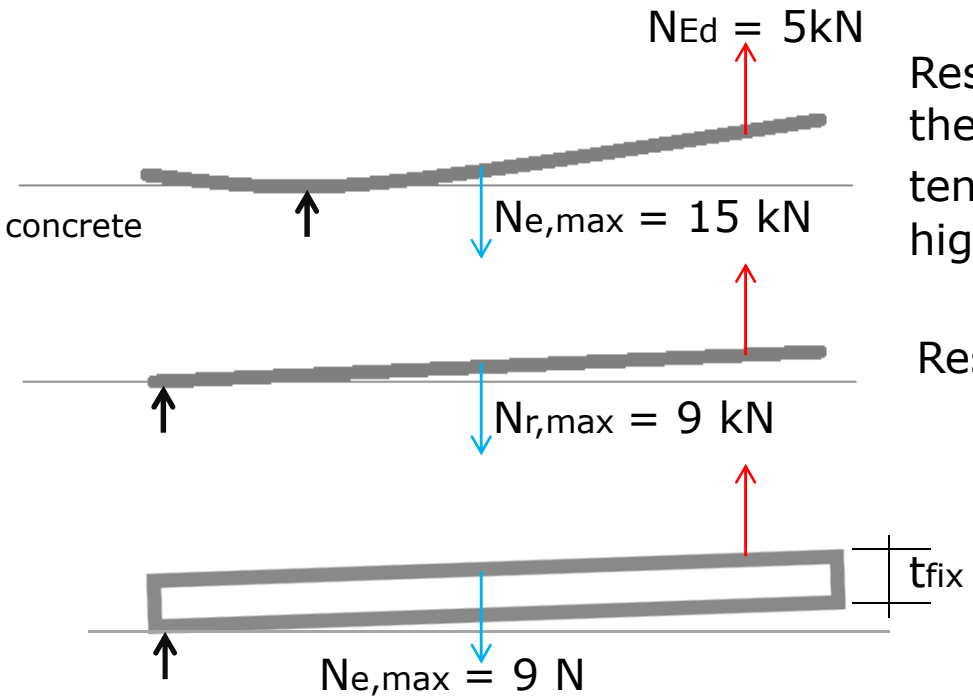
2. The thickness of the base plate fulfills the stiffness condition that the maximum anchor tension force calculated with rigid base plate $N_{r,\,max}$ is equal to the maximum anchor tension force calculated with elastic base plate $N_{e,\,max}$ by Finite Element Analysis in the anchor group

   $N_{r,\,max} = N_{e,\,max}$

Example for verifying the flexurally rigid base plate



Example 1
Bonded anchor M12, hef = 120 mm
Concrete C20/25

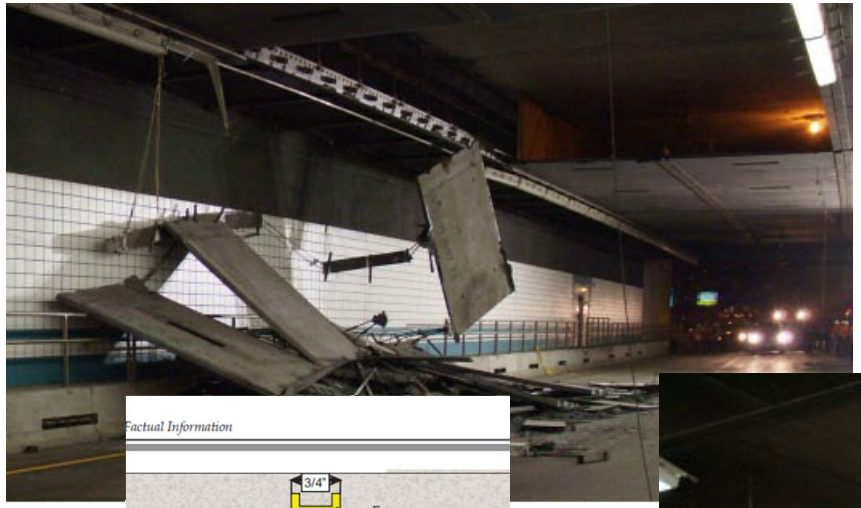


Results of FEA with t_{fix} = 20 mm fulfill the condition $\sigma_{Ed} < \sigma_{Rd,}$ but the anchor tension force $N_{e,max}$=15 kN is much higher than $N_{r,max}$=9 kN.

Results of assumed rigid base plate

FEA with the condition of $N_{e,max}$ = 9 kN results in the required thickness of t_{fix} =41 mm for flexurally rigid base plate.

Example for verifying the flexurally rigid base plate



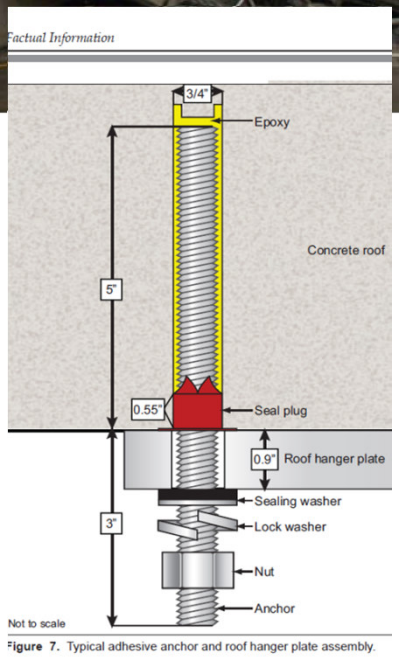
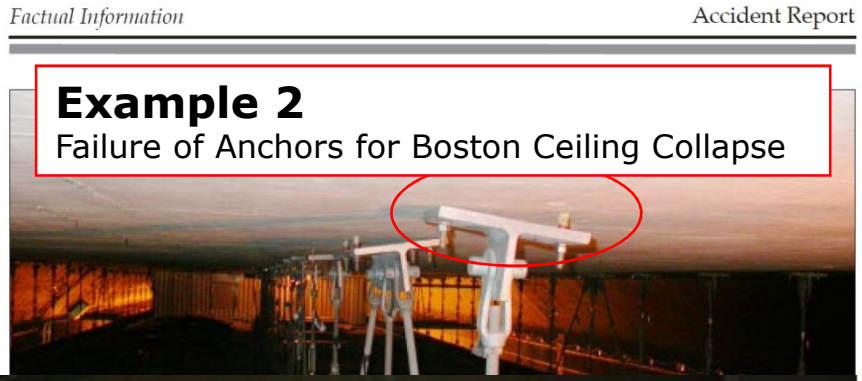
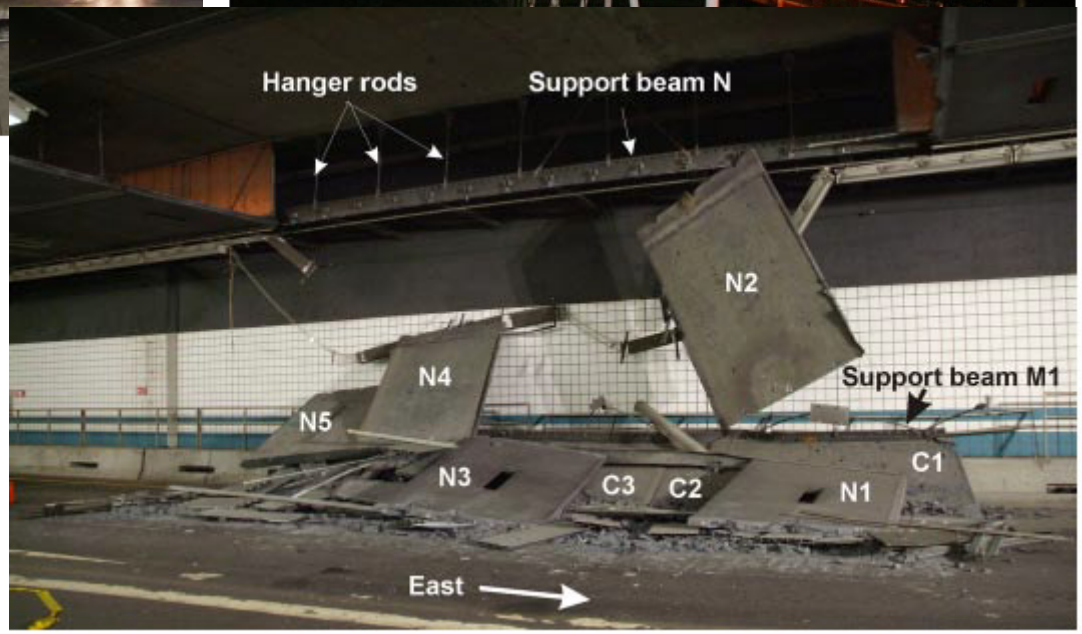
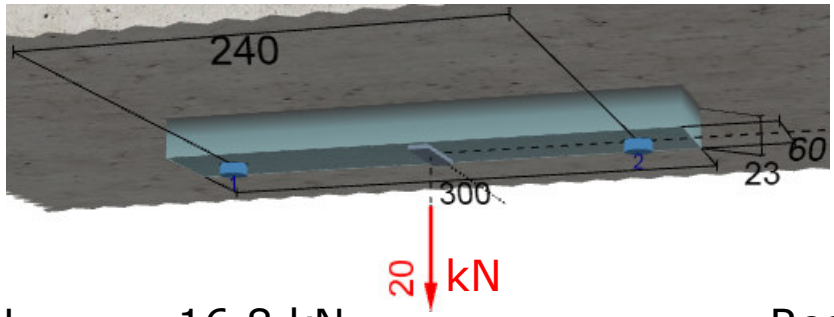


Figure 7. Typical adhesive anchor and roof hanger plate assembly.

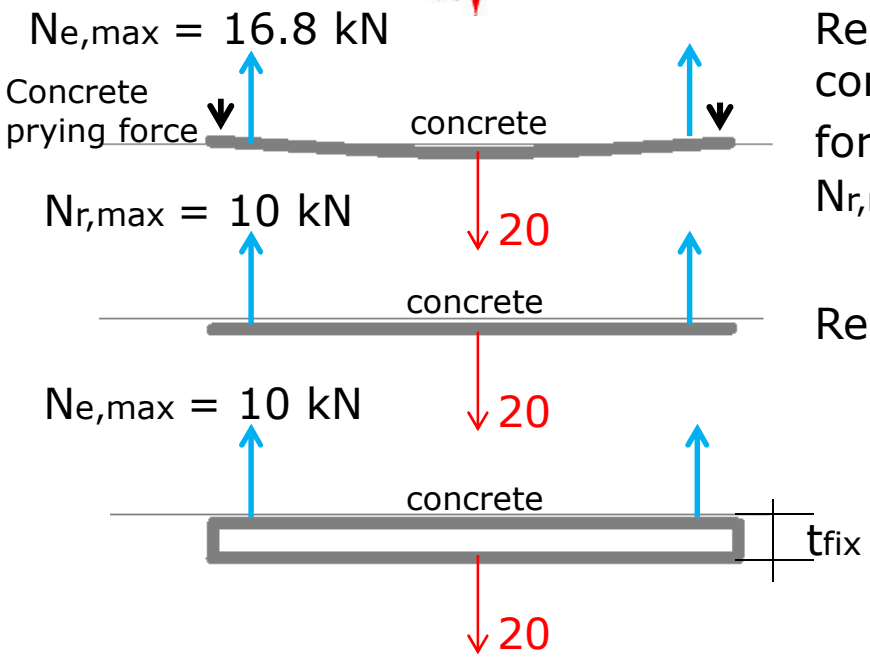




Figures from Ceiling Collapse in the Interstate 90 Connector Tunnel Boston, Massachusetts July 10, 2006



Example 2 (continued)
Failure of anchors for Boston Ceiling Collapse, **Analysis of base plate**

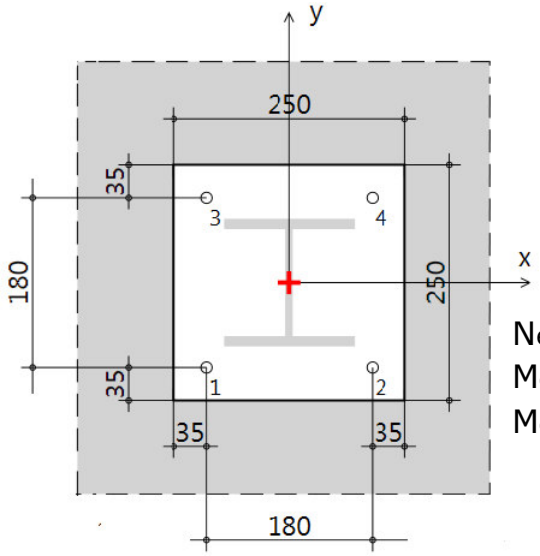


Results of FEA with t_{fix} = 23 mm fulfill the condition $\sigma_{Ed} < \sigma_{Rd,}$ but the anchor tension force $N_{e,max}$ =16.8 kN is much higher than $N_{r,max}$=10 kN.

Results of assumed rigid base plate

FEA with the condition of $N_{e,max}$ = 10 kN results in the required thickness of t_{fix} = 35 mm for flexurally rigid base plate.

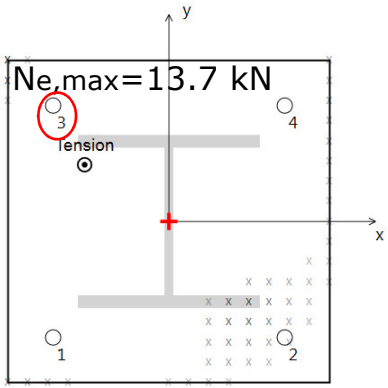
Example for verifying the flexurally rigid base plate



Example 3

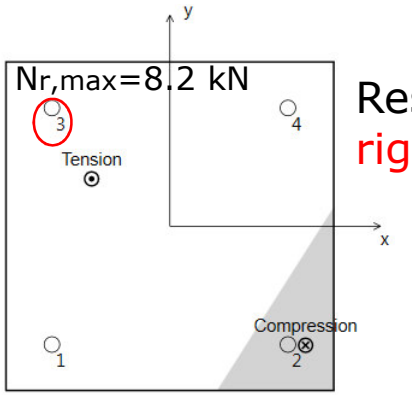
Bonded anchor M12, hef = 70 mm, Concrete C20/25

Ned= 5 kN
Med,x = 1.5 kNm
Med,y = 2 kNm



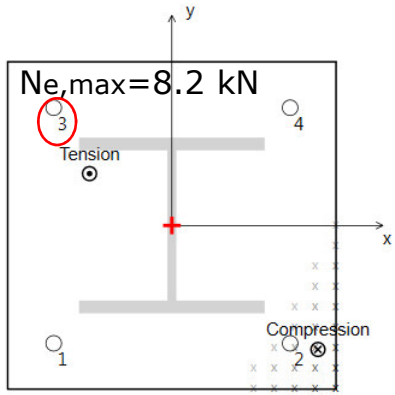
x : concrete compression or prying force

Results of FEA with t_{fix} = 12 mm fulfill the condition $\sigma_{Ed} < \sigma_{Rd,}$ but the anchor tension force $N_{e,max}$=13.7 kN is much higher than $N_{r,max}$=8.2 kN.



Results of assumed rigid base plate

Equivalent



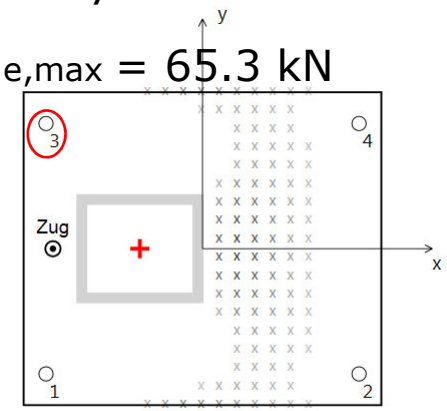
x : concrete compression or prying force

FEA with the condition of Ne,max = 8.2 kN results in the required thickness of t_{fix} = 58 mm for flexurally rigid base plate.

Example 4

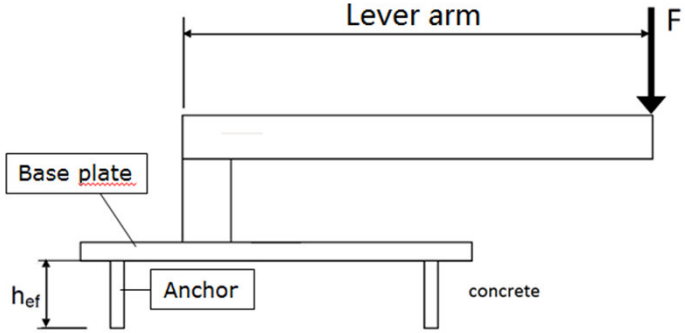
Analysis of Test 1 shown before

$N_{e,max}$ = 65.3 kN

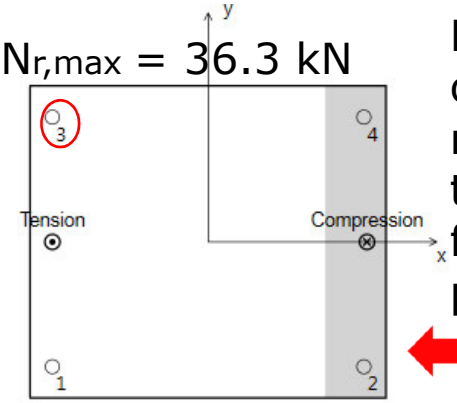


x : Betondruckkraft oder Stützkraft

Results of FEA with t_{fix} = 30 mm fulfill the condition $\sigma_{Ed} < \sigma_{Rd,}$ but the anchor tension force $N_{e,max}$=65.3 kN is much higher than $N_{r,max}$=36.3 kN.



$N_{r,max}$ = 36.3 kN



FEA with the condition of Ne,max = 36,3 kN results in the required thickness of t_{fix}=78 mm for flexurally rigid base plate.

Equivalent

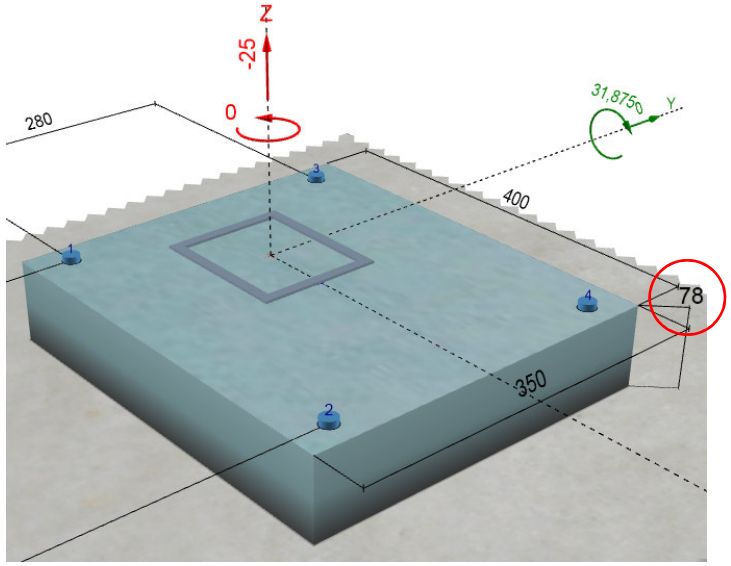
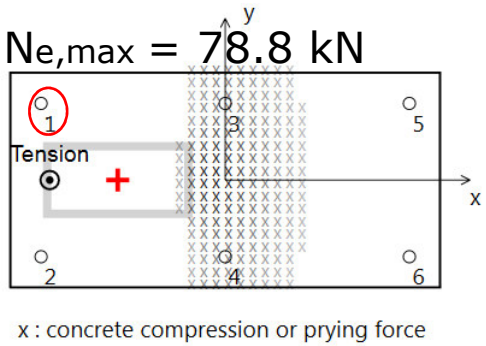


Figure from the design software **Anchor Profi** of Dr. Li Anchor Profi GmbH

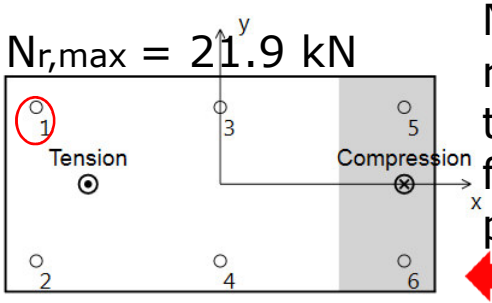
Example 5

Analysis of Test 3 shown before



x : concrete compression or prying force

Results of FEA with t_{fix} = 60 mm fulfill the condition $\sigma_{Ed} < \sigma_{Rd,}$ but the anchor tension force $N_{e,max}$=78.8 kN is much higher than $N_{r,max}$=21.9 kN.



FEA with the condition of Ne,max = 21.9 kN results in the required thickness of t_{fix}=188 mm for flexurally rigid base plate.

Equivalent

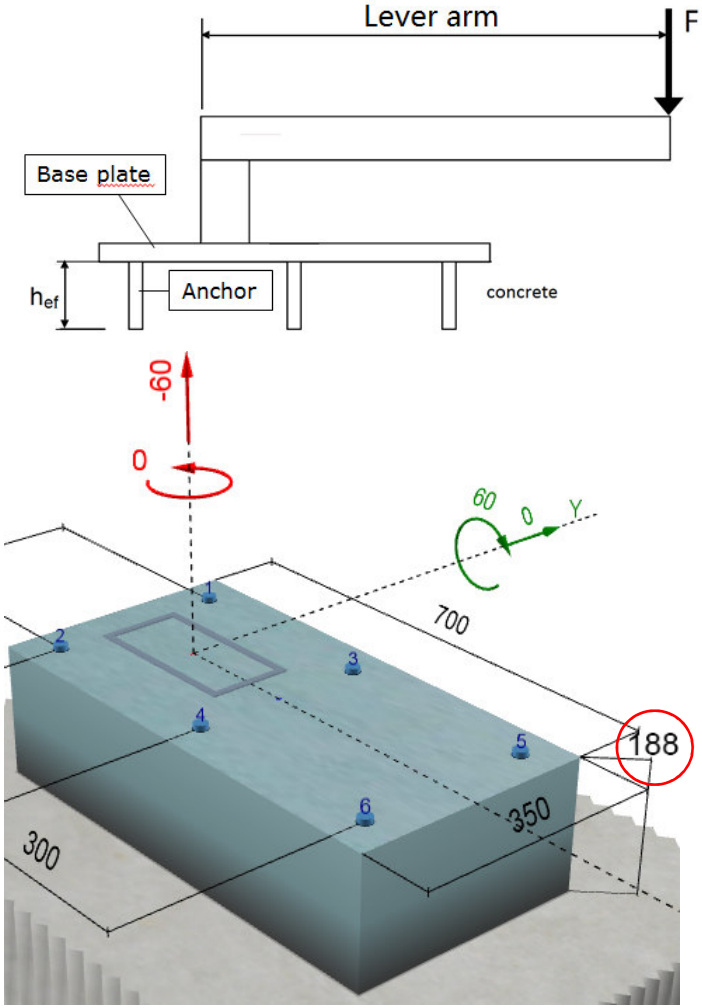


Figure from the design software **Anchor Profi** of Dr. Li Anchor Profi GmbH

1. The design of anchor fastenings with flexurally rigid base plate requires very large base plate thickness that may not be realistic for normal application cases.
2. For practically applicable base plate thickness we need to consider the deformation of base plate by finite element analysis that is available from **Anchor Profi** 2.4.9.