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Pile Load Tests and Foundation of the Highest Skyscraper in Northern Germany

Rolf Katzenbach*, Anke Werner and Sebastian Fischer

Engineering Society, Germany

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***Corresponding author:** Rolf Katzenbach, GmbH Pfaffenwiese, Frankfurt am Main, Engineering Society, Germany

Abstract

This paper gives a short overview of concept and structural design of the highest skyscraper in northern Germany. The new building will get an overall height of 245 m. Due to the little bearing capacity of the ground a deep foundation is needed. For the foundation piles with length up to 75 m will be executed. In advance, to determine the bearing capacity of the surrounding soil, pile load tests are carried out.

Keywords: Structural design; Skyscraper, Foundation piles; High-rise building; Drillings Reinforcement; Pile-raft; Numerical model

Subscription of the Building

The highest skyscraper in northern Germany will be located in the area "Hafencity Hamburg" close to the river Elbe (Figure 1). (Figure 2) shows a model of the planned new skyscraper. The skyscraper with an overall height of 245 m (Figure 2) will be erected on a foundation plate with an area of about 17,000 m^2. The triangular foundation plate owns dimensions of nearly 200 m in north-south-direction and nearly 130 m in the east-west-direction. The structural load of the 60 floors of the high-rise building results in approx. 2,200 MN which corresponds to a mass of 220,000 tons. Due to the very high loads and the different height of the base building and the high-rise building, which are built on the above-mentioned monolithic foundation-plate, large caliber foundation piles are needed.

Figure 1: Location of the construction site in Hamburg.

Soil Conditions

Based on extensive soil investigations (e.g., exploration drillings, cross hole measurements etc.) the following soil model (Figure 3) has been elaborated:

a. Layer 1: sandy filling, partly rubble

b. Layer 2: clay and mud, cohesive filling, partly rubble

c. Layer 3: sand with silty deposits

d. Layer 4: sand middle dense to dense

e. Layer 5: sand dense to very dense

f. Layer 6a/b: clay/silt with thin sandy layers

g. Layer 7: sand partly silty with silty layers

Pile Load Tests

To determine the bearing capacity 4 pile load tests have been carried out (Figures 4 & 5). To be able to make a prediction for all affected soil layers, piles with different lengths have been executed. The most important layer for the load transfer is layer 7. For this reason, 2 piles reach this layer. The following piles have been executed:

a) Testpile 1: length = 110 m, ultimate load of the test-segment (l = 6,5 m) = 22,500 kN

b) Testpile 2: length = 110 m, ultimate load of the test-segment (l = 6,5 m) = 27,500 kN

c) Testpile 3: length = 75 m, ultimate load of the test-segment (l = 5,5 m) = 15,700 kN

d) Testpile 4: length = 35 m, ultimate load of the test-segment (l = 5,5 m) = 10,750 kN

Figure 2: Model of the skyscraper.

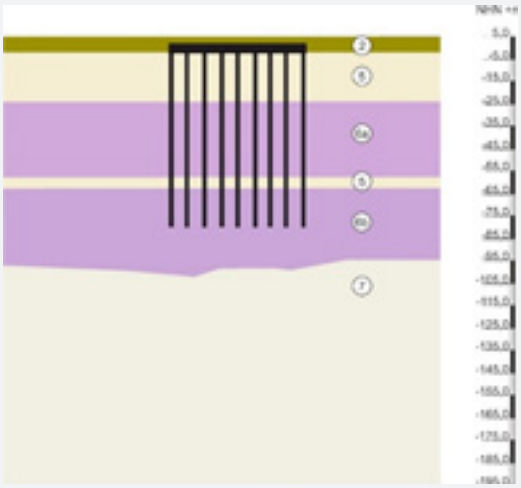

Figure 3: Soil model of the construction site

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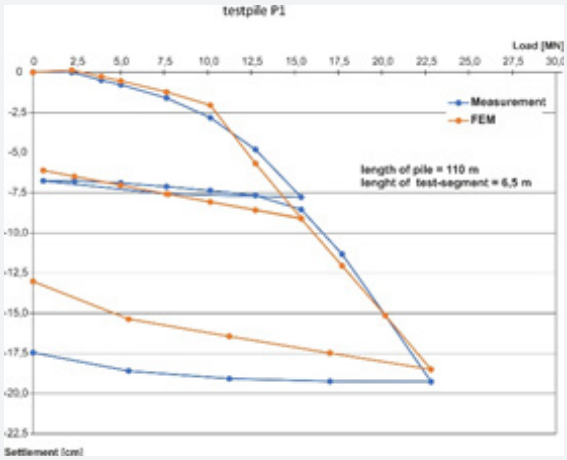

Figure 4: Load-settlement-curve of testpile P1.

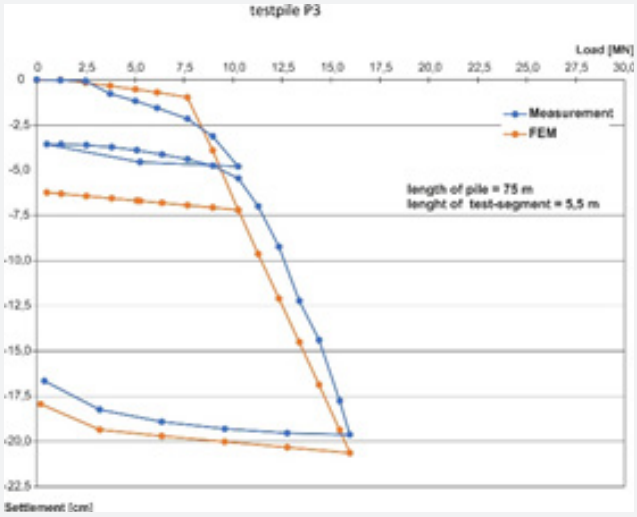

Figure 5: Load-settlement-curve of testpile P3.

Impressions from Construction Site

Figure 6: Construction site overview.

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(Figures 6 & 7) give some impressions of the construction site. The piles have been bored with bentonite slurry in order to stabilize the borehole. Drilling, installation of reinforcement and concreting of the two 110 m long piles lasted about 90 hours (nearly 4 days and nights per pile).

Figure 7: Drill rig.

Foundation

The deep foundation is designed as Combined Pile-Raft Foundation (CPRF). An overview on the design of piled rafts and its behavior is given in [1-7]. For the prediction of the settlements and especially to proof the acceptable inclination of the skyscraper, various three-dimensional numerical calculations were executed taking into consideration scientific works like [8-9] and [10] etc. (Figure 8) shows the dimensions of the numerical model. In the result of the calculations, including several sensitivity studies, the foundation consists of 66 large caliber piles with diameter d = 2.0 m and length l = 75 m, which leads in accordance with [11] to a safe and economical design of the foundation for the highest skyscraper in northern Germany.

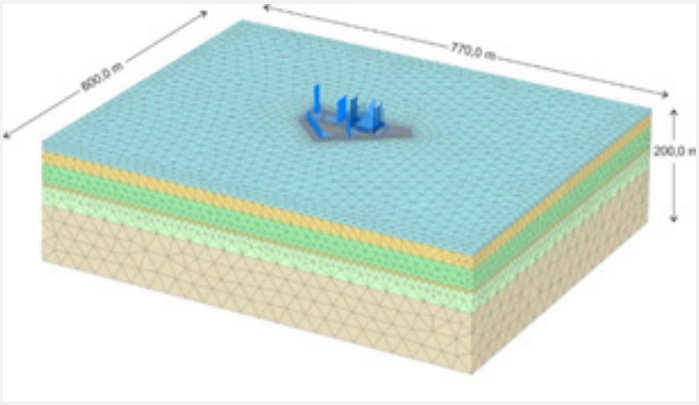

Figure 8: Dimension of the numerical model for the settlement prediction.

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