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Discharge capacity of prefabricated vertical drains and its influence on the consolidation process

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Introduction

The use of prefabricated vertical drains (PVD) considerably accelerates the consolidation process of soft subsoils, which can be predicted by a number of different consolidation theories. Nevertheless, those theoretical solutions comprise a couple of different factors and parameters which have a large influence on the prediction results. By the means of this thesis, known theories for vertical and horizontal consolidation have been reviewed and put into practice, using a realized drainage project in the Netherlands as a case study to find out more about the leading factors for the consolidation process. Thereby special emphasize has been put on the factor discharge capacity. Beside finding the required discharge capacity of a PVD, the influence of the length, type and deformation of the PVD on the discharge capacity have been investigated by reviewing different laboratory discharge capacity tests.

Radial Consolidation Theory

The basic theory of radial consolidation by Barron (1948) around a vertical drain system is an extension of the 1-D-consolidation theory and developed under ideal conditions using an axisymmetric unit cell model (see Fig. 1). The solution is given in a general form (1) as a function of the time factor T_h and reduction factor $F=F_n+F_s+F_r$. Based on this solution, Hansbo, Onoue, Zeng & Xie, Lo, and Walker and Indraratna developed different solutions for drain spacing (F_n), smear zone (F_s) and well resistance (F_r).

$$U_h = 1 - e^{\frac{-8\cdot T_h}{F}} \quad (1)$$

$$T_h = \frac{c_h \cdot t}{d_e^2} \quad (2)$$

c_h =coefficient of horizontal consolidation and t =time

Drain Spacing – F_n

Drain spacing depends on the proposed equivalent diameter d_w, which is a conversion of the rectangular cross section of a PVD into a circular cross section.

Smear Zone - F_s

The smear zone is modelled by dividing the soil cylinder dewatered by the central drain into the zone in the immediate vicinity of the drain (d_s) with a reduced soil permeability k_s and into the undisturbed zone (d_w) .

Well Resistance - F_r

If the discharge capacity of the drain is reached during the consolidation period, the overall consolidation process is retarded. In such cases, the drains exhibit a resistance to water flow into them which known as well resistance.

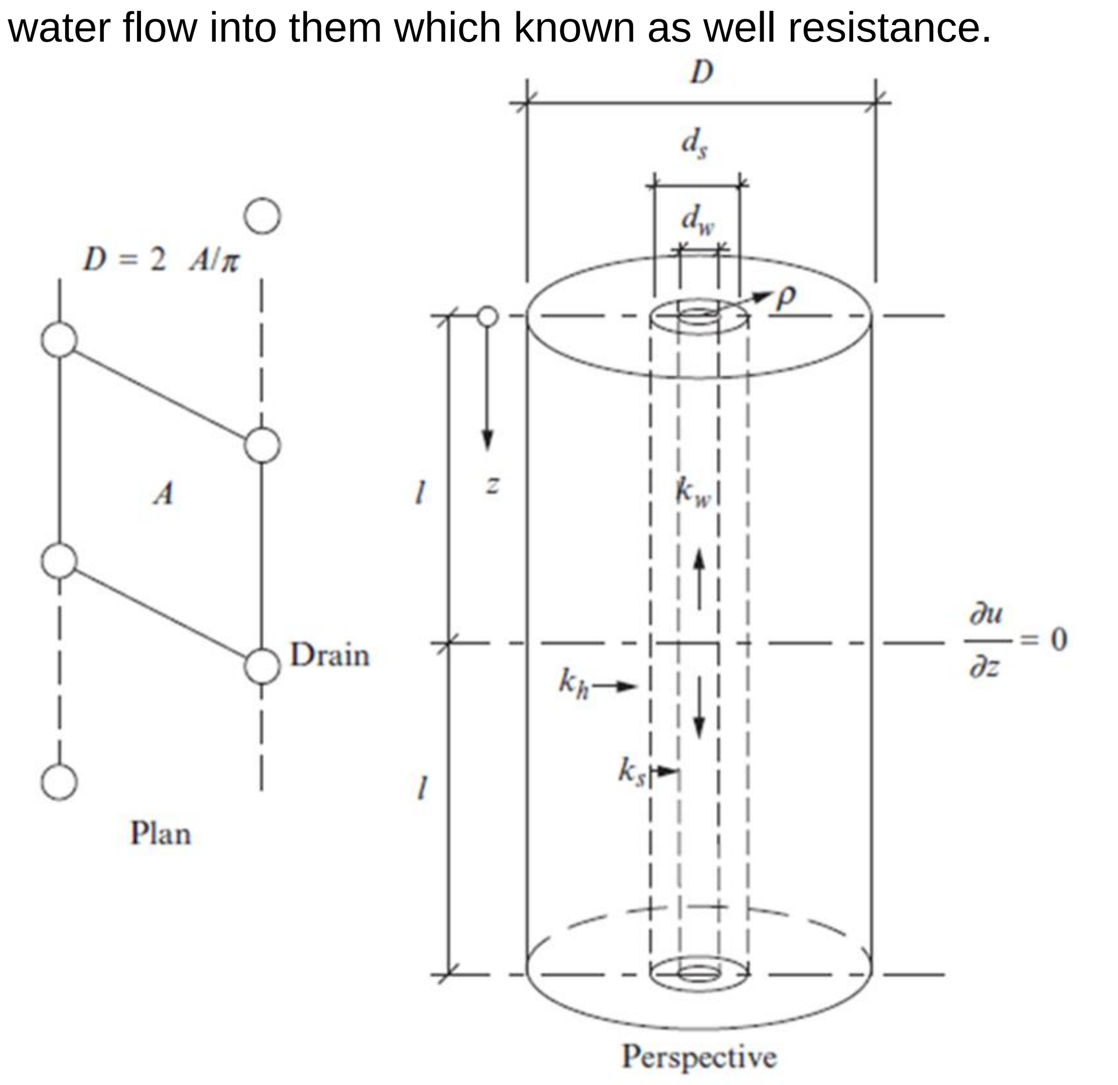

Fig. 1 (Hansbo, 2015) : Axisymmetric Unit Cell Modell with D=d_e=diameter of soil cylinder dewatered by a drain; d_w=equivalent drain diameter; d_s=diameter of zone of smear; l=length of drain, z=depth coordinate; k_w=permeability in the longitudinal direction of the drain; k_h=horizontal soil permeability; k_s=horizontal soil permeability in smear zone

Discharge Capacity Laboratory Tests

The discharge capacity has been determined for two types of PVD (NG and Reg) with different samples lengths under straight and buckled conditions, using the apparatus proposed in EN ISO 18325 [2] and two kinds of buckling device. The main principle of the apparatus is the simulation of the soil conditions acting on the PVD by the use of a membrane sealed PVD in a pressurized water cell. The cell is pressurized up to 200kPa (buckled conditions) or 300kPa (straight conditions) and the flow of water through the specimen is measured at a defined head loss. The measurements are taken during and over a standardized period of 30 days.

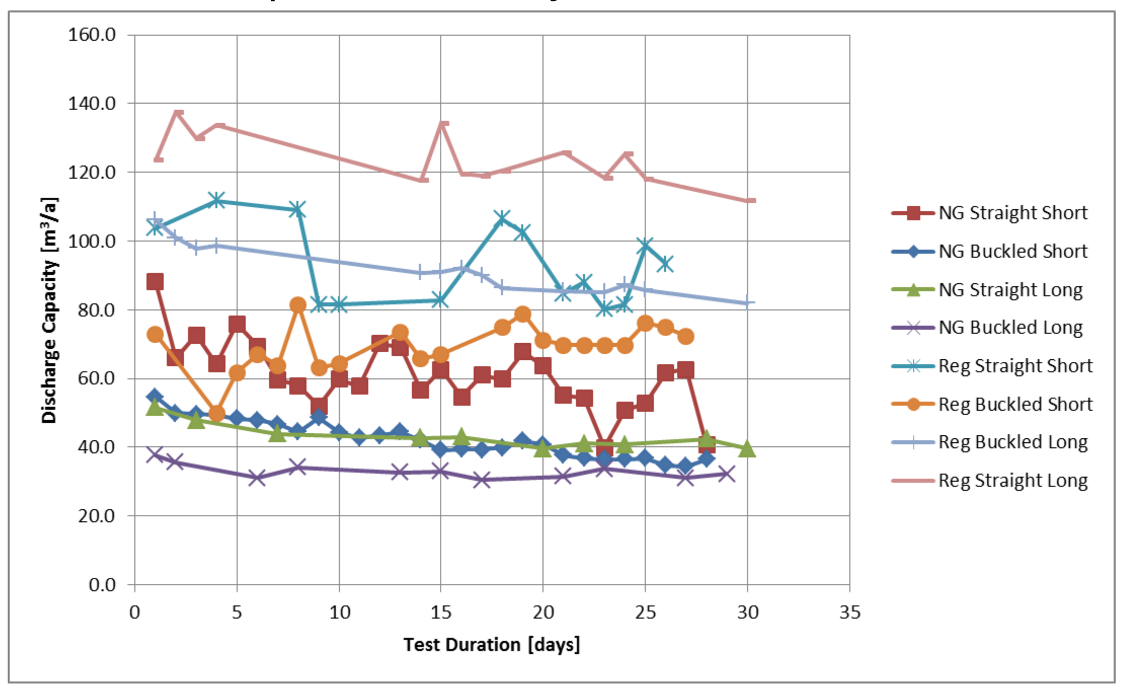

Fig. 2: Test Results

Test Results

According to the test results, the discharge capacity for a gradient=0.1 ranges between 32 m³/a and 112 m³/a. Thereby, it was found that the discharge capacity mainly depends on the PVD type. It was also observed that the buckling of the PVD leads to a lower discharge capacity. Thereby, no difference between the times that the drain was buckled (one or four times) was noted. Regarding the length of the specimen, no distinct influence was observed. Moreover it was observed that the discharge capacity increases with an increasing gradient.

Case Study

When using the data from a realized drainage project for the proposed solutions [2], it was found that only Hansbo's [3] and Walker and Indraratna's solution leads to a significant different degree of consolidation. Moreover the degree of consolidation for the theoretical solutions was found to be an average of the observational method to determine the degree of consolidation by Tan and Asaoka, which are both based on settlement data from the case study. This leads to the conclusion that the proposed solutions represent quite well realistic predictions of the consolidation process

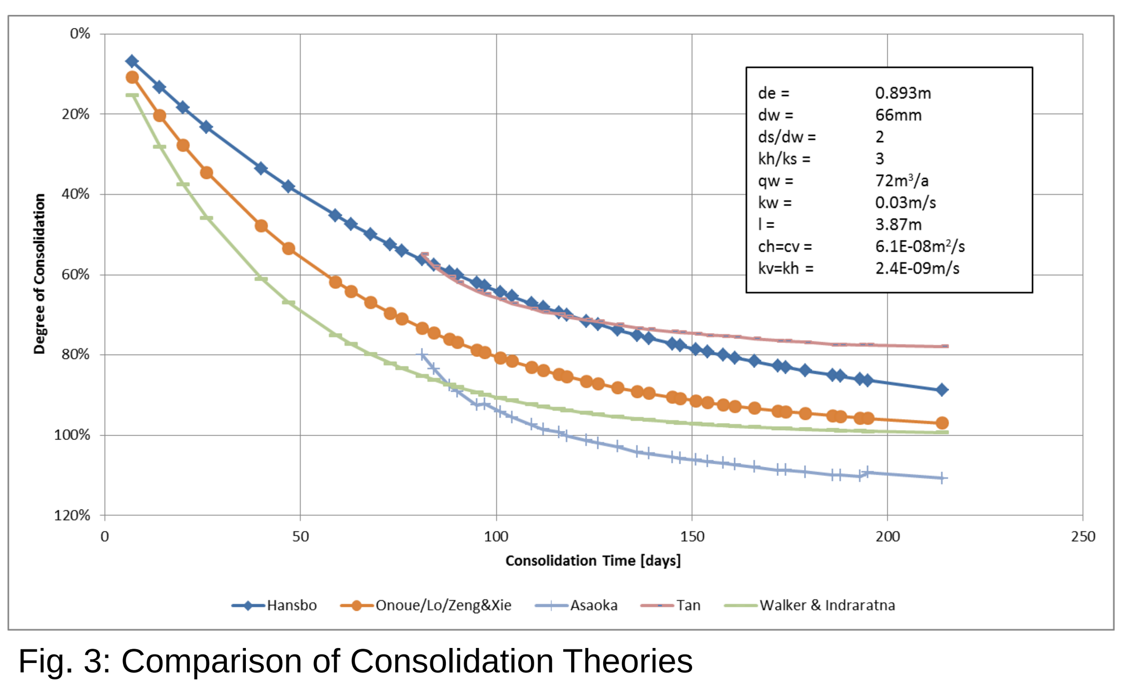

Fig. 3: Comparison of Consolidation Theories

Parameter Study

A parameter study has been performed based on [1] to further determine the influence of the parameters when varying values.

Using any of the proposed solutions for the drain spacing, it was found that F_n increases with an increasing PVD spacing and an increasing equivalent diameter, as presented in Fig. 4.

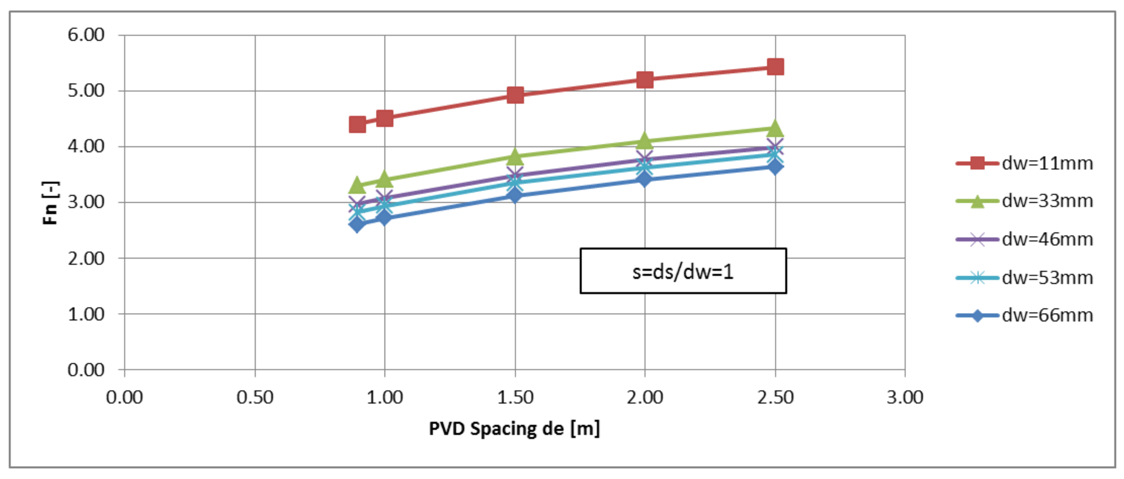

Fig. 4: Effects of Spacing on Fn

Using the proposed solution from Hansbo [3], F_s increases linearly with an increasing k_h/k_s and d_s/d_w, as presented in Figure 5.

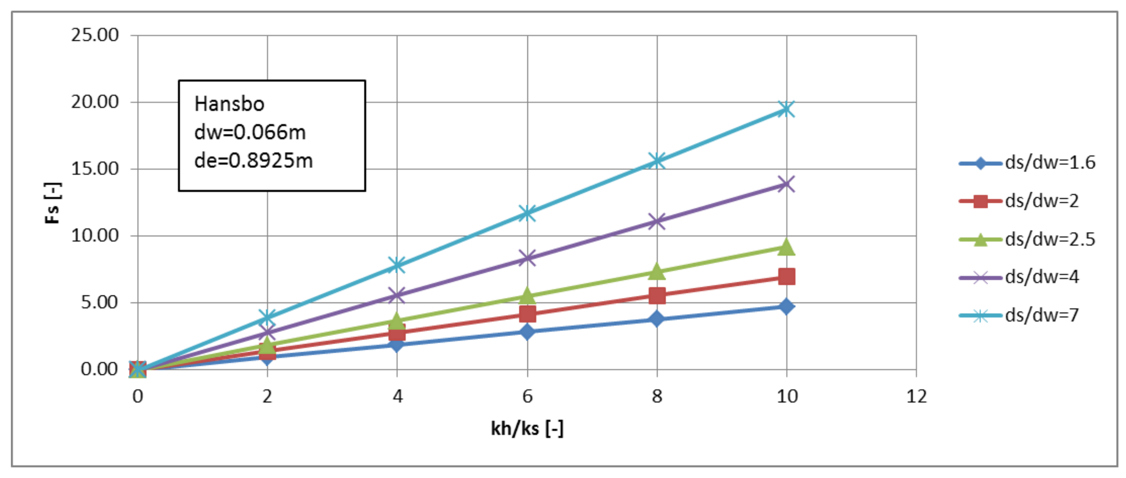

Fig. 5: Effects of kh/ks and dw on Fs

Using the proposed solution by Zeng & Xie, it was found that an increasing k_h-value leads to an increasing well resistance. Moreover a low discharge capacities only leads to a significant well resistance when having long drains.

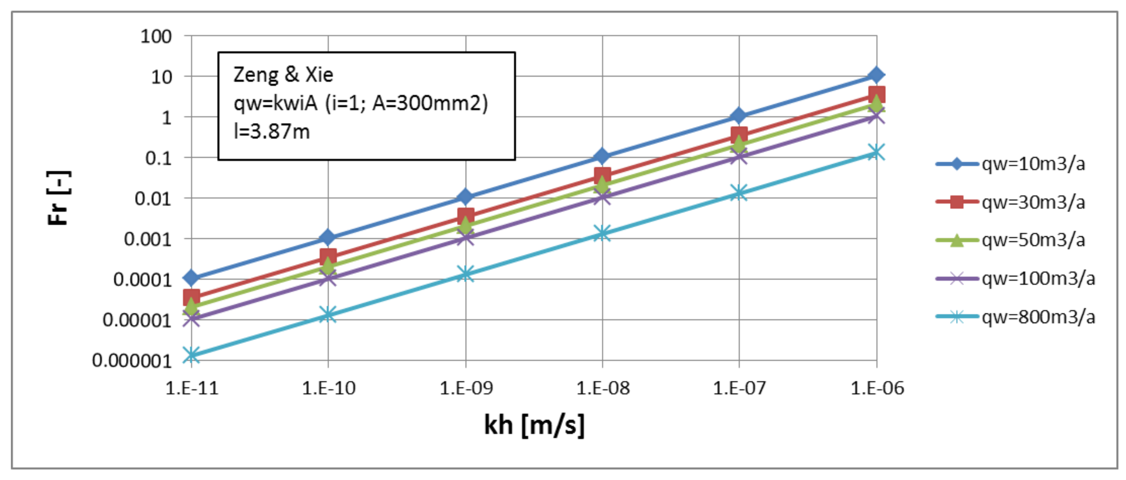

Fig. 6: Effects of k_h and q_w on F_r

Conclusion

For the case study, it can be concluded that the discharge capacity of 72 m³/a for the regular PVD type, that has been obtained by the laboratory tests, does not cause any well resistance, when having a 3.87 m long PVD and a soil permeability with k_h = 2.4E-9 m/s and therefore does not delay the consolidation. This is also supported by most of the proposed solutions for the required discharge capacity ranging from 5.67 m³/a to 44.49 m³/a, when using l =3.87 m, c_h = 6.1E-08 m²/s and k_h = 2.4E-9 m/s. Nevertheless, the required discharge capacity highly depends on the chosen soil parameters and can therefore not be taken as a fix value for other projects.

By the means of this thesis, the appropriate values and influence of each parameter concerning the consolidation process were discussed, which can be used to further determine the range of the required discharge capacity.

Bibliography

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Project
Projektarbeit

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