# *APPENDIX*

# *INTAKE FACTOR OF THE MINI-PIEZOMETER IN SITU*

## A.1 INTRODUCTION

Intake factors are geometric constants used in the study and interpretation of in situ flow tests in order to determine the permeability of soils. Correct determination of intake factor of piezometers is a key issue when analysing flow tests in the field. Many studies have been performed in the last 50 years to determine the intake factor of different piezometers. The intake factor depends on the geometry of the cavity of the piezometer, the boundary conditions and the anisotropy of the soil. Hvorslev (1951) provided the first expressions of intake factors where the main hypotheses were infinite domain, the soil is not altered and fully saturated and there are no significant head losses in the piezometer. Several authors provided further refinements of the previous expressions by introducing numerical analysis of the problem for different geometries and boundary conditions: Youngs (1968); Al-Dhahir & Morgenstern, (1969); Brand & Premchitt (1980a); Brand & Premchitt (1980b) or Ratnam et al. (2001). Some of these authors proved that great differences that exist if usual expressions for infinite medium are used for finite medium.

In our case, the determination of the intake factor was important to study the pulse tests performed with this new mini-piezometer. Two different situations were studied in chapter 4: finite domain and infinite domain.

Intake factor of the mini-piezometer used in the pulse tests performed in laboratory was numerically determined by means of CODE_BRIGHT (Olivella et al., 1996) as detailed in chapter 4. This finite element code was used to reproduce the geometry and boundary conditions of a constant head test within the cell designed to perform the pulse test in laboratory. Equation 1 was used to calculate the intake factor.

$$k = \frac{Q_\infty}{FH} \rightarrow F = \frac{Q_\infty}{kH} \tag{1}$$

Where $F$ is the intake factor (L), $k$ is the permeability (L/T), $Q_\infty$ ($L^3$/T) is the flow under steady-state conditions and $H$ is the applied head of water (L). A finite element mesh, reproducing the cell, the mini-piezometer and the draining geotextile, was created and a constant head test was simulated. The flow of water under steady-state conditions was estimated and used to determine the intake factors in this situation. The so-calculated intake factor was F = 0.667 m.

## A.2 INTAKE FACTOR OF THE MINI-PIEZOMETER IN SITU

As pointed out by Premchitt & Brand (1981), it was recognised the important effects of determining the intake factor of a cylindrical piezometer assuming a spherical tip geometry. The pulse tests carried out in situ in the ZEDEX gallery present similar situation when analysing them by means of the Gibson’s model. The mini-piezometer was assumed to be spherical and therefore, an equivalent radius was calculated. The intake factor of a spherical tip is F = 4πλ where $\lambda$ is the radius of the tip. This expression was used to estimate the intake factor of the mini-piezometer and the equivalent radius estimated by means of three different criteria: same volume of the cavity of the spherical piezometer and cavity of the cylindrical piezometer, same draining area of the spherical tip and the cylindrical piezometer and, finally, estimating the intake factor of the cylindrical piezometer by an expression provided by Ratnam et al. (2001) in infinite medium and compare it with the intake factor of a spherical tip. The diameter of the cylindrical piezometer is a = 0.05 m and the draining length is b = 0.1 m.

1. SAME VOLUME.

$$\left.\begin{aligned} V_{sphere} &= \frac{4}{3}\pi\lambda_{eq}^3 \\ V_{cylinder} &= \frac{1}{4}\pi a^2 b \end{aligned}\right\} \rightarrow \lambda_{eq} = \frac{3}{16}\left(a^2 b\right)^{1/3} = 0.0360\ \text{m} \rightarrow F_1 = 4\pi\lambda_{eq} = 0.4530\ \text{m} \qquad (2)$$

2. SAME DRAINING AREA.

$$\left.\begin{aligned} S_{sphere} &= 4\pi\lambda_{eq}^2 \\ S_{cylinder} &= \pi ab \end{aligned}\right\} \rightarrow \lambda_{eq} = \frac{1}{2}\left(ab\right)^{1/2} = 0.0353\ \text{m} \rightarrow F_2 = 4\pi\lambda_{eq} = 0.4442\ \text{m} \qquad (3)$$

3. SAME INTAKE FACTOR.

$$\left.\begin{aligned} F_{sphere} &= 4\pi\lambda_{eq} \\ \frac{F_{cyl}}{a} &= \left(3.11 + 1.18\frac{b}{a} + 2.41\sqrt{\frac{b}{a}}\right) \end{aligned}\right\} \rightarrow \lambda_{eq} = \frac{F_{cyl}}{4\pi} = 0.0354\ \text{m} \rightarrow F_3 = 0.4451\ \text{m} \qquad (4)$$

It can be observed that very similar equivalent radius of the spherical tip (i.e. intake factor) was obtained by using the three different approaches. When using the Gibson's model to analyse the pulse tests performed in the ZEDEX gallery the intake factor is used in the expression of the dimensionless stiffness (expression 10, chapter 4). In this expression, the dimensionless stiffness is raised to cube, however, the small variations calculated produce small variations of the dimensionless stiffness among the three different values of the intake factor (up to 6% comparing dimensionless stiffness obtained by using $F_1$ and $F_2$).

Hvorslev (1951) provided the intake factor for the geometry shown in figure A.1 (which represents a simple packer system in a borehole). This situation is similar to mini-piezometers placed at the ZEDEX gallery but not exactly the same. This expression also provides a similar value of the intake factor, but if dimensionless stiffness, obtained by using $F_1$ and $F_4$, are compared, the difference raises up to 11.5%.

$$F_4 = \frac{2\pi b}{\ln\left\{\frac{b}{a} + \sqrt{1 + \left(\frac{b}{a}\right)^2}\right\}} = 0.4352\ \text{m} \qquad (5)$$

As a result, intake factor $F_3$ was chosen for the analysis of the pulse tests performed in situ as it was estimated by fitting the results obtained by finite element simulation of a geometry with a system of double packer.

## A.3 REFERENCES


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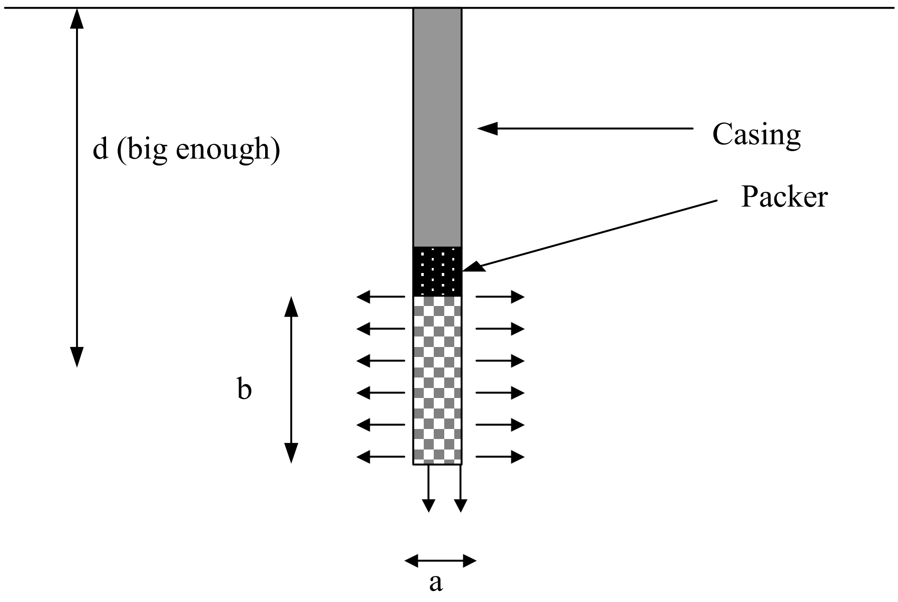


Figure A.1: Simplified geometry of a simple packer system within a borehole. This is one of the most common geometries when performing flow tests in boreholes.