# Crack formation in newly reclaimed sediments in the IJsselmeer polders

CRACK FORMATION IN NEWLY RECLAIMED
SEDIMENTS IN THE IJSSELMEERPOLDERS

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## 1. Introduction

In the former ZuyderZee -nowadays called IJsselmeer- four polders have been reclaimed. Just after reclamation the clayey sediments in these polders can be characterised as very soft and wet and unsuited for agricultural production. Although the pore volume is high, there are no larger pores and so the soil is virtually impermeable, making drainage impossible. By a process, called soil ripening, the sediments are transformed in normal soils, very suitable for agricultural use.
The physical part of this process starts as soon as the water is pumped out of the polder. Due to the evaporation surplus in summer under the dutch climatic conditions, the watercontent decreases and the compaction of the soil leads to subsidence and crack formation. By the newly developed cracks the permeability of the soil increases so that water can be drained away. The compaction of the soil is almost completely irreversible.
Recently a simulation model for this process has been developed (RIJNIERSCE, 1983). A specific problem during this development was the simulation of the crack formation. In this abstract this part of the model will be described.

## 2. General description of the model for soil ripening

In the simulation model for ripening, the soil moisture suction $\Psi$ is chosen as the "mastervariable". In this model the $\Psi$ not only defines the stored amount of water and the conductivity, but also the rate of compaction. In the model the soil profile is divided into layers, in which the content of solid parts remains the same during the simulation. The soil in a layer is divided into "solid soil" including the solid parts, the water and evt. air and the so-called "big cracks". All the soil properties, like pF-curves, bulk densities etc. are related to the "solid soil".

## 3. Submodel for subsidence and crack formation

In soil mechanics subsidence is mostly calculated using Terzaghi's formula. In its most simple form this formula is:

$$\Delta z/z=(1/c).\ \ln(p_2/p_1) \qquad (1)$$

where $\Delta z/z$ is the relative subsidence, c is a consolidation constant and $p_2$ and $p_1$ are the grain pressures after and before loading. The c-value depends on soil properties. A relation between the pore space and this value is given by DE GLOPPER (1977).

This Terzaghi formula can give incorrect results. If $p_2$ is sufficiently greater than $p_1$, $\Delta z/z$ will be greater than 1, which is impermissible. Besides, the results obtained with this formula are affected by the magnitude of the steps in the increase of the load.

In the model for ripening it is assumed that $p_2$ is equal to the suction, so very high values can be reached. For the above mentioned reasons it was necessary to develop a new compaction formula.

A formula which satisfies the condition that $\Delta v$(=relative compaction) $\rightarrow \varepsilon$ ($\varepsilon$=porosity before loading) if $p_2 \rightarrow \infty$ and which gives results independant of the magnitude of the load steps is:

$$\Delta v = \varepsilon . \{1/(\ln(p_2/p_1) + (1-\varepsilon)/K_2\ .\varepsilon)\}\ .\ \ln(p_2/p_1) \qquad (2)$$

where $K_2$ is a constant. By calibration it was found that this constant has a value of o.192.

The increase in bulk density during ripening can now be calculated using:

$$\Delta v=\Delta\rho/\rho \qquad (3) \qquad \text{and thus} \ \rho_2=\rho_1/(1-\Delta v) \qquad (4)$$

where $\rho_2$ and $\rho_1$ are the bulk densities after and before loading.

An increasing bulk density can result in subsidence (shrinkage in the vertical direction) and in crack formation (shrinkage in the horizontal direction). If the compaction occurs only in the vertical direction, the soil will only subside and will not crak. The soil can also shrink equally in all three directions. Rather than shrinking entirely in one direction or uniformly in all three directions, the soil may show a distribution of cracking and subsidence which lies somewhere between these two extremes. If the distribution factor for crack formation and subsidence is designated as $r_s$, so that $r_s=3$ if the soil shrinks equally in all directions and $r_s=1$ if solely subsidence occurs, then it may be shown that:

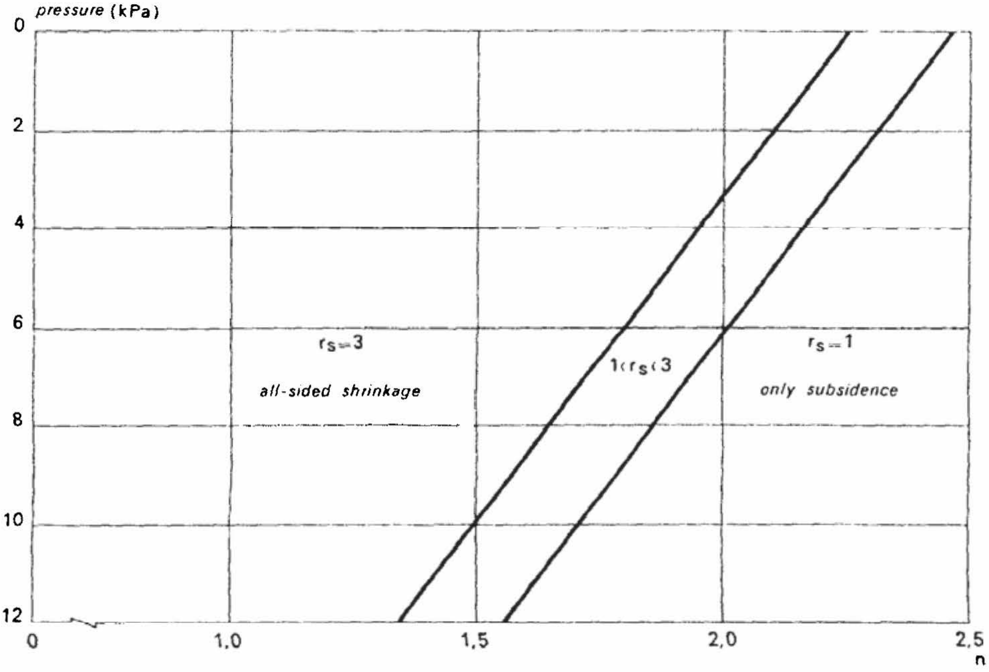
$$d_2=d_1.(1-\Delta v)^{\frac{1}{r_s}} \qquad (5)$$

and

$$\mu_2=1-\{(1-\mu 1)(1-\Delta v)\}/(1-\Delta v)^{\frac{1}{r_s}} \qquad (6)$$

where d is the thickness of the layer and $\mu$ is volume fraction of the "big cracks".
On research spots on ripening soils in the IJsselmeerpolders RIJNIERSCE (1976) found that in layers, characterised as soft, the increase in bulk desity in a dry summer occured entirely in the vertical direction, whereas in layers regarded as firm the shrinkage took place in three directions. This observation may be explained as follows: a soil that is still soft is not coherent enough to crack and continue to bear the load by the overlaying layers. If any cracks would be developed, the soil immediately flows in and closes them. Crack formation can only occur if the soil is firm enough to bear the load without flowing. The limit at which cracking can occur was determined by plotting the load by the overlying layer against the waterfactor (n) of the soil. The waterfactor is the number of grams of water bound to 1 gram of clay ($<2\ \mu m$). This relationship is shown in figure 1, from which it may be seen that as the load increases, the n-factor must became smaller in order to permit cracking, as one would expect from the above explanation.
The simulation model assumes a relationship represented by a line parallel

to the first mentioned line above which the factor $r_s$ has a value of 3. This line is also given in the figure. Using these relationships a good agreement was achieved between the results of the simulation and the values measured in the field.



## LITERATURE

Glopper, R.J. de, 1977. The application of consolidation constants derived from the pore space, in subsidence calculations. In: Proc. Land Subsidence Symposium, Washington.

Rijniersce, K., 1976. Het verband tussen het A-cyfer en het volumegewicht in jonge gronden na de droge zomer van 1976. R.IJ.P.-rapport 1976-34 Bbw, Lelystad.

Rijniersce, K., 1983. A simulation model for physical soil ripening in the IJsselmeerpolders. Flevobericht no. 203, Lelystad.