Modeling of Soft Filter Cake Behavior Using the Finite Element Method

Aram M. Raheem[1], C. Vipulanandan[1] and D. Richardson[2]
[1]Center for Innovative Grouting Material and Technology (CIGMAT)
Department of Civil and Environmental Engineering
University of Houston, Houston, Texas 77204-4003
Email: amraheem@uh.edu, cvipulanandan@uh.edu Phone: (713) 743-4278
[2]Program Manager – RPSEA, Sugar Land, Texas

Abstract: In this study, behavior of soft filter cake (low modulus and unit weight) under varying pressure was investigated using a two dimensional axisymmetric finite element model. The mud cake was modeled as a linearly elastic-perfectly plastic material with Mohr-Coulomb failure criteria. It was shown that the the fluid loss increased nonlinearly with time and applied pressure.

1. Introduction

Cake filtration is widely used in chemical and processing industries for solid/liquid separation. In the cake filtration, the suspension to be treated is forced, under pressure, through a septum which allows the passage of the suspending liquid but retains the suspended particles, leading to the formation of a filter cake at the upstream side of the septum. According to the conventional cake filtration theory, the resistance to liquid flow offered by a cake can be characterized by its specific cake resistance, which is inversely proportional to the product of the permeability (k), and porosity (n_s) of the cake (Zhao et al. 2003).The cake permeability is directly proportional to the void ratio which is considered one of the most critical cake properties to be quantified (Sherwood 1997).

2. Objective

The main objective of this study was to investigate the changes of the filter cake void ratio and fluid loss (consolidation) with the applied pressure using numerical method.

3. Methods and Materials

The properties summarized in Table 1 were used to model the soft filter cake using the finite element method incorporating Mohr-Coulomb elasto-plastic model coupled with flow of water using the Darcy law to model the cake consolidation. Figure 1 shows the finite element mesh for both stress and flow conditions.

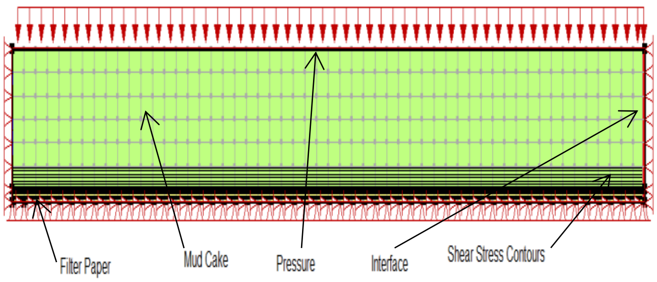
Table 1. Cake Material Properties

D (mm)	H (mm)	γ (kN/m^3)	E (kPa)	μ	C (kPa)	Nodes	Elements
54	3	11	1000	0.4	5	448	385

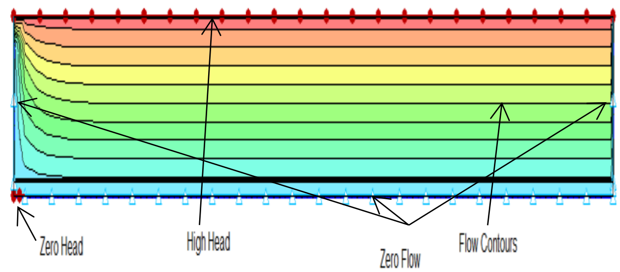
Where: D = diameter, H = thickness, γ= cake density, E= elastic modulus, μ= Poisson's ratio, C= cohesion.

4. Results

Finite element method was used to evaluate the variation in the cake void ratio with the time and the variations in the accumulative discharge versus time for different pressure as shown in Figure 2. Rate of reduction in void ratio of the filter cake increased almost linearly with pressure and time. Fluid loss from the filter cake increased nonlinearly with time and pressure.

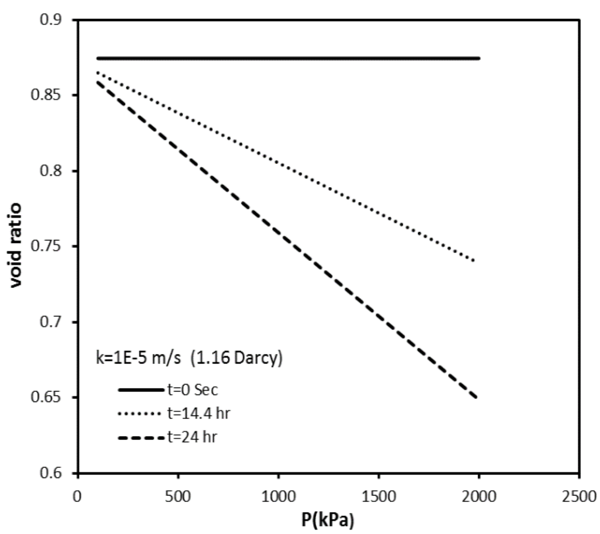


(a)

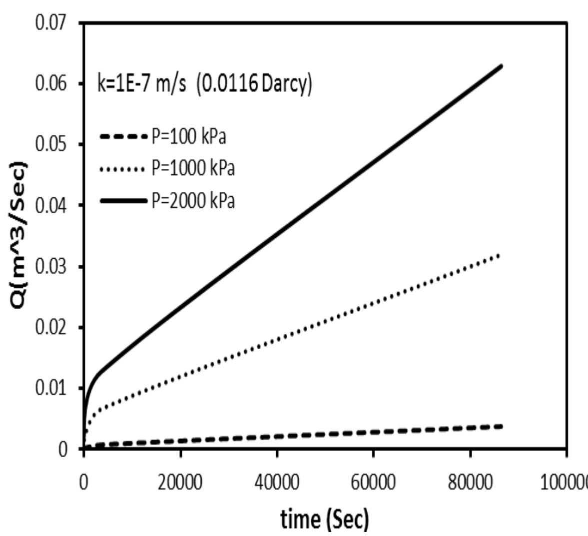


(b)

Figure 1. (a) Finite Element Mesh with Boundary Conditions of Stress Analysis, (b) Boundary Conditions of Transient Flow Analysis.



(a)



(b)

Figure 2. Behavior of Filter Cake (a) Void Ratio with Pressure and Time, (b) Fluid Loss with Time

5. Conclusions

Based on the numerical analyses following conclusions are advanced:

1- Reduction in void ratio was linear related to the applied pressure and time.
2- Fluid loss increased nonlinearly with time and applied pressure.

6. Acknowledgements

This study was supported by the Center for Innovative Grouting Materials and Technology (CIGMAT), University of Houston, Houston, Texas with funding from the Ultra Deepwater Program DOE/NETL/RPSEA (Project No. 10121-4501-01).

7. References

1. Sherwood J.D. (1997), "Initial and Final Stages of Compressible Filtercake Compaction", AIChE Journal, Vol.43, No.6, pp 1488-1493.
2. Zhao J., Wang C.H., Lee D.J., and Tien C. (2003),"Cake Consolidation in a Compression-Permeability Cell: Effect of Side-Wall Friction", Colloid and Interface Science Journal, Vol. 262, pp 60-72.