

# Experimental and numerical investigation of particle-fluid systems in geotechnical engineering

von

**Manuela Kanitz**

Herausgegeben von

**J. Grabe**

Technische Universität Hamburg  
Institut für Geotechnik und Baubetrieb

# Contents

<b>0</b>	<b>Preliminary remarks</b>	<b>1</b>
<b>1</b>	<b>Introduction</b>	<b>3</b>
<b>2</b>	<b>State of research</b>	<b>5</b>
2.1	Numerical modelling of multiphase problems . . . . .	5
2.2	Numerical modelling of soil-water interactions at particle-scale . . . . .	7
<b>3</b>	<b>Objectives</b>	<b>10</b>
3.1	Methodology for the performed research work . . . . .	12
3.2	Structure of this thesis . . . . .	12
<b>4</b>	<b>Numerical fundamentals of unresolved coupled CFD-DEM</b>	<b>14</b>
4.1	Discrete Element Method . . . . .	14
4.2	Coupling of CFD and DEM . . . . .	19
4.3	Fluid-particle interaction forces . . . . .	21
4.4	Void fraction schemes . . . . .	24
4.5	Immersed Boundary Method . . . . .	25
<b>5</b>	<b>Material parameter and instrumentation</b>	<b>26</b>
5.1	Calibration of material parameters . . . . .	26
5.2	Particle displacement measurements . . . . .	35
<b>6</b>	<b>Internal Fluidisation</b>	<b>38</b>
6.1	Introduction . . . . .	38
6.2	Experimental setup . . . . .	40
6.3	Numerical setup . . . . .	41
6.4	Experimental results . . . . .	44
6.5	Numerical results . . . . .	47
6.6	Summary . . . . .	60
<b>7</b>	<b>Suffusion</b>	<b>63</b>
7.1	Introduction . . . . .	63
7.2	Drag force in particle assemblies . . . . .	65
7.3	Influence of different drag force model on suffusion . . . . .	68
7.4	Experimental setup . . . . .	72
7.5	Numerical setup . . . . .	76
7.6	Experimental results . . . . .	80
7.7	Numerical results . . . . .	83

---

7.8	Influence of the seepage velocity on the drag force models . . . . .	97
7.9	Critical assessment of the investigations . . . . .	99
7.10	Summary . . . . .	99
<b>8</b>	<b>Suction dredging</b>	<b>101</b>
8.1	Failure mechanisms of subaqueous slopes . . . . .	101
8.2	Experimental setup . . . . .	102
8.3	Numerical setup . . . . .	105
8.4	Results . . . . .	107
8.5	Approaches to model shear-dilatancy response in fluid . . . . .	122
8.6	Verification of the new cohesion models . . . . .	129
<b>9</b>	<b>Extraction resistance of embedded objects</b>	<b>138</b>
9.1	Introduction . . . . .	138
9.2	Experimental setup . . . . .	139
9.3	Numerical setup . . . . .	142
9.4	Results . . . . .	143
<b>10</b>	<b>Conclusion</b>	<b>155</b>
	<b>References</b>	<b>159</b>
	<b>Norms and standards</b>	<b>169</b>
	<b>Appendix A Notation</b>	<b>170</b>
	<b>Appendix B Material tests</b>	<b>175</b>
B.1	Shear cell test . . . . .	176
B.2	Triaxial test . . . . .	190
B.3	Loosest and densest packing . . . . .	196
B.4	Permeability . . . . .	199
	<b>Appendix C Cohesion model implementation in LIGGGHTS®</b>	<b>203</b>