

Shear Band Propagation in Soils and Dynamics of Tsunamigenic Landslides

Erich Saurer

Veröffentlichungen des Instituts für Geotechnik (IGT) der ETH Zürich
Band 233, Juni 2010

Table of Contents

Preface	iii
Acknowledgment	v
Abstract	vii
Zusammenfassung	ix
List of Figures	xv
List of Tables	xviii
Notation and Abbreviations	xix
1 Introduction	1
1.1 <i>Rationale and Objectives</i>	1
1.2 <i>Structure of this Thesis</i>	4
2 Overview and State of the Art	5
2.1 <i>Tsunamis and their Sources</i>	5
2.1.1 Normal Faulting of Earth Plates.....	5
2.1.2 Volcanic Eruptions.....	6
2.1.3 Subaerial Landslides.....	6
2.1.4 Submarine Landslides and Slumps.....	7
2.2 <i>Mechanics of Tsunamigenic Landslides</i>	8
2.2.1 Failure Stages.....	8
2.2.2 Triggering Mechanisms of Submarine Landslides.....	9
2.3 <i>Progressive and Catastrophic Failure in Soils</i>	11
2.3.1 Progressive Failure in Slopes.....	12
2.3.2 Strain Localization and Shear Band Propagation.....	13
2.3.3 Fracture Mechanics Energy Balance Approach.....	15
3 Progressive Shear Band Propagation in Trapdoor Tests	19
3.1 <i>Introduction</i>	19
3.2 <i>Physical Trapdoor Tests</i>	20
3.2.1 Concept.....	20

3.2.2	Test Setup.....	21
3.2.3	Material Properties.....	22
3.2.4	Experimental Program and Test Interpretation.....	25
3.2.5	Test Results.....	26
3.3	<i>Analytical Modelling</i>	29
3.3.1	Formulation of the Problem.....	29
3.3.2	Assumptions.....	30
3.3.3	Cohesive Material.....	31
3.3.4	Validation of Energy Terms.....	41
3.3.5	Frictional-Dilatant Material.....	46
3.4	<i>Sensitivity Analysis</i>	54
3.5	<i>Comparison with Experimental Data</i>	57
3.6	<i>Analytical versus Numerical Solutions</i>	61
3.6.1	Method.....	61
3.6.2	Comparison.....	63
3.7	<i>Conclusions</i>	66
4	Progressive Shear Band Propagation in Shear Blade Tests.....	67
4.1	<i>Introduction</i>	67
4.2	<i>Physical Tests</i>	67
4.2.1	Test Setup.....	68
4.2.2	Material Properties.....	68
4.2.3	Sample Preparation and Test Procedure.....	70
4.2.4	Test Interpretation.....	71
4.3	<i>Analytical Modelling – Cohesive Material</i>	72
4.3.1	Geometry and Assumptions.....	72
4.3.2	Cohesive Material Plane Stress.....	74
4.3.3	Cohesive Material Plane Strain.....	80
4.4	<i>Analytical Modelling – Frictional-Dilatant Material</i>	81
4.4.1	Shear Strength and Dilation.....	81
4.4.2	Frictional-Dilatant Material Plane Stress.....	83
4.4.3	Frictional-Dilatant Material Plane Strain.....	92
4.5	<i>Parametric Study</i>	99
4.6	<i>Comparison of Analytical Curves with Experimental Data</i>	101

4.7	<i>Validation of Analytical Solution with Numerical Analysis</i>	103
4.8	<i>Conclusions</i>	107
5	Catastrophic Shear Band Propagation in Biaxial Tests	109
5.1	<i>Introduction</i>	109
5.2	<i>Physical Tests</i>	111
5.2.1	Test Setup.....	111
5.2.2	Sample Preparation and Test Procedure.....	112
5.2.3	Post-processing of Data.....	113
5.3	<i>Results of Physical Tests</i>	114
5.3.1	Test 13-2.....	114
5.3.2	Test 15-1.....	116
5.4	<i>An Upper Bound – Shear Wave Velocity</i>	118
5.5	<i>Comparison</i>	119
5.6	<i>Conclusions</i>	120
6	A Dynamic Solution of the Shear Band Propagation in Submerged Landslides	121
6.1	<i>Introduction</i>	121
6.2	<i>Dynamic Shear Band Propagation in an Infinite Slope</i>	123
6.2.1	Geometry and Soil Behaviour	123
6.2.2	Equation of Motion	124
6.2.3	Energy Balance Approach	125
6.2.4	Differential Equation of the Shear Band Propagation	128
6.2.5	Simplified Solution for the Velocity of the Shear Band Propagation.....	129
6.2.6	Limiting Condition for the Shear Band Propagation Velocity ..	130
6.3	<i>Parametric Study</i>	131
6.3.1	Soil Properties.....	131
6.3.2	Velocity of the Shear Band Propagation	132
6.3.3	Effects of the Viscosity of Water	133
6.3.4	Parametric and Sensitivity Study	136
6.4	<i>Conclusions</i>	138

7	Application to Historic and Recent Tsunamigenic Landslides.....	139
7.1	<i>Storegga Slide.....</i>	139
7.1.1	Calculation of Initial Landslide Velocity.....	141
7.2	<i>Western Goleta Slide</i>	142
7.3	<i>Slides in Lake Lucerne.....</i>	143
7.4	<i>Summary of Initial Velocity Calculations</i>	145
7.5	<i>Dependency of Tsunami Wave Height on Landslide Velocity.....</i>	146
7.6	<i>Conclusions.....</i>	148
8	Summary and Outlook.....	149
8.1	<i>Summary of the Main Findings.....</i>	149
8.2	<i>Outlook.....</i>	150
	References	153
	Appendices	161