

Contents

	Preface	8
1.	Introduction	9
1.1	General remarks	9
1.2	Causes of dam failures	9
1.3	Failure of embankment dams caused by overtopping	12
2.	Basic definitions and parameters of embankment dam failures due to overtopping	14
2.1	Time related parameters	14
2.2	Dimensional parameters of a breach	15
2.3	Discharge	15
3.	Failure statistics for dams and levees	16
3.1	Large dams	16
3.1.1	Existing statistics for dams	16
3.1.2	Dam failure classification	19
3.1.3	Dam failure statistics	19
3.2	Small reservoirs	34
3.3	Flood levees	35
3.4	Lessons learned from recorded failures	37
4.	Mechanisms of embankment dam failures due to overtopping	38
4.1	Causes and development of failures	38
4.1.1	Homogeneous embankment dams	41
4.1.2	Dams with artificial sealing elements	45
4.2	Evaluation of the erosion process	48
4.2.1	The beginning of erosion	48
4.2.1.1	Unlined surfaces	48
4.2.1.2	Lined surfaces	51
4.2.2	Transport of sediments	54
4.2.2.1	Bed load transport	55
4.2.2.2	Total bed load transport	56
4.2.2.3	Changes to the cross-sectional area of a breach	56
4.2.2.4	Comparison of the results of calculations and experiments	58
5.	Deterministic models of embankment dam failures due to overtopping	62
5.1	Introduction to deterministic models	62
5.2	Empirical equations	63
5.2.1	Estimation of time characteristics	63
5.2.2	Breach characteristics	65
5.2.3	Estimation of maximum breach discharge	67
5.3	Mathematical models of dam failure due to overtopping	70
5.4	A simplified model of dam failure	72
5.4.1	Analytical solutions	73
5.4.2	Numerical solution	76
5.4.3	Sensitivity analysis	77
5.4.3.1	Breach shape analysis	78
5.4.3.2	Effects of coefficients α_1 and β_1	80
5.4.3.3	Effects of coefficients α_2 and β_2	80
5.4.4	Concluding remarks	80
5.5	Numerical model applied using the BREACH program	81
5.5.1	Basic information about the program, and input data requirements	81
5.5.2	Computational algorithm	83
5.5.3	Breach discharge and the water level in the reservoir	84
5.5.4	Breach hydraulics	85
5.5.5	The beginning of downstream face erosion	86

5.5.6	Calculation of breach shape and size	86
5.5.7	Transport of particles	87
5.5.8	Further capabilities of the program, and requirements for calculation	87
5.5.8.1	Breach increase due to landslide	87
5.5.8.2	Calculation requirements	88
6.	Statistical modelling	89
6.1	The Monte-Carlo method	89
6.1.1	Latin Hypercube Sampling	89
6.1.2	Generating pseudo-random numbers	90
6.1.3	Probability distributions	91
6.1.4	Descriptive statistics	92
6.2	The "NATRZ" program	93
7.	Experimental research	94
7.1	General remarks	94
7.1.1	Remarks on similarity	94
7.1.2	Laboratory scale models	95
7.1.3	Large-scale field experiments	95
7.2	Research carried out at the Laboratory of the Institute of Water Structures FCE BUT	96
7.2.1	Description of the experimental equipment	96
7.2.2	Description of measuring facilities and devices	99
7.2.3	The course of the experiment	100
7.2.4	Measurements and observations	101
7.2.5	Evaluation of the experiment and records	107
8.	Practical applications of particular methods	111
8.1	Comparison of the experiment with the results of calculations	111
8.1.1	Comparison with the results of the analytical solution	111
8.1.2	Comparison with the results of the numerical solution	113
8.1.3	Results of statistical modelling	114
8.2	The Slusovice Dam	116
8.2.1	Characteristics of the dam site	116
8.2.2	Characteristics of the dam body and dam equipment	117
8.2.3	Analysis of potential causes of dam failure	118
8.2.4	Results of the solution	119
8.2.4.1	Preliminary estimate using empirical equations	119
8.2.4.2	Analytical procedure	120
8.2.4.3	Numerical solution using the BREACH program	121
8.2.4.4	The analogy method	122
8.2.5	Discussion of results	124
8.2.6	Statistical assessment	126
8.3	The Korycany Dam	128
8.3.1	Characteristics of the dam site	128
8.3.2	Characteristics of the dam body and dam equipment	129
8.3.3	Analysis of the potential cause of dam failure	130
8.3.4	Results of the solution	131
8.3.4.1	Preliminary estimate using empirical equations	131
8.3.4.2	Numerical solution using the BREACH program	132
8.3.4.3	Statistical modelling using the NATRZ program	132
8.3.5	Discussion of results	134
8.4	Levee failure by the village of Kvasice	135
8.4.1	Characteristics of the levee site	135
8.4.2	Characteristics of the levee body	135
8.4.3	Analysis of the levee failure	136
8.4.4	Results of modelling	137
8.5	Incidents of small dams during extreme floods in the Czech Republic	138
8.5.1	Basic data for analysis	139

