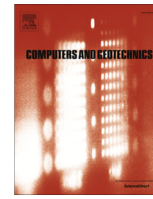
Computers and Geotechnics 69 (2015) 1–6

Contents lists available at ScienceDirect

Computers and Geotechnics

journal homepage: www.elsevier.com/locate/compgeo



Technical Communication

A neural network assessment tool for estimating the potential for backward erosion in internal erosion studies

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ARTICLE INFO

Article history:
Received 9 February 2015
Received in revised form 31 March 2015
Accepted 17 April 2015

Keywords:
Artificial neural networks
Backward erosion
Internal erosion
Piping
Dams

ABSTRACT

A new technique and approach for characterizing piping problems using artificial neural networks is introduced. Recent studies suggest that most large dam failures are a result of internal erosion, although this particular failure mechanism is often less highlighted in the standard procedures for dam designs. Over toppling, foundation analysis, spillway, structural and slope stability analyses are more commonly conducted. In addition, current internal erosion/piping risk assessments are limited because they often tend to be qualitatively based. This is because there is very little understanding of the mechanics of internal erosion with regard to seepage. The contribution of this work is a new approach/tool based on quantitative parameters and soil mechanics.

1. Introduction

Internal erosion or "piping" is a common term used by geotechnical engineers to describe the unwanted removal of soil particles from a soil matrix via seepage water flow, and is used to describe specific failure modes of water-retaining structures. The development of internal erosion can pose a serious threat to the stability of mine tailings dams, levees and other earthen embankments [18,19,10,12,4,3,11,21,14,16,9]. Richards and Reddy [14] have identified six distinct modes of internal erosion based on the mechanism of soil particle migration:

- Backward Erosion – the process of creating a pipe; where particles are progressively dislodged from the soil matrix via intergranular seeping water at the exit point and progressing backward toward the dam or reservoir,
- Internal Erosion (Proper) – where water flows through preexisting cracks in cohesive materials or voids along a soil-structure planar contact,
- Tunneling or jugging – occurs through the vadose zone and is as a result of chemical dispersion of clays by infiltration,
- Suffusion and Suffosion – gradual migration of fine material through a coarse matrix leading to failure. The result is a loose framework of granular material with high seepage flow. Suffosion refers to the movement of fines in a gap graded soil and does not result in a loose framework of granular material, and
- Heave – Occurs when a semi permeable barrier overlies a pervious zone under relatively high fluid pressure.

The surface expressions of internal erosion are widely known and well described (via sand boils, excess seepage, slope instability, surface rills, depressions, and crevasses). However, the processes of internal erosion that are hidden beneath the surface are difficult to observe and analytically define. The subsurface processes of backward erosion have been widely defined as **initiation** of a concentrated leak caused by a loading event, **continuation** of the erosion toward the source of water because the hydraulic gradient increases as more particles are removed, **progression** toward failure because flow continues to increase through a larger void (pipe), and **failure** through breaching of the crest caused by collapse of the pipe.

However, the factor of safety against general internal erosion is usually based upon the limits of **initiation** because of the complexity of the other processes, and because it makes sense to focus on stopping the initiation. The US Army Corps of Engineers levee design guidelines [20] apply the critical gradient concept [18] to describe the initiation of backward erosion, and to determine the factor of safety against consequential internal erosion for USACE levees and dams. The critical gradient according to Terzaghis' theory is equal to 1, and the factor of safety is equal to the ratio of the exit gradient to the critical gradient. Currently, the USACE

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http://dx.doi.org/10.1016/j.compgeo.2015.04.010
0266-352X/

Table 1
Soil kinetic energy data used to develop the neural network model based on velocity, porosity, and seepage path angles.

Porosity	Initial void ratio	Critical kinetic energy (J) By seepage angle from horizontal				
n	e	0°	−10°	−5°	5°	10°
0.17	0.20	0.34	0.18	0.26	0.42	0.49
0.17	0.21	0.33	0.18	0.26	0.41	0.49
0.17	0.21	0.33	0.18	0.25	0.40	0.48
0.18	0.22	0.33	0.18	0.25	0.40	0.47
0.18	0.22	0.32	0.17	0.25	0.39	0.47
0.19	0.23	0.32	0.17	0.24	0.39	0.46
0.19	0.24	0.31	0.17	0.24	0.38	0.46
0.19	0.24	0.31	0.17	0.24	0.38	0.45
0.20	0.25	0.30	0.16	0.23	0.37	0.44
0.20	0.25	0.30	0.16	0.23	0.37	0.44
0.21	0.26	0.30	0.16	0.23	0.36	0.43
0.21	0.27	0.29	0.16	0.22	0.36	0.43
0.21	0.27	0.29	0.16	0.22	0.35	0.42
0.22	0.28	0.28	0.15	0.22	0.35	0.41
0.22	0.28	0.28	0.15	0.22	0.34	0.41
0.22	0.29	0.28	0.15	0.21	0.34	0.40
0.23	0.30	0.27	0.15	0.21	0.33	0.40
0.23	0.30	0.27	0.14	0.21	0.33	0.39
0.24	0.31	0.26	0.14	0.20	0.32	0.38
0.24	0.31	0.26	0.14	0.20	0.32	0.38
0.24	0.32	0.25	0.14	0.20	0.31	0.37
0.25	0.33	0.25	0.14	0.19	0.31	0.37
0.25	0.33	0.25	0.13	0.19	0.30	0.36
0.25	0.34	0.24	0.13	0.19	0.30	0.35
0.26	0.34	0.24	0.13	0.18	0.29	0.35
0.26	0.35	0.23	0.13	0.18	0.29	0.34
0.26	0.36	0.23	0.12	0.18	0.28	0.34
0.27	0.36	0.23	0.12	0.17	0.28	0.33
0.27	0.37	0.22	0.12	0.17	0.27	0.32
0.27	0.37	0.22	0.12	0.17	0.27	0.32
0.28	0.38	0.21	0.11	0.16	0.26	0.31
0.28	0.39	0.21	0.11	0.16	0.26	0.30
0.28	0.39	0.20	0.11	0.16	0.25	0.30
0.28	0.40	0.20	0.11	0.15	0.25	0.29
0.29	0.40	0.20	0.11	0.15	0.24	0.29
0.29	0.41	0.19	0.10	0.15	0.24	0.28
0.29	0.42	0.19	0.10	0.14	0.23	0.27
0.30	0.42	0.18	0.10	0.14	0.23	0.27
0.30	0.43	0.18	0.10	0.14	0.22	0.26
0.30	0.43	0.18	0.09	0.14	0.22	0.26
0.31	0.44	0.17	0.09	0.13	0.21	0.25
0.31	0.45	0.17	0.09	0.13	0.21	0.24
0.31	0.45	0.16	0.09	0.13	0.20	0.24
0.31	0.46	0.16	0.09	0.12	0.20	0.23
0.32	0.46	0.15	0.08	0.12	0.19	0.23
0.32	0.47	0.15	0.08	0.12	0.19	0.22
0.32	0.48	0.15	0.08	0.11	0.18	0.21
0.33	0.48	0.14	0.08	0.11	0.18	0.21
0.33	0.49	0.14	0.07	0.11	0.17	0.20
0.33	0.49	0.13	0.07	0.10	0.16	0.20
0.33	0.50	0.13	0.07	0.10	0.16	0.19
0.34	0.51	0.13	0.07	0.10	0.15	0.18
0.34	0.51	0.12	0.07	0.09	0.15	0.18
0.34	0.52	0.12	0.06	0.09	0.14	0.17
0.34	0.52	0.11	0.06	0.09	0.14	0.17
0.35	0.53	0.11	0.06	0.08	0.13	0.16
0.35	0.54	0.10	0.06	0.08	0.13	0.15
0.35	0.54	0.10	0.05	0.08	0.12	0.15
0.35	0.55	0.10	0.05	0.07	0.12	0.14
0.36	0.55	0.09	0.05	0.07	0.11	0.14
0.36	0.56	0.09	0.05	0.07	0.11	0.13
0.36	0.57	0.08	0.05	0.06	0.10	0.12
0.36	0.57	0.08	0.04	0.06	0.10	0.12
0.37	0.58	0.08	0.04	0.06	0.09	0.11
0.37	0.58	0.07	0.04	0.06	0.09	0.10
0.37	0.59	0.07	0.04	0.05	0.08	0.10
0.37	0.60	0.06	0.03	0.05	0.08	0.09
0.38	0.60	0.06	0.03	0.05	0.07	0.09
0.38	0.61	0.06	0.03	0.04	0.07	0.08
0.38	0.61	0.05	0.03	0.04	0.06	0.07
0.38	0.62	0.05	0.03	0.04	0.06	0.07
0.38	0.63	0.04	0.02	0.03	0.05	0.06