Effects of Burrowing Animals on Seepage Behavior of Earthen Dams

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INTRODUCTION

Earth-fill dams are the most preferred dam types around the world since they can be constructed at almost every site conditions. However, since they are natural habitat for rodent animals such as muskrat, beaver, badger, gopher, etc., earth-fill dams tend to be damaged or even destroyed by them. The dig tunnels and holes of these animals on earthen dams can extend into the dam body up to couple of meters. The burrows may lead to the failure of the structure which may result in huge economic losses or even loss of lives. Many of the studies in the literature define rodent animals active on dams and their impacts. The objective of this study is to reveal the effects of rodents on pore water pressure distribution throughout the dam body, phreatic line position, seepage rate passing through the dam and the length of the seepage face developing at the downstream side of the dam. Comparisons are made between burrowed and undisturbed dam body cases for the rodents considered. The findings of the study showed that the animal burrows in embankments have adverse effects on the seepage rate and the pore water pressures.

BURROWING ANIMALS ACTIVE ON EARTHEN DAMS

In nature, there are several types of rodent animals that damage embankment dams and cause various seepage or stability related problems. In this study, only three of the common ones, which are badgers, beavers, and muskrats, are considered. These three types of animals have different effects on embankment dams due to their varying digging properties. A badger can dig holes having 20-30 cm diameter and 9.0 m length, a beaver is able to open cavities in the soil having 30 cm diameter and 1.2 m depth, and a muskrat can excavate holes with 45 cm diameter and 3.0 m depth. An illustration is provided in Figure 1 for the burrows of muskrat and badger in an earth-fill dam.

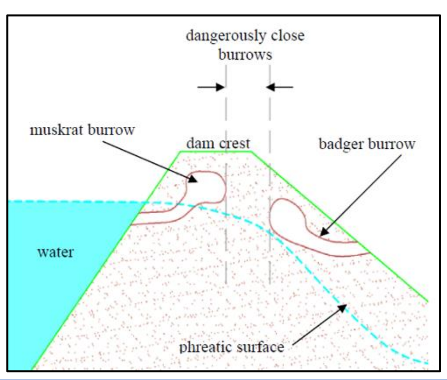

Figure 1. Demonstration of burrow of muskrat and badger (Montana Watercourse and Department of Natural Resources and Conservation, no date)

MODELING OF SEEPAGE

The dam is analyzed for the seepage passing through its body. This phenomenon can be modeled using Darcy's law (Richards, 1931). The constitutive equation of the seepage is given below.

$$\frac{\partial}{\partial x}\left(K_x\frac{\partial H}{\partial x}\right)+\frac{\partial}{\partial y}\left(K_y\frac{\partial H}{\partial y}\right)+Q'=\frac{\partial \theta}{\partial t} \qquad (1)$$

where, H is the total head, K_x and K_y, are the hydraulic conductivities in x and y directions, respectively, Q' is the external boundary flux, θ is the volumetric water content, and t is the time. Eq. (1) can be solved to determine the pore water pressures, total heads, and flow rates in an earth-fill dam. In this study, the software SEEP/ W (Geo-Slope Int. Ltd, 2013) is used to conduct steady-state seepage analyses. The software adopts finite element method to solve the nonlinear governing differential equation of the seepage given in Eq. (1). Also, van Genuchten Method (van Genuchten, 1980) is utilized to determine the characteristics of the unsaturated part of the embankment.

APPLICATION STUDY

Earthen Dam Model

A homogenous 20.5 m high earth-fill dam is selected as the application problem. The dam is considered to be at its normal operation condition with an 18.25 m of water level in its upstream and with no tail water. The dimensions and side slopes of the dam are determined using USBR's small dam design specifications (USBR, 1987). The upstream and downstream side slopes are selected as 1V:2H. The foundation of the dam is assumed to be impervious bedrock. The fill material is selected as isotropic sandy clay.

Burrow Simulation

Four different cases of the embankment dam are considered, i.e., undisturbed, disturbed by a badger, a beaver, and a muskrat. In the undisturbed model, it is assumed that there are no burrows or dig holes created by rodent animals. Then, the dam is modelled for seepage for the cases including burrows of badger, beaver and muskrat. In order to simulate the burrows in SEEP/W software, the parts disturbed by rodents are kept empty in the dam geometry.

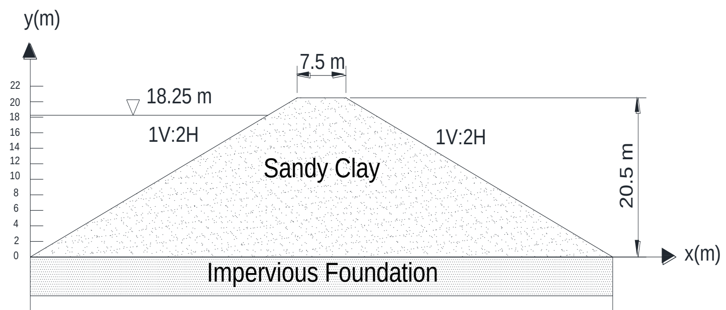

Figure 2. The geometry and material properties of selected dam body

RESULTS & DISCUSSION

The selected cases are analyzed for steady-state seepage through the embankment dam body. The results included the phreatic surface locations, the seepage rates passing through the dam centerline, the lengths of the seepage faces, and the pore water pressures at pre-determined points. The effect of three burrowing animals on the phreatic line of the seepage is presented in Figure 3 along with that of the undisturbed case. According to the results, the phreatic lines of the models which represent burrows of beaver and muskrat shift upwards, whereas that of obtained for the badger burrow case shifts downwards.

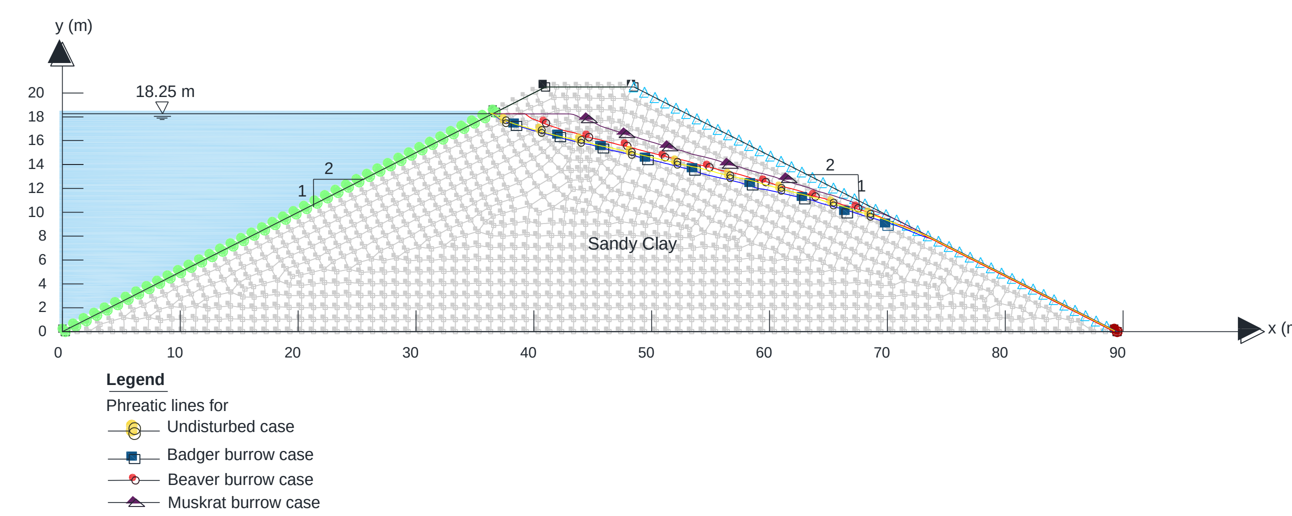

Figure 3. Phreatic surfaces of four different cases

The change in seepage rate at centerline and the seepage face length are presented in Figures 4 and 5. The predefined points and pore water pressures at these point are given in Figures 6 and 7.

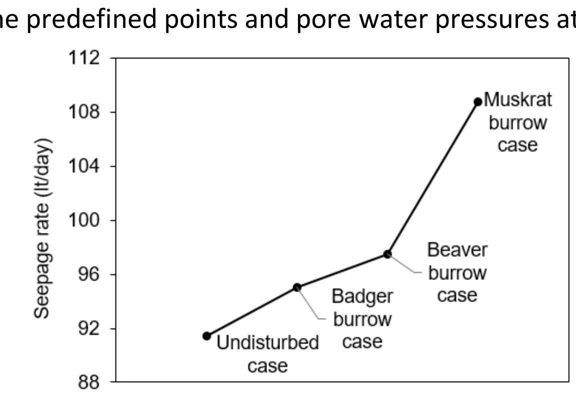

Figure 4. Seepage rates passing through the centerline for four different cases

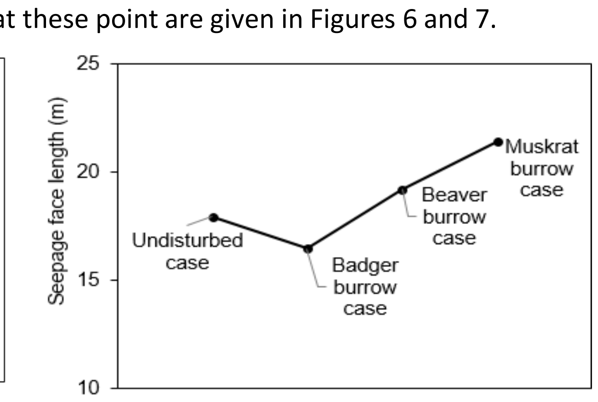

Figure 5. Seepage face lengths for four different cases

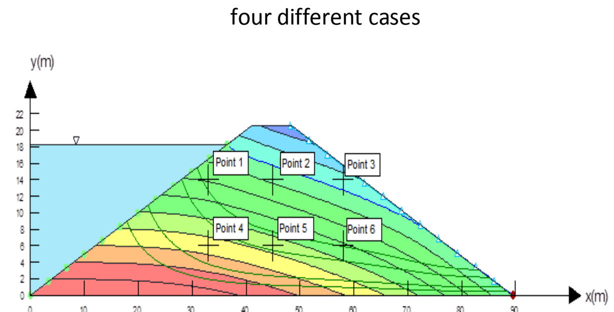

Figure 6. Predefined points to obtain pore water pressures

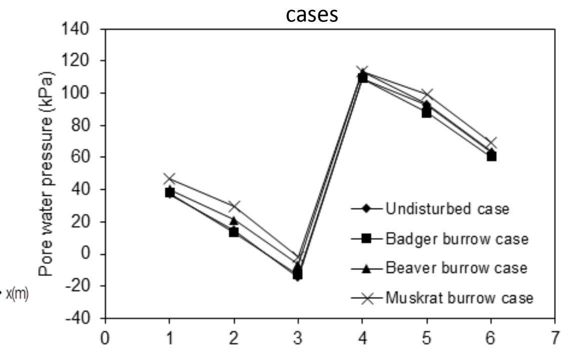

Figure 7. The change of pore water pressures with respect to different cases

CONCLUSION

The results of the analyses showed that the rodents adversely affect the seepage behavior of the dam. If the burrows are created from the upstream side of the dam, commonly, the elevations of the phreatic surface increases. When the burrows are based at the downstream part, the elevations of the phreatic surface slightly decrease. Also, the hydraulic gradients increase when a dam subject to animal burrows and this cause an increase in the seepage rate. All rodents considered caused an increase in the seepage rate. If the dam is burrowed from the upstream side, seepage face length increases. Contrary to this, when the burrows are on the downstream side, the seepage face length may decrease. Among the considered rodents, the most hazardous rodent is seen to be the muskrat due to its impacts on pore water pressures, seepage rate and seepage face length.

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