Nat. Hazards Earth Syst. Sci. Discuss.,
https://doi.org/10.5194/nhess-2020-143-AC3, 2020

Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Experimental assessment of the relationship between rainfall intensity and sinkholes caused by damaged sewer pipes" *by* Tae-Young Kwak et al.

Tae-Young Kwak et al.

goldenrain91@gmail.com

Received and published: 17 September 2020

1. General comments

This paper reports a series of experiments to analyze the sinkhole formation associated with rainfall intensity by simulating a leakage of an underground damaged sewer pipe. A slit at the bottom of the experiment chamber was considered as damage of pipe, and three different rainfall intensities were designed by controlling the hydraulic head connected to the slit of the chamber. The ground settlement was measured, and the deformation of soils around the pipe is captured by the particle image velocimetry (PIV) technique. Overall, the authors in this work present a rising issue of the sinkhole and

Printer-friendly version

Discussion paper

its relationship to rainfall by utilizing an experimental model set-up. I believe this paper will be of interest to the audience and would support publication after the following comments are addressed.

Answer: Thank you very much for your thorough and helpful review. Based on your concerns and comments, we believe that our manuscript has been improved. Please check our answers corresponding to your concerns.

1) Authors should clearly address and explain how the test procedure is designed to simulate the rainfall and the sewer pipes. a. In the test procedure, the hydraulic head was selected as a variable to represent the rainfall intensity, which eventually formed different target groundwater levels. Therefore, the amount of water introduced into the chamber and the duration of water supply stage may indicate additional information related to the rainfall intensity. For example, if the water supply stage of Test 3 took longer than that of Test 1, this set-up may not properly reflect the actual rainfall intensity and its influence on the groundwater level around the pipes. In addition, the flow from the damaged sewer pipe may not be the only source of water supply into the underground.

Answer: The ground condition of each test is the same; thus, the amount of water introduced into the chamber which has a linear relationship with the groundwater level is also a function of the rainfall intensity. In addition, the time to form the target groundwater levels during the water supply stage was almost the same. In this study, we investigated the soil erosion due to damaged sewer pipes in urban areas by performing model tests. The large area of the ground surface in an urban areas is covered with impervious pavement. Thus, we presumed the flow from damaged sewer pipes to be the main source of water supply into the underground.

b. In this work, the damage of sewer pipes is approximated as a slit of which the size is determined followed by the previous study. While this damage could be the main source of water supply into the ground, the drainage may not occur through this damage. In other words, the water drainage set-up using the slit and drainage valve

may lead to an extra discharge of soils and water. If the groundwater is discharged through a thin slit at the bottom of the chamber, it may be easily expected that the soil around the slit may easily collapse and deformed.

Answer: In this study, the model test procedure consisted of (1) the water supply stage, in which sewer water infiltrates from the pipes to the ground through damaged sections during heavy rainfall periods, and (2) the water drainage stage, which describes the drainage of groundwater into the sewer pipes through the damaged sections after heavy rainfall periods. As the reviewer noted, overflows may occur in the other direction rather than through damaged sections. After heavy rainfall, however, the hydraulic pressure of a sewer pipe becomes lower (as the sewer pipe becomes vacant); thus, it is the most likely that the groundwater will flow back through the damaged portions. The authors found that a description of what each step actually meant in field conditions was lacking. Thus, appropriate descriptions have been added in the manuscript.

2. Specific comments

1) Line 149: What's the meaning of multiple cycles?

Answer: Based on your comment, the authors removed the term "multiple cycles."

2) Line 173: As point out by the authors, the test-set up is likely to the piping simulation. Then, is it possible to analyze the sinkholes and rainfall intensity though the piping analysis? For example, using the critical hydraulic gradient?

Answer: The authors think that the piping analysis is valid only for the water supply stage. During the water supply stage (which describes the situation during rainfall), the effective stress decreases because upward seepage occurs through the slit; therefore, piping could occur. During the water supply stage, the water pressure (as compared to the soil pressure) was not sufficient to induce the piping in test 1 and 2; however, in test 3, piping occurred during the water supply stage, which implies that the water pressure has sufficient magnitude to reduce the soil effective stress to zero. During the

water drainage stage, however, the use of the piping concept for sinkhole analysis is limited. The critical hydraulic gradient is usually valid when the seepage has a direction different from that of the gravitational force; however, the seepage and gravitational force have the same direction near the slit during the water drainage through the slit. In this case, soil particles freely fall with water and the ground cavity (or cave-in) expands until (apparent) cohesion recovers because of partial saturation. For all tests described in the manuscript, ground cavities (or cave-ins) occurred.

3) Line 255: How is the resistance factor determined? If there's an equation, it could be helpful for readers. 4) Line 262: Is the matric suction analyze in a quantitative manner? Because of cohesion, this may limitedly affect the behavior of soils.

Answer (for both 3) and 4)): The authors think that the ability of the model tests to enable quantitative evaluation of the resistance factor or matric suction is limited. The authors are planning a numerical parametric study (such as coupled analysis between soil and groundwater) for this purpose.

5) Lines 279-280: The meaning is not clear.

Answer: The authors decided that Lines 279 and 280 were unnecessary and removed them from the manuscript.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2020-143, 2020.