Effects of air entrapment in a soil pipe on initiation of soil pipe flow

*Takuhei Yamasaki[1], Hiromi Imoto[1], Shoichiro Hamamoto[1], Taku Nishimura[1]

1.The University of Tokyo

Introduction

Soil pipes, continuous macropores parallel to the slope, are often observed at hillslope. Recent intensive field studies showed that soil pipes had an important role in hillslope hydrological processes as well as slope stability. Laboratory experiments using artificial soil pipes have investigated the effects of soil pipe properties on groundwater table under steady state water flow, slope stability and erodibility of the pipe wall. However, most laboratory studies as well as field researches rarely examined the state of water flow in the soil pipe directly, especially in the closed soil pipes. It is because that it is difficult to observe inside of natural soil pipes without destruction of the slope. Even at laboratory, soil water pressure around the soil pipe indirectly estimated occurrence of soil pipe flow. The objective of this study is to clarify water flow dynamics in the closed soil pipe directly by the laboratory experiment using soil box with an artificial soil pipe.

Materials and Methods

An acrylic plastic pipe, 7 mm inner diameter, 10 mm outer diameter, and 50 cm long, was used as an artificial soil pipe. Drain holes with 3 mm diameter were evenly opened on the pipe wall. Soil pipe was covered by nylon mesh to prevent sediment inflow. Soil pipe was connected to pressure transducer measure air pressure in the soil pipe. Two-needle electrodes were set inside the soil pipe to detect water flow in the soil pipe.

Acrylic plastic rectangular box, 100 cm long, 5 cm wide and 22 cm high, was used. This box was divided into 90 cm long soil section and 10 cm long reservoir section by stainless steel mesh. At the downward outlet, three drain holes were opened at 3 cm high and covered nylon mesh. Toyoura sand was packed to the soil section with a dry bulk density of 1.43 g cm^{-3} to a thickness of 18 cm. Artificial soil pipe was buried at center of soil section and 1.5 cm high from the base of the soil box. Water was supplied to the reservoir at constant inflow rate until steady state water flow was achieved. During experiments, outflow rate, soil water pressure and water level in the reservoir were measured. Four experimental conditions changing occurrence of soil pipe (NoPipe or ClosePipe), air continuity between inside of soil pipe and atmosphere (AirPipe), and inflow rate (3.6 or 0.9 L h^{-1}) were examined.

Results and Discussion

Groundwater table In ClosePipe, only under high inflow rate (3.6 L $h\text{-}^{1}$), soil pipe flow occurred then groundwater level decreased compared to that without soil pipe. Initiation of soil pipe flow depended on inflow rate. Once soil pipe flow occurred, soil pipe flow did not cease after inflow rate decreased. In AirPipe, soil pipe flow started even under low inflow rate.

Water and air pressure and electrode response In ClosePipe under high inflow rate condition, water saturation at the upper end of the soil pipe firstly occurred, while air pressure in the soil pipe still equaled to barometric pressure. Soon after that electrode in the soil pipe responded, showing initiation of soil pipe flow. The timing of electrode response corresponded to that of water saturation at same position estimated by temporal variation of water pressure in soil matrix. On the other hand, under low inflow rate, air pressure in the soil pipe firstly rose, which means air in the soil pipe had been isolated from atmosphere. Entrapped air hardly escape to atmosphere, then prevented invasion of water into the soil pipe. No electrode response under this condition supported no water flow in the soil pipe.

Water flow in closed soil pipes starts only when water saturation at a part of soil around soil pipe occur before whole soil around soil pipe reaches enough water content for air entrapment. Otherwise, soil pipe with air pathway such as vertical macropores like AirPipe experiment could initiate pipe flow.

Keywords: Soil pipes, entrapped air, laboratory experiment

