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# Experimental study of barrier effect on moisture movement and mechanical behaviors of loess soil

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ABSTRACT

The moisture movement is of great significance to the long-term performance of loess subgrade since it leads to prominent changes in mechanical behaviors of soil. The capillary barrier system has proven to be effective to resist the moisture movement from capillary rise and water infiltration. In this paper, the capillary barrier effect on the moisture movement and mechanical behavior in loess soil was investigated experimentally. In the experiment of capillary rise, the water front rises quickly in the loess specimen and keeps stable after 32 days. However, there is no significant rise of capillary water in the specimen compacted with gravel layer. The difference of moisture movement is evaluated by measuring the volumetric water content using the Time Domain Reflectometry (TDR) system. The effect of coarse sand barrier on the water infiltration is also investigated, and it is found that, the coarse sand barrier could effectively decreases the rate of water downwards infiltration and provides the temporary water storage so that the water won't infiltrate into the loess layer immediately comparing with the loess specimen. After that, the mechanical property of the specimens is evaluated through the cone penetration test and loading test. The cone tip resistance and load-settlement relationship are analyzed, and the influence of capillary barrier on the characteristic of loess soil is explored. It is concluded that the existence of capillary barrier could effectively decreases the possibility of moisture movement and improve the mechanical behavior of loess soil in terms of strength and deformation.

## 1. Introduction

Loess soil is a kind of special water-sensitive soil and the moisture increase in loess soil will lead to the volume reduction under a given load (Clemence and Finbarr, 1982; Houston et al., 2001; Cerato et al., 2009). For the highway construction in the northwestern China, the loess soil is widely used as the construction material of subgrade, and the subsidence or collapse of loess soil induced by water movement will significantly influence the highway performance. As shown in Fig. 1, the subgrade is exposed to the natural environment and subjects to complex process of moisture migration from rainfall infiltration, capillary rise and evaporations. Therefore, the study on moisture migration in loess soil is of great importance to the understanding of long term behavior of subgrade in loess area.

Numerous works have been conducted to explore the relationship between the moisture movement and mechanical properties of loess subgrade. The infiltration of rainfall can lead to significant decrease of shear strength and resilient modulus of loess subgrade (Zhou et al., 2014; Li et al., 2009), and the capillary rise from groundwater can influence the humidity field of loess subgrade (Li et al., 2014), which lead to the reduction of bearing capacity and softening deformation. Accordingly, a variety of methods have been proposed to stabilize or improve the loess soil in subgrade or foundation during the construction stage, such as lime treatment (Tonoz et al., 2003; Abiodun and Nalbantoglu, 2014), dynamic compaction (Li et al., 2012; Feng et al., 2015), partial replacement (Ali, 2015) and additives (Sokolovich and Semkin, 1984; Semkin et al., 1986; Sun and Zhang, 2014; Ayeldeen et al., 2017). However, most of the methods cannot solve the deleterious consequences in subgrade resulted from moisture migration in terms of long term performance.

The capillary barrier system has proven to be effective to prevent or decrease the moisture movement in soils (Benson et al., 2002). The capillary barrier comprises the layers of fine-grained soil and coarse-grained soil. The particle size difference of the soils in the capillary barrier results in the difference in the hydraulic properties (i.e., soil-water characteristic curves and coefficient of permeability), and capillary barrier effect exists at the interface of the two soil layers influences the moisture movement significantly. For its advantages of low cost,

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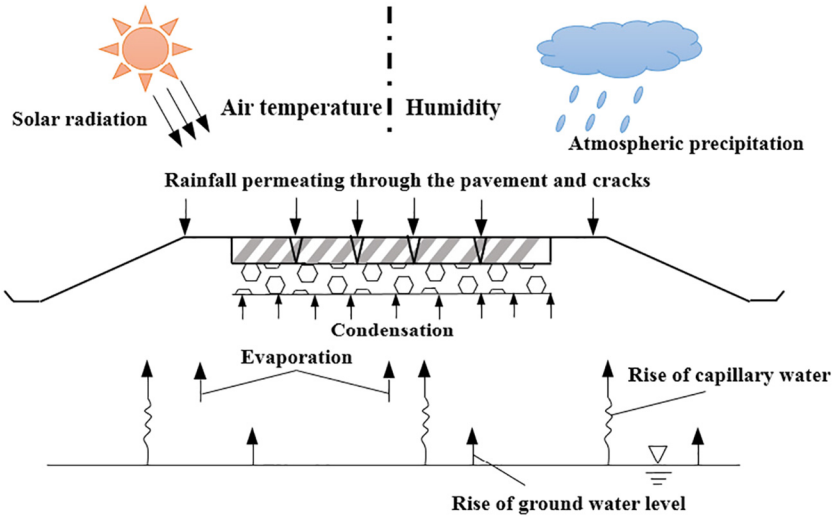


**Fig. 1.** The moisture migration in subgrade due to natural environment.

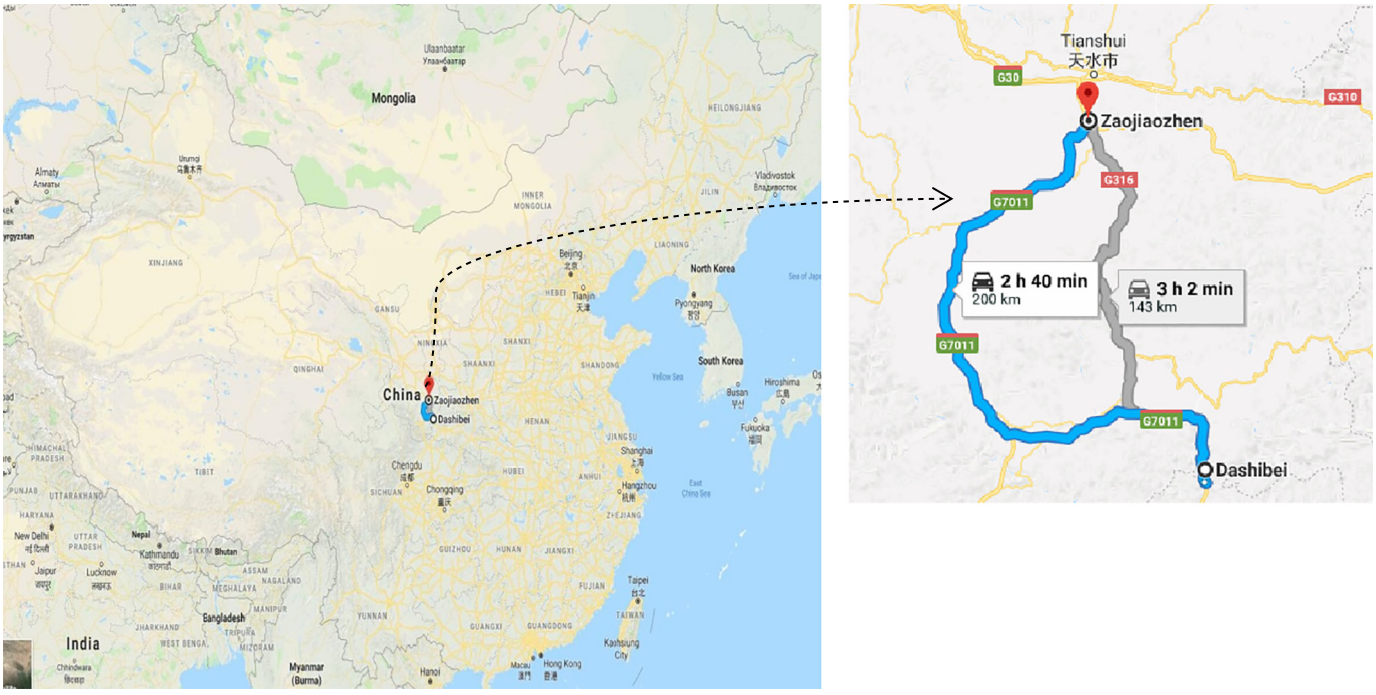


**Fig. 2.** The location to obtain the loess soil.

**Table 1**
Physical properties of loess soil.

| Physical indexes of soil in native state | | | Plastic limit (%) | Liquid limit (%) | Plasticity index | Grain composing of soil (%) | | |
|---|---|---|---|---|---|---|---|---|
| Dry density (g/cm$^3$) | Specific gravity | Moisture content (%) | | | | Sand | Silt | Clay |
| 1.33 | 2.7 | 16.5 | 19.2 | 30.7 | 11.5 | 10.13 | 71.15 | 18.72 |

easy construction and long service time, the capillary barrier has been widely used in landfills (Vachon et al., 2015; Ng et al., 2015), tailings disposal (Oldecop et al., 2017) and nuclear waste repository (Qian et al., 2010). Meanwhile, it has also been used to control the vertical water infiltration (Khire et al., 1997; Stormont and Anderson, 1999) and to solve the rainfall-induced stability problems of loess slope (Rahardjo et al., 2007). However, the application of capillary barrier in loess subgrade is rarely reported and the mechanism behind it is not systematically investigated.

Therefore, the main objective of this paper is to evaluate the performance of capillary barrier in preventing the moisture movement in loess soil and its ability to improve the engineering behavior of loess soil. To this end, the moisture movement due to capillary rise is experimentally investigated for both the loess specimen and the loess specimen sandwiched with capillary barrier. The (Time Domain Reflectometry) TDR system is used to obtain the moisture content at