



NOTE

On the Kinetics of Loess Disintegration

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The disintegration kinetics of loess was investigated in presence of various initial water contents. The disintegration rates were determined by reading the volume of the disintegration as a function of time. Effect of the water content on the kinetic stability of loess was also discussed. The disintegration behaviour was well fitted by the empirical equation $W_t = W_{\max}t^n/(K^n + t^n)$. Three distinct stages of loess disintegration behaviour determined by independent mechanisms were identified from analysis of the rate of loess disintegration as a function of time. The mechanism of influence on the disintegration made by initial water ratio is analyzed.

Key Words: Loess, Disintegration, Kinetic model.

As an engineering material, loess is often thought as one of the more problematic geologic deposits with which the geotechnical profession must deal. Perhaps much of this apprehension can be attributed to the emphasis which has been placed on the metastable behaviour or potential for sudden structural collapse, of certain loess deposits upon wetting. Cases of collapse have been documented extensively in the China and in other parts of the world and is typically associated with saturation by water, from broken water pipes or other artificial flooding from the surface or from upward water saturation from perched water. In fact, the technique of artificially wetting loess soils prior to construction has been utilized in some areas to induce ground movement in an attempt to eliminate future problems. In general, highly collapsible loess has been noted to occur in areas near the loess source where loess thickness is a maximum and where the landscape are not conducive to development of long term saturated conditions within the loess¹.

Loess can cause a number of problems associated with its sudden settlement. An example is a three storey building in Xining, Qinghai, destroyed beyond repair due to subsidence of the foundation soils upon wetting. Problems result because loess undergoes structural collapse when wetted. This happens when the initial dry density is low and initial water content is low. There is still some argument as to why loess collapses. However, so far it received insufficient attention particularly. To elucidate this problem it is necessary to examine both macroscopic and microscopic aspects of loess collapse². The

objective of this work is to reveal the disintegration kinetics by measuring the volume of the disintegration as a function of time. Effect of the water content on the kinetic stability of loess was also discussed.

Soil samples were taken from Shaanxi Province in the Northwest. Water content of loess was monitored with a TDR100 time domain reflectometer, a CR10X data logger, SDMX50 coaxial multiplexers and PC400 software and eight homemade three-rod time domain reflectometry (TDR) probes. In order to compare accuracy of TDR measurement, we adopt weight loss method to bake loess samples for 12 h at 378 K, then weighing the mass difference between before and after calculating the antecedent water content. Particle size distribution of the loess was determined by a Malvern Mastersizer S laser diffraction system (Malvern Instruments Ltd., Malvern, UK). The average particle size of a sample was quantified by a volume-weighted mean diameter or $D(4, 3)$.

Immersion of aggregates in water is the simplest way to check their stability. It may be recommended as a simple, rapid and qualitative field test. Although often criticized because it emphasizes the slaking compared to others, it appears in almost all the methods. It is a good way to compare the behaviour of a large range of soils on rapid wetting (heavy rain storms in summer). The calibrated loess samples are gently immersed in a 250 mL beaker filled with 50 mL of deionized water³. The disintegration behaviour was measured by reading the volume of the disintegration as a function of time under the different water content. Reported values in this paper are the means of at least two replicates.

Under water saturation, most specimens were disaggregated or the particles dispersed quickly. Fig. 1 shows disintegration behaviour of loess as a function of time. It was seen from Fig. 1 that the diverse loesses tested all resulted in disintegration curves of the same form which exhibits an "S"-shaped profile. It may be inferred from this that basic mechanism of disintegration behaviour was similar in all these cases.

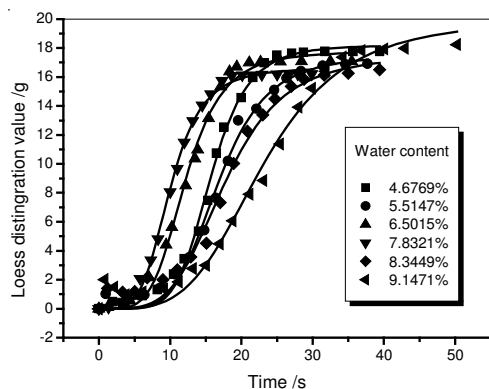


Fig. 1. Time dependence of the disintegration volume of loess at various water ratios

To describe the curves in Fig. 1, the following three parameters equation was proposed:

$$W_t = W_{\max} \frac{t^n}{K^n + t^n} \quad (1)$$

where W_t refers to the volume of loess disintegration at time, t , W_{\max} refers to the maximum volume of loess disintegration, n describes the sigmoidal character of the curve and K is equal to the half-life ($t_{1/2}$) of loess disintegration.

Parameters W_{\max} , K and n were estimated using nonlinear least squares regression. Eqn. 1 fitted the experimental data very well (R^2 ranged from 0.996 to 0.999). The comparison between experimental and predicted curves is shown in Fig. 1. A good agreement between predicted and experimental values could be observed.

Aggregate breakdown by water may result from a variety of physico-chemical and physical mechanisms and may involve different scales of soil structure from clay particle interactions to the macroscopic behaviour of aggregates. Three main mechanisms can be identified from the various reviews already available: (i) slaking, *i.e.* breakdown caused by the compression of entrapped air during wetting; (ii) breakdown by differential swelling; (iii) physico-chemical dispersion due to osmotic stress⁴.

It is concluded from above disintegration curves that the whole disintegration process could be divided into three stages. The loess disintegration data of water content of loess was selected for an example as shown in Fig. 2. The first stage displays a level line at the initial value giving life times of 10 min without any occurrence of disintegration phenomenon (A region). With a same manner, a similar stable stage was observed for other water content of loess systems. The second stage is dominated by slaking and accounts for the removal of more than 90 % of the total soil (B region). This primary disintegration stage is rapid and almost linear against time with different slope. Longer the water content, smaller is for rate

of slope. The last disintegration is comparatively much slower (C region).

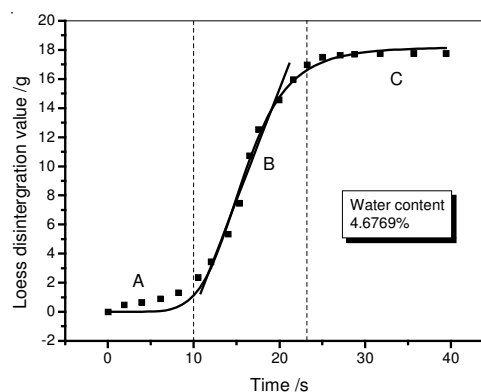


Fig. 2. Rate of disintegration from loess as a function of time

Disintegration is caused by the compression of air entrapped inside aggregates during wetting. It occurs when dry aggregates are immersed in water or rapidly wetted. The effect of trapped air depends on the volume of air inside the aggregates, on the rate of wetting and on the shear strength of wet aggregates. Disintegration occurs even without any shaking of soil in water, although shaking increases the effect of slaking because of additional mechanical breakdown or dispersion. The slaking decreases as the initial moisture content increases until saturation is reached. This is due to the reduction of the volume of air that is entrapped during wetting and also to the reduction of gradients of matric potential. Differential swelling and shrinkage during wetting and drying of loess result in a microcracking of aggregates. Physico-chemical dispersion results from the reduction of the attractive forces between colloidal particles while wetting^{5,6}.

Eqn. 1 would be an adequate mathematical model to describe disintegration behaviour from diverse water content of loesses. Several parameters such as rate constants (K_d) and the half-life ($t_{1/2}$) of disintegration behaviour to characterize disintegration stability could be derived from parameters W_{\max} , K and n . Three distinct stages of disintegration determined by independent mechanisms were identified from analysis of the rate of disintegration as a function of time. The results of this study would provide a useful insight into the mechanisms and would also help for the catastrophic failure from loess.

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