



Experimental study on the disintegration of loess in the Loess Plateau of China

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Abstract

The strength and mechanical behaviour of loess are especially affected by water, and loess tends to disintegrate in the presence of water. Loess disintegration is closely related to the formation of caves, rills, and gullies on slopes and landslides. In this study, we conducted in situ tests and laboratory tests on Q₃ Malan loess using self-developed disintegration instruments (small and large test blocks) to determine the characteristics and mechanisms of loess disintegration and their relationships with influencing factors such as initial water content, structure, curvature, and surface shape. The results show that the disintegration behaviour of loess conforms to a dynamic model. We propose that the fragmentation process and the breaking process are instantaneous and irreversible, whereas the separation process requires more time and is somewhat reversible. The disintegration time of the loess was controlled by the wetting velocity. An investigation of the boundary effect on the disintegration of the loess indicated that the presence of a disintegration nucleus was the result of slower water penetration of the inner layer caused by the temporary boundary confinement of the outer wetted layer. The boundary effect became more obvious with decreasing the water depth, increasing the curvature of the slot surfaces, and sharpening the edges of the convex upright in situ samples. The results of this study are intended to provide basic theoretical support for soil and water conservation and engineering construction in loess areas.

Keywords Loess · Disintegration · Dynamic model · Mechanism · Boundary effect · Test

Introduction

Loess is widely distributed worldwide, including Asia, Africa, central and southern Europe, northern Russia, the American Midwest, and northern France (Roberts et al. 2007; Zárate 2007; Giménez et al. 2012; Liu et al. 2015). Among these areas, China has the largest loess area in the world, covering approximately 65×10^4 km² and accounting for approximately 7% of the total land area in China (Liu 1985; Tan 1988; Derbyshire et al. 1995; Derbyshire 2001). The Loess Plateau is the most representative area because the loess is

stratigraphically complete continuously distributed and has the greatest thickness (Fig. 1). Loess is a Quaternary sediment that forms in arid and semi-arid climates. Because of the specific formation environment, the material composition and structural characteristics are unique. The strength and mechanical behaviour of loess are especially affected by water, and loess tends to disintegrate in the presence of water (Rogers et al. 1994; Pye 1995; Smalley and Rogers 1996; Zhang and Liu 2010; Li et al. 2009; Wang et al. 2014; Sun et al. 2016; Peng et al. 2018).

The characteristics of loess disintegration are related to the wetting and suspension of the loess when it encounters water. Because the disintegration mechanisms of loess are closely related to the erosion process, these mechanisms were previously investigated as important indicators of erosion resistance (Emerson 1991; Zhang et al. 2003; Piccarreta et al. 2006; Erguler and Ulusay 2009; Wang et al. 2013; Zheng and Wang 2014). In the presence of water, loess disintegrates rapidly and becomes suspended in the water; this process increases erosion and causes rills and gullies on the slopes, which have negative impacts on water and soil conservation (Fig. 2 a, b; Fuller 1922; Jones 1971; Heede 1971; Arkin

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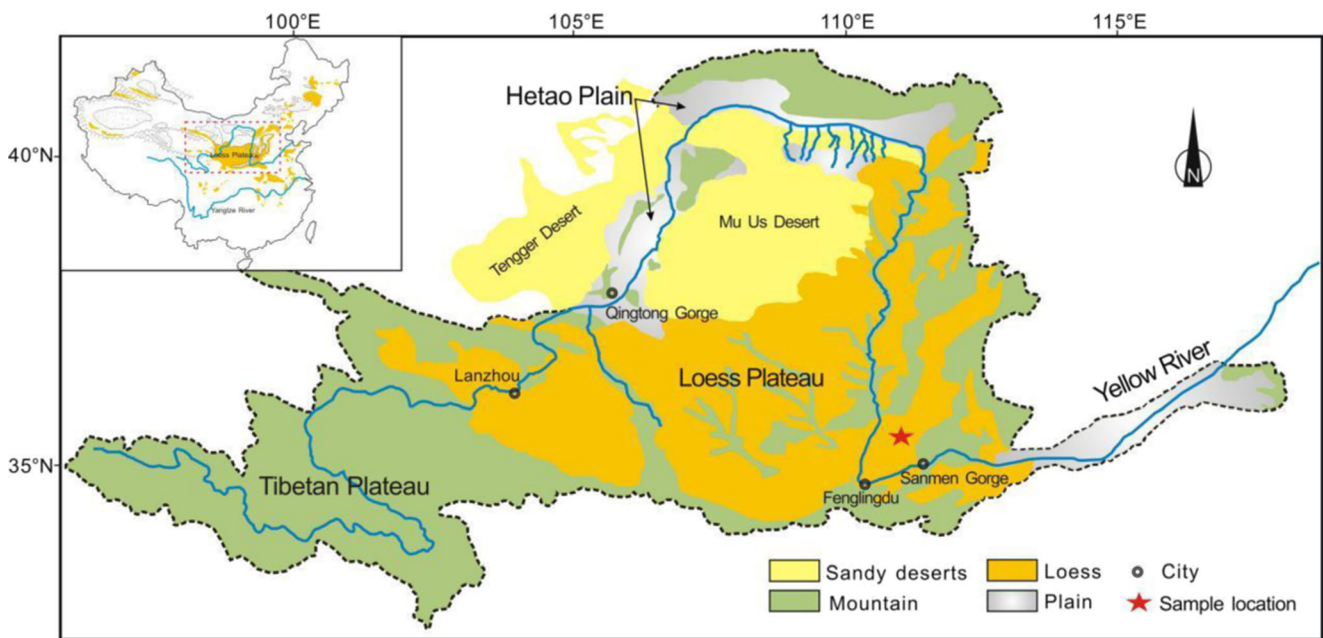


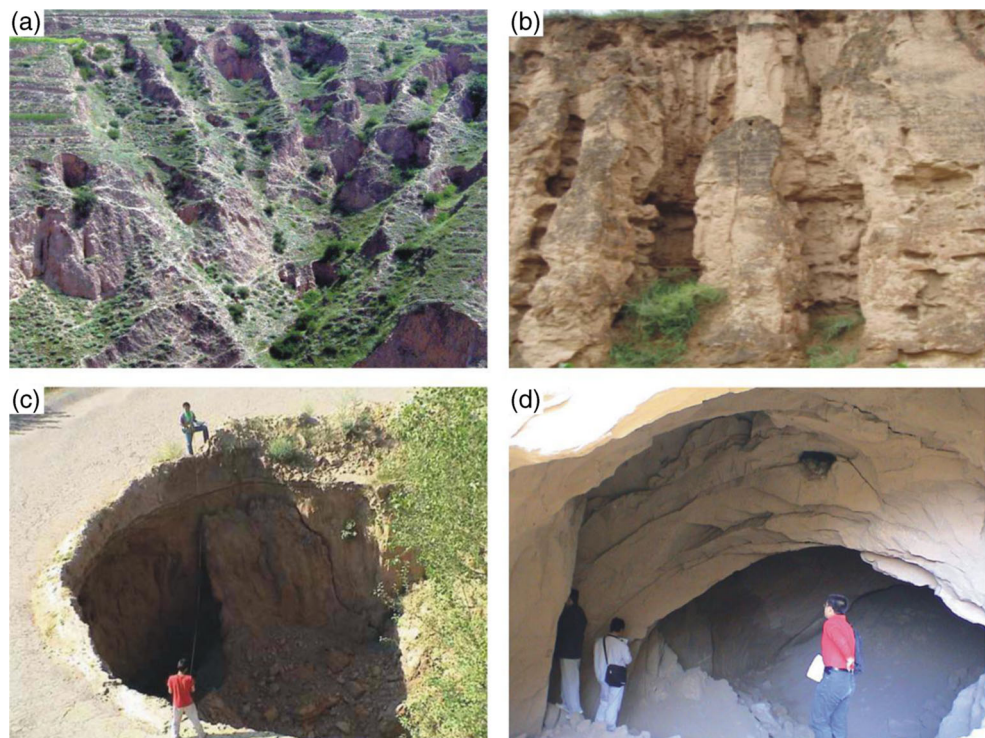
Fig. 1 Map showing loess distribution in China and the sampling site

1988; Ternan et al. 1998; Vandekerckhove et al. 2000; Zhu et al. 2002; Lado et al. 2004; Zhu 2012; Faulkner 2013). Research has shown that most slope failures on loess soil are related to rainfall. In addition, slope disintegration can result in large sinkholes under certain conditions (Fig. 2 c, d; Shi et al. 2016; Wang et al. 2018). Furthermore, the disintegration of loess areas often leads to frequent debris flows on the Loess Plateau. Therefore, the disintegration of loess is of crucial

theoretical and practical significance for soil and water conservation and in the field of engineering geology.

In recent years, engineering geological problems caused by the disintegration of rock and soil masses have become increasingly prominent, and people have gradually realized the importance of disintegrating rock and soil masses. Many scholars have understood the disintegration of soft rock, such as clay rock and mudstone (Lyles et al. 1969; Arkin 1988;

Fig. 2 Geological features resulting in engineering problems in loess areas



Lado et al. 2004; Sadisun et al. 2005; Erguler and Ulusay 2009; Sharma et al. 2017). However, studies related to the disintegration of loess are still relatively scarce. For example, the conventional method for studying the disintegration of loess is to immerse test pieces with different dimensions in water and observe the disintegration process. Due to the limitation of sample size, it is difficult to test samples with different porosities, and the errors are large because the specimens' surfaces immersed in water are much larger than the actual surfaces that are under water. In situ disintegration tests have not been conducted to date, and many basic questions about the disintegration mechanisms of loess remain unknown, such as the basic principles, the driving forces, the dynamic processes of loess disintegration, the erosion of loess slopes, the fact that disintegration of slopes does not occur as rapidly as in experiments, and the limitation of the continuing disintegration or erosion process.

In this study, we use a self-developed disintegration instrument (for small and large test blocks) and in situ tests to investigate the disintegration of loess. A kinetic disintegration model of the loess is proposed based on the experimental results, and the disintegration mechanisms of loess are analysed in detail.

Materials and methods

Materials

The late Pleistocene (Q_3) Malan loess samples used in this study were collected in Yuncheng, Shanxi, China (Fig. 1). The sample depths were 4 m below the surface. Specifically, after determining the sampling point, the surface soil was removed, and the sample was obtained from the sampling depth. The samples were carefully cut into columns with a diameter of 10 cm and a height of 20 cm and were subsequently placed into sample barrels. The barrels were sealed with cling film and transparent tape and were wrapped carefully with a 1-cm-thick pearl shock-proof membrane to reduce the sample disturbance during transport to the laboratory. The basic physical properties of the loess samples were determined according to the Chinese National Standards (CNS) GB/T50123–1999 [Standardization Administration of China (SAC) 1999] and are shown in Table 1. The particle size distribution of the

samples was determined using a laser particle size analyser (Bettersize 2000), which indicated that the loess samples consisted mainly of silt (approximately 83.66%) with some clay (approximately 10.93%; Table 1 and Fig. 3). The X-ray diffraction (XRD) and differential scanning calorimetry (DSC) tests showed that the clays in the cement consisted of mixed-layer minerals of illite and montmorillonite; the soluble and partially soluble salts included NaHCO_3 , $\text{Na}_2\text{SO}_4 \cdot 10\text{H}_2\text{O}$, NaCl , $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$, CaCl_2 , MgCl_2 , Na_2CO_3 , and $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$, and the total salt content was in the range of 50–100 mg/100 g (Figs. 4 and 5).

Testing apparatus and procedures

Loess disintegration test using a small test block

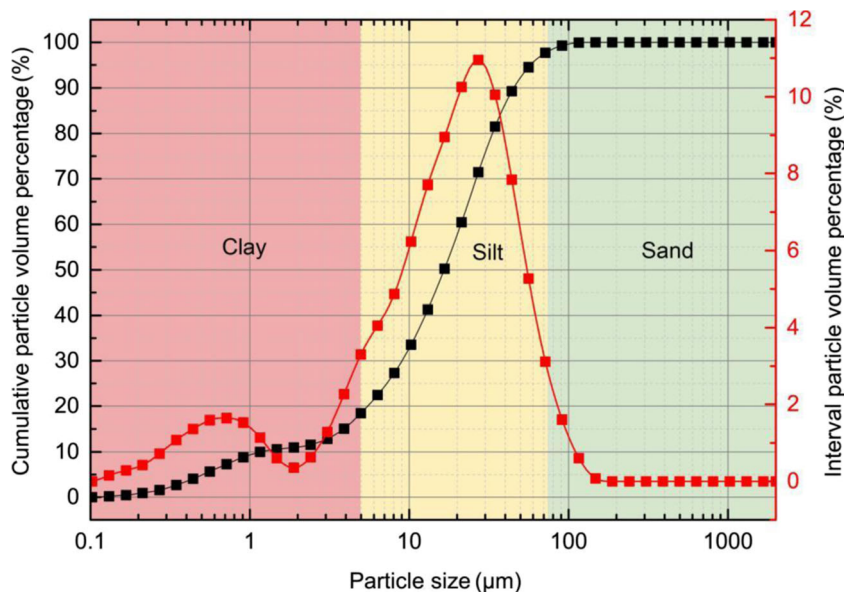
The intact loess samples used in this study were obtained according to the CNS GB/T50123–1999 (SAC 1999) and were placed in a moist chamber for 24 h after adding the water to absorb the required water content. After the water content was uniform, a ring sampler and geotechnical knife were used to whittle the loess samples into cylindrical shapes with a diameter and height of 2.5 cm each (Fig. 6 a–d). The most important parameter in this experiment was the water content w . Therefore, the time required to set up the experiment should be as short as possible to avoid water loss while tracking and measuring the water content. In addition, multiple tests were conducted for every sample to reduce the errors.

The disintegration rate was tested with a self-developed loess disintegration instrument (Fig. 6 e) and was based on the mass change during disintegration. The water temperature was maintained at 25–27 °C. The loess sample was hung in the centre of the sample plate below the electronic balance. Then, using the transmission system (Fig. 6 f), the tray salver was lifted and drove the cylinder upwards until the water contained in the cylinder completely submerged the loess sample. When the soil sample was completely submerged, the stopwatch was turned on, and the data displayed by the electronic balance were recorded. The data for the initial state and the instantaneous mass change during the disintegration could be obtained directly. A video camera was also used to record and observe the process, and the slow playback of the video provided data on the time, the amount of disintegration, and other details.

Table 1 Basic physical properties of the loess samples

Depth (m)	Dry density (KN/m^3)	Specific gravity	Initial water content (%)	Void ratio	Atterberg limits (%)		Particle size distribution		
					Liquid limits (%)	Plastic limits (%)	Clay (< 0.002 mm; %)	Silt (0.002–0.075 mm; %)	Sand (> 0.075 mm; %)
4	1.4	2.7	10.97	0.819	28.1	17.2	10.93	83.66	5.41

Fig. 3 Particle size distribution of the loess samples; (Black curve: grain size accumulation curve of the loess samples; red curve: grain size frequency curves of the loess samples)



Loess disintegration test using a large test block

The self-developed loess disintegration apparatus for large blocks is composed of two parts, an inner cylinder and an outer cylinder (Fig. 7 a). The inner cylinder is a buoy that is 500 mm in height and 180 mm in diameter. There are eight positioning points on the outer wall of the inner cylinder and a suspended steel wire net at the bottom that holds the samples. The outer cylinder is 90 cm in height and 30 cm in diameter. There are graduations on the sidewall (the smallest interval is one millimetre). On the top of the outer cylinder are two holes at 28.5 cm and 2 cm from the edge for the water injection pipes to keep the water level constant during the test. With this apparatus, samples with dimensions of 15 × 15 × 15 cm can be tested (Fig. 7 b–e). The test method is as follows: The bottom of the inner cylinder is connected to the hanging net

with the loess test block, and the inner cylinder is placed vertically into the outer cylinder with a certain amount of water in advance. At this time, the water level inside the outer cylinder is at the position of the overflow hole. For each interval of 10–20 s, the reading pointer is the indicating value marked on the wall of the outer cylinder, and the disintegration of the loess sample at this time point is described. According to the disintegration of the loess sample, the time interval can be appropriately shortened or increased. When the sample falls completely through the grid, the test is complete.

In situ disintegration test

To study the boundary effect on loess disintegration, a series of in situ specimens or test grooves were designed, including a

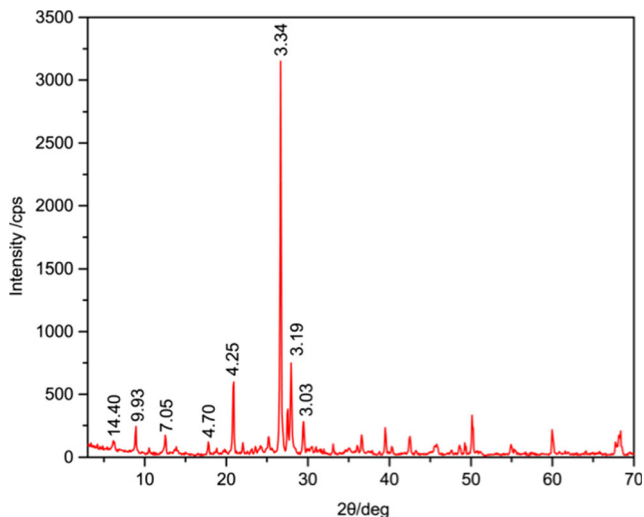


Fig. 4 XRD results for the loess samples

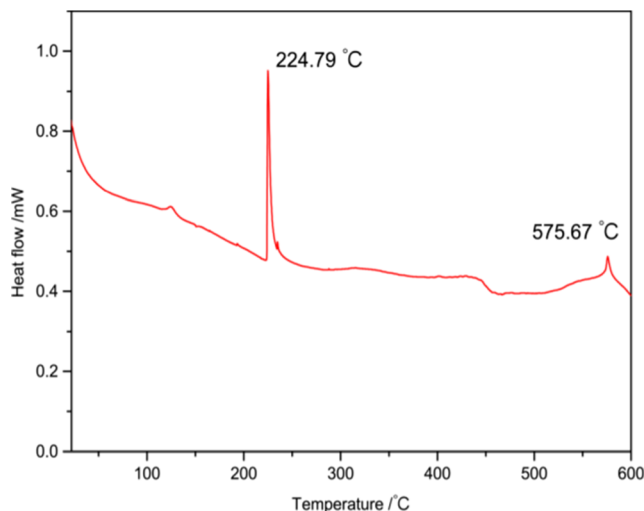
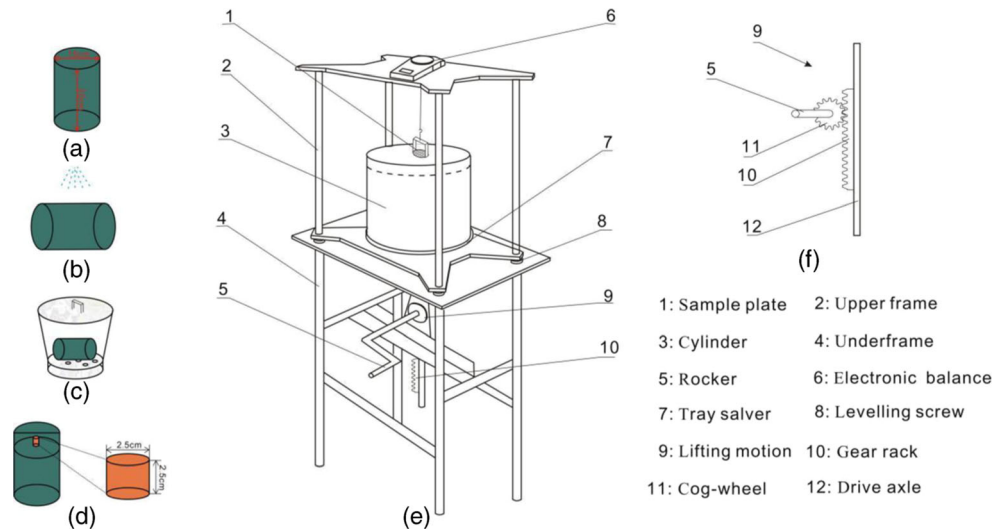


Fig. 5 DSC thermogram of the loess samples

Fig. 6 Small-sized disintegration instrument and sample preparation. a Original sample. b Prepared target moisture content. c Curing. d Sample preparation. e Test apparatus. f Transmission system



triangular prism, a quadrangular prism, a pentagonal prism, a hexagonal prism, a convex upright cylinder (cylinders with different curvatures), a concave upright cylinder (circular grooves with different curvatures), and a single-sided upright cylinder (Fig. 8).

Dynamic model of loess disintegration

Disintegration process curve

Figure 9 shows the disintegration volume of the loess over time and illustrates that the initial moisture content

has significant influence on the disintegration of loess. Under the same conditions, the disintegration rate of loess decreases with increasing initial moisture content. When the water content increases to a certain extent, the disintegration almost disappears. Furthermore, the figure shows that all the disintegration curves are basically s-shaped. This result indicates that a certain generality exists for the disintegration of the loess with different water contents. The steepness of stage B of the disintegration curve reflects the speed of disintegration. Experimental results show that the disintegration rate is stable at this stage and that it is feasible to characterize the rate using the average slope in stage B.

Fig. 7 Large-sized disintegration instrument and sample preparation

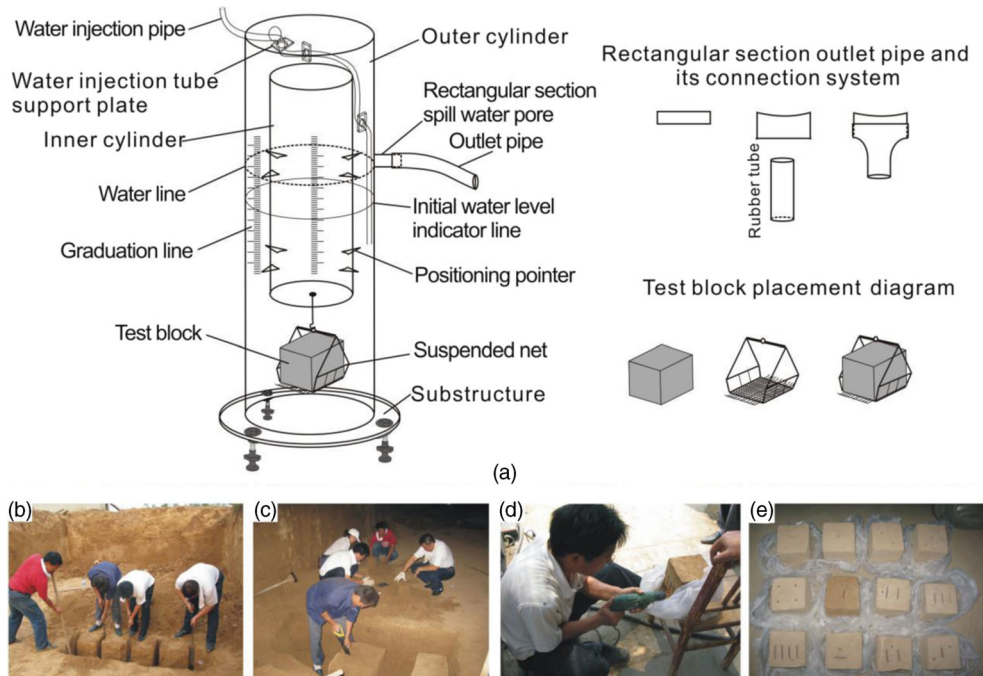
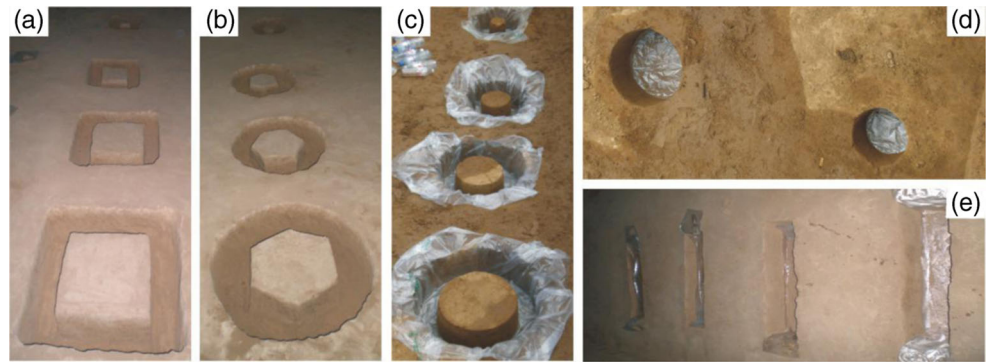


Fig. 8 Some of the designs for the field disintegration tests. a Quadrangular prism. b Hexagonal prism. c Cylinder. d Circular groove. e Chamfer



Dynamical model of the disintegration process

To describe the disintegration processes of loess under different conditions (Fig. 9), we used the following mathematical model:

$$W_t = W_{\max} \frac{t^n}{K^n + t^n} \tag{1}$$

where W_t represents the disintegration volume (g) within time t ; t is the time (s) required for the disintegration; W_{\max} is a model parameter that describes the maximum volume of the loess disintegration (g); K is a model parameter that is equivalent to the half-life period in the disintegration process ($t_{1/2}$); and n is a model parameter that denotes the recurvate characteristic index.

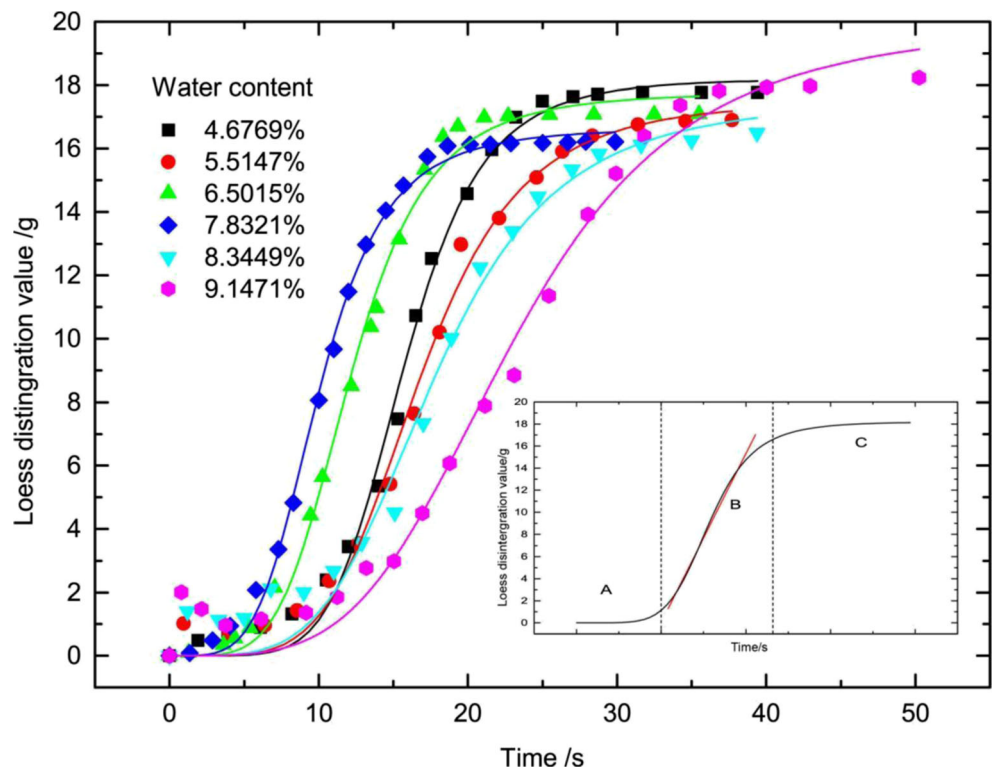
The estimation of the parameters W_t , K , and n was performed in MATLAB 6.1 using a nonlinear least squares regression. The fitted curves in Fig. 9 indicate satisfactory fits with the R^2 value in the range of 0.985 to 0.996.

Loess disintegration process

The nature of loess disintegration

Three distinct stages are observed during the process of loess disintegration in water (Fig. 10). During stage A, water permeates the pores and micro-fissures after soaking. The gas in the pores of the loess sample is forced out and forms a few bubbles. A small portion of the loess grains on the soaking

Fig. 9 Time dependence of the disintegration volume of loess for various water concentrations



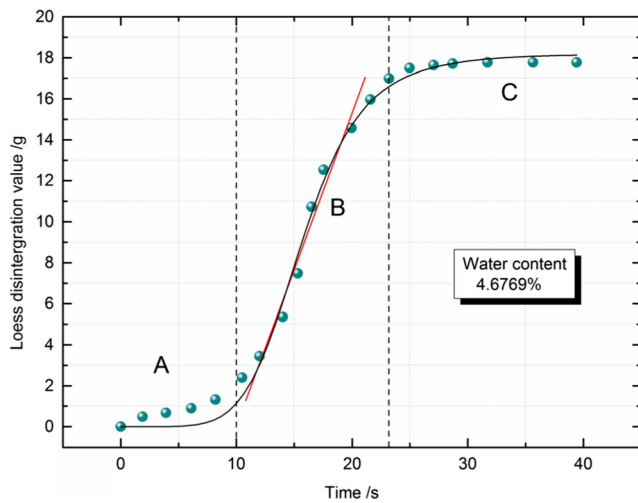


Fig. 10 Rate of disintegration of loess over time

surface separate from the loess matrix successively in the form of scales and single grains; this stage is called the soaking stage, and the rate of disintegration is slow (Fig. 11 a). Stage B is the softening stage when continuous soaking occurs. During this stage, a mass of bubbles is formed in the void (pore) walls, and the loess is soaked and softened. In addition, bubbles form and shed loess grains on the ends (sections) of the voids (pores). Furthermore, some small block elements that form the pore walls of the loess are separated from the matrix due to the expansive force of the bubbles. This stage is the disintegration stage; it is the main stage during the process of disintegration and is characterized by a fast rate of disintegration. The surface of the loess sample breaks up and separates (Fig. 11 b). Nevertheless, the rate of disintegration is stable, as shown in stage B in Fig. 10. In stage C, most of the disintegration is complete. The voids (pores) on the soaking surface of the loess sample have been completely filled with water; the number of bubbles decreases, and the loess is fully soaked and softened. The remainder of the pores seek stable angles of repose, and with a low rate of disintegration, some of the soil separates and the disintegration is complete (Fig. 11 c; Li et al. 2009; Zhang et al. 2016).

The disintegration process of the loess is attributed to weakening cementation of the loess grains in the presence of

water. The weak water stability of loess is the reason for the disintegration (Barden et al. 1973; Lutenecker and Hallberg 1988; Emerson 1994; Piccarreta et al. 2006). The strength of the cementation among the loess grains is determined by the composition of the cementing particles and can be influenced by their characteristics. In the dry state, the cemented particles have greater strength and cementation, which makes the soil solid. In contrast, the cements of soluble salts dissolve faster. When the loess is soaked in water, the cement weakens rapidly due to the dispersion of the loess in the water. Due to the low content of soluble salts, their influence on disintegration is limited. Carbonate does not dissolve in a short time and does not contribute to the disintegration of the loess. In addition, the loess is rich in clay minerals. Among them, illite and montmorillonite have a three-layer structure. The cohesion force of the crystal cells is relatively weak. The crystal framework is extremely active and possesses a large specific surface. When wetting occurs, water molecules fill the spaces between the crystal lattices, thus generating expansion and sharply weakening the cementation. Therefore, the cementation by clay minerals is the main reason for the disintegration of the loess grains in the presence of water. Finally, the stress condition of the disintegration should also be considered. Disintegration occurs only when the disintegration force is greater than the cohesion force of the soil block (Derbyshire et al. 1994; Klukanova and Sajgalik 1994; Díaz et al. 2007; Kruse et al. 2007; Zhang et al. 2016).

During the disintegration process, single particles separate from the loess matrix. The force that resists disintegration is the cohesion force between the disintegrating particles and the contact particles. The force that causes disintegration is the swelling of the cement, and the presence of a water film acting as a wedge, including the normal component of the particle contact surface and the floating weight of the fragmentation particles, is caused by the hydrophilic loess particles. When the resultant force of the last three forces (i.e., the expansive force of clay minerals in the presence of water, the wedge force of the water film, and the floating gravity) is greater than the bonding force, fragmentation occurs.

The trigger for the breaking process is the expansion force or the force generated by the bubble overflow. When seepage flow occurs in the voids (pores), air bubbles are forced to escape



Fig. 11 Images of the process of loess disintegration

outward. During the escape of the air bubbles, the volume increases as the pressure from the surroundings gradually decreases. Since the external soil particles are immersed in water for a longer time than the internal soil particles, the bond strength between the external soil particles is weaker; therefore, under the action of the thrust generated by the bubble expansion, the outlet end particle aggregates (or small soil blocks) of the voids (pores) are likely to break and detach from the matrix. Similarly, as the seepage flow advances through the pores, the internal pressure of the closed bubbles increases, and the cementing force weakens. These two combined actions cause the bubbles to burst in the voids (pores) and the wall particles (small soil blocks) to aggregate and break. When the loess samples are soaked, part of the loess from the submerged surface falls into the water when breaking, whereas the inner portions of the loess are softened; the cohesion and internal friction angles decrease, and the loess becomes viscous or viscoplastic after softening. The loess tends to change to the natural angle of repose under the action of gravity. At this time, the loess and matrix separate (Figs. 12 and 13).

The characteristics of loess disintegration

The dynamic conditions triggered by fragmentation, breaking, and separation are different, resulting in different characteristics in terms of action time, rate, and scale. Fragmentation occurs almost throughout the entire disintegration process; breaking occurs only when the loess has soaked up a sufficient amount of water such that the voids (pores) are filled with water. In contrast, separation occurs only later during the disintegration process. The processes of fragmentation and breaking are instantaneous and irreversible, whereas separation requires a certain amount of time. During the initial stage of separation, the loess blocks tend to separate, form cracks in the matrix, and then collapse. The process is still irreversible. However, if the water evaporates at the beginning of the separation, the loess blocks and the matrix remain intact as the moisture content of the loess returns to normal. Therefore, the fragmentation, breaking, and separation of the loess in the

water are attributed to the disintegration of the loess; the initial stage of separation can be reversed under certain conditions. In terms of the scale, separation occurs at the largest scale, followed by breaking and fragmentation at smaller scales; this contrast results from the different objects of the various disintegration effects. In terms of the rate of disintegration, the fragmentation processes are slow and uniform, the breaking process is the fastest, and the separation is in the middle.

Influencing factors and mechanisms of loess disintegration

Effect of natural water content on loess disintegration

Figures 14 and 15 indicate that the disintegration rate decreases with increasing initial water content. For the same type of loess, the initial water content is the primary factor that influences disintegration. First, as the water content increases, the water film around the particles increases in thickness, resulting in a better distribution of the film. Second, as the water content increases, the cemented clay minerals expand due to stress and boundary restrictions. Given their increased volumes, the pores are filled, and the residual expansion energy is reduced. The plasticity increases during the expansion process, and the cemented area increases and becomes more uniform. Thus, although the cementation is not as strong as it is under dry conditions, the concentration of the stress is not as likely to occur in the second soaking (Levy et al. 2003; Blanco-Canqui et al. 2007; Annabi et al. 2007; Vermang et al. 2009; Li et al. 2009). Clearly, the increase in the initial water content increases the loess plasticity and reduces the porosity, matric suction, permeability, and water percolation. The second soaking slows the process, which reduces the rate of disintegration. There is no doubt that loess disintegration is influenced to some degree by the chemical properties of the soil and the temperature and pH of the water. However, these factors have far less influence than the water content. When the water content increases to a certain value, the rate of

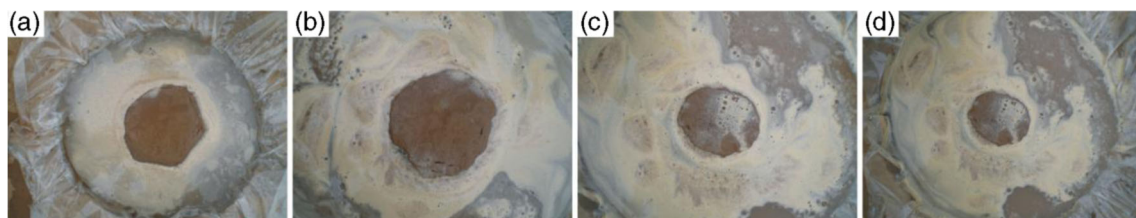


Fig. 12 Escaped foam and separation from the matrix during the disintegration tests in the field samples; a bubble overflows from the voids (pores) of the test block, and the submerged surface undergoes slight fragmentation; b a large number of bubbles remains in the voids (pores) of the test block, and a small portion of the loess grains on the soaking surface separates from the loess matrix successively in the form of scales and single grains; c the soil on the edge of the sample collapses

and the disintegration is severe; d the voids (pores) on the soaking surface of the loess sample have been completely filled with water; the number of bubbles decreases, and the loess is fully soaked and softened. The remainder of the pores seek stable angles of repose and with a low rate of disintegration, some of the soil separates and the disintegration is complete

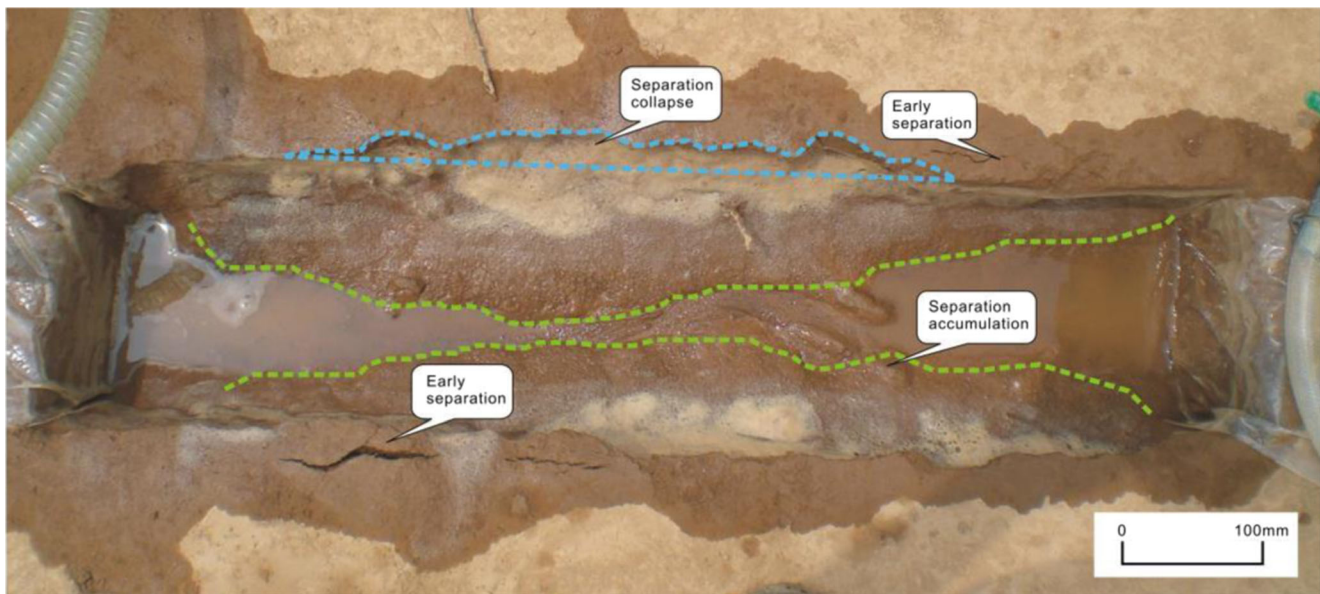


Fig. 13 Separation from the matrix observed after the field disintegration

disintegration decreases rapidly, and a negative correlation is observed between the water content and the rate of disintegration; i.e., disintegration occurs only with a rapid wetting rate.

The influence of loess structure on disintegration

The structural characteristics of loess have two aspects: the grain structure and the voids (pores). The particle size distribution is an important component. In general, the coarser the particles are, the greater the rate of disintegration. The reason is that the particle size distribution determines the porosity, permeability, and cementation state of the loess. The disintegration of clay particles is mainly related to the clay structure and clay content. The higher the content of clay aggregates is, the higher the degree of cementation between the loess

particles, the lower the porosity and the water permeability and the lower the rate of disintegration (Liu 1985; Sadisun et al. 2005; Zhang et al. 2016). The void (pore) and fissure structure of the loess determine the type and rate of disintegration when water is encountered. Loess with undeveloped voids (pores) and fissures generally has a slow and uniform disintegration rate, whereas loess with high porosity breaks and separates, and its disintegration rate is rapid. Loess with a wide distribution of voids (pores) and joints (fissures) exhibits separation, and the disintegration process is often very rapid (Li et al. 2009; Wang et al. 2014). Figure 16 shows the relationship between the average disintegration rate and the porosity of the large test blocks of loess. A significant positive correlation between the disintegration rate and the porosity is evident. As the porosity increases, soaking occurs more

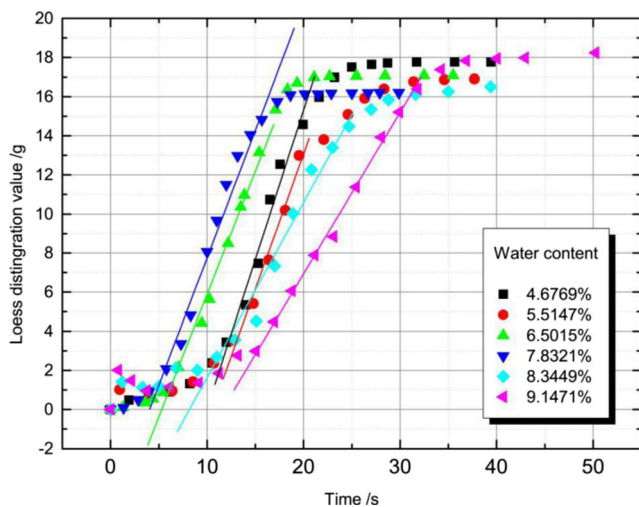


Fig. 14 Effects of water content on disintegration rate fitted by linear regression

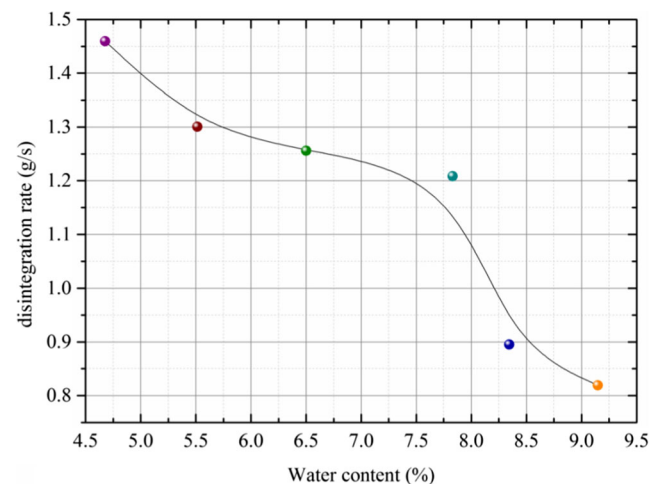


Fig. 15 The relationship between disintegration rate and initial water content

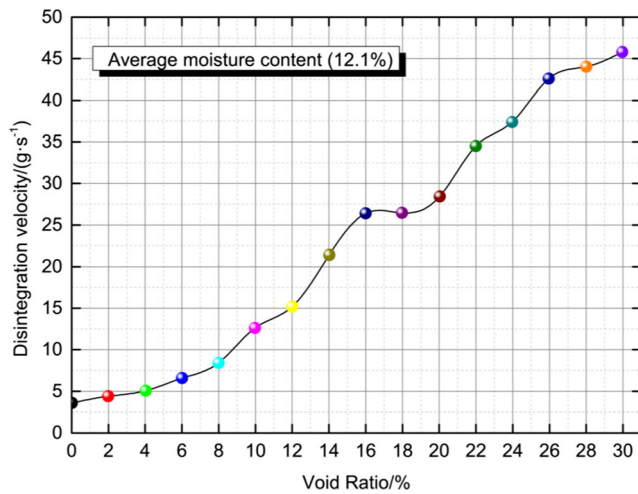


Fig. 16 Relationship between the average velocity of disintegration and the void ratio

rapidly, and the rate of disintegration increases. In addition, as the submerged surface becomes soaked, the increase in the void ratio results in a larger surface area where disintegration can occur, which increases the fragmentation and breaking.

The boundary effect on loess disintegration

The in situ disintegration test and large block disintegration test show that the disintegration process does not develop infinitely but is restricted by the immersed boundary; i.e., a boundary effect is observed. For the in situ disintegration test pits, the immersed boundary disintegrates after water immersion, and the disintegration rate changes first from slow to fast, and then from fast to slow, and finally reaches a steady state without disintegration. Similarly, in situ disintegration of the large block samples with small void ratios and in situ disintegration of the samples with larger sizes does not continue after the disintegration proceeds for a certain time. A disintegration nucleus remains and consists of an interior portion with a certain structural strength and an outer soft layer that has not disintegrated (Fig. 17).

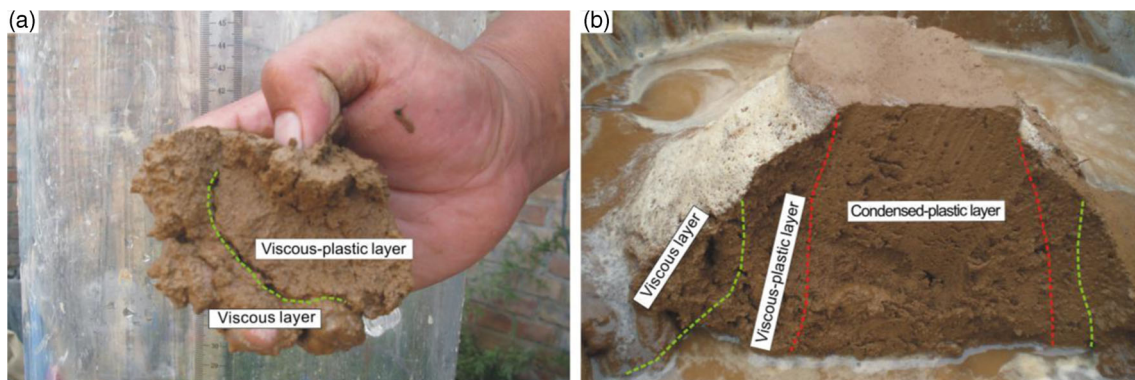


Fig. 17 Remaining nucleus after the disintegration of (a) large-sized samples and (b) field disintegration

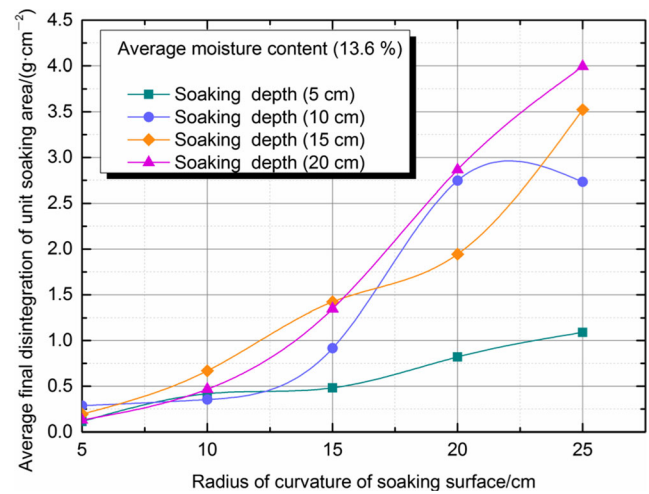
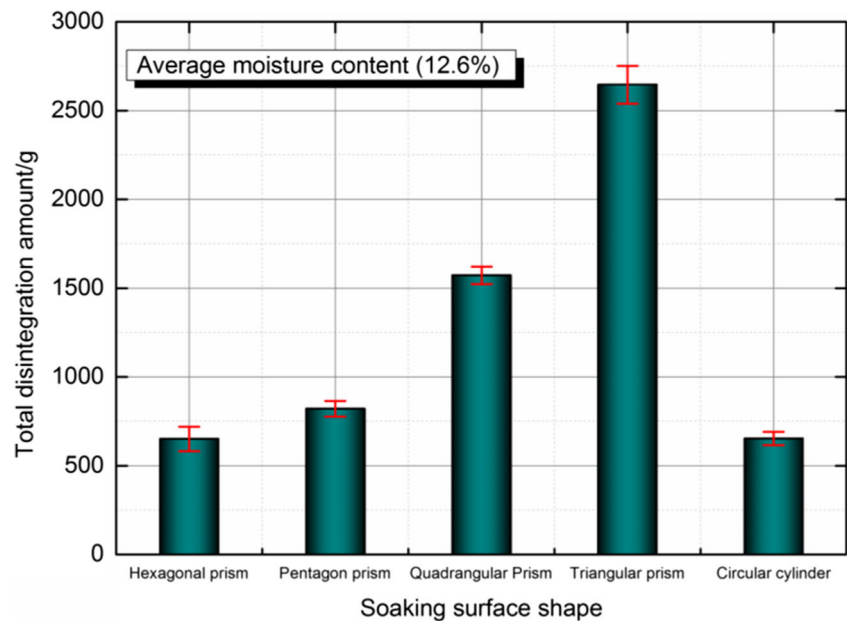


Fig. 18 Relationship between the disintegration amount and the curvature of the soaking face

There are two main reasons for these results. First, the penetration from the submerged surface to the inner layer slows down during the disintegration process. The inner layer of the loess is temporarily confined by the boundary of the outer layer while the water content slowly increases. Therefore, disintegration does not occur. Second, the complete disintegration of the immersed outer layer requires a certain amount of time, during which the moisture content of the interior increases. Small loess blocks generally disintegrate completely without forming nuclei because these two conditions cannot occur in a small soil volume.

The boundary effect is also influenced by the shape of the submerged surface. The disintegration rate is slow during the in situ disintegration process when the immersion surface has a small diameter and is concave. The small diameter has small boundary effect, and the larger the curvature is, the greater the boundary effect (Fig. 18). In addition, in the in situ disintegration test, the lowest amount of final disintegration is observed for the upright cylinder, followed by the hexagonal prism, pentagonal prism, quadrangular prism, and triangular prism with the same height (Fig. 19). This result indicates that the

Fig. 19 Disintegration amounts of convex upright field samples with different shapes



more edges are present in the in situ convex upright specimen, the faster the disintegration rate is. The tests show that separation occurs first at the edges of the cylindrical specimens, which results in gradual rounding and nearly circular shapes (Figs. 12 and 17 b).

Conclusions

- 1) A mathematical model to describe the disintegration process is proposed. The physical meanings of the three model parameters are clear, and the parameters k_d and $t_{1/2}$ can be calculated, thus providing necessary theoretical guidance for research on the dynamic process of loess disintegration.
- 2) The disintegration process of undisturbed loess can be divided into three stages: fragmentation, breaking, and separation. Cementation by clay minerals is the underlying reason for loess disintegration. The expansive force of clay minerals in the presence of water, the thrust generated by air bubbles in voids (pores) overflow, the wedge force of water film, and the floating gravity are the main factors that trigger disintegration.
- 3) The initial water content and the structure of the loess are important factors affecting the rate of disintegration. An increase in the initial water content increases the loess plasticity and reduces the porosity, matric suction, permeability, and water percolation. The second soaking slows the process, which reduces the rate of disintegration. In addition, the wetting rate contributes to the speed of disintegration. The contents of coarse grains and clay grains determine the porosity, permeability, and cementation state of the loess and thus influence the rate of

disintegration to some degree. Finally, the rate of disintegration of the clay is related mainly to the clay structure and clay content. The void (pore) and fissure structure of the loess determines the type of disintegration in the presence of water and determines the disintegration rate. Loess with undeveloped voids (pores) and fissures generally has a slow and uniform disintegration rate, whereas loess with high porosity breaks and separates, and the disintegration rate is fast. Loess with a wide distribution of voids (pores) and joints (fissures) separates, and the disintegration process is often very rapid.

- 4) Due to the constraint of the boundary effect, the disintegration of loess tends to have a limited range without continuing to develop indefinitely after soaking. In addition, the disintegration of loess is affected by the shape and curvature of the immersed surface during the in situ disintegration test. A concave test tank with a shallow immersed surface and a smaller diameter has a slower disintegration rate of loess disintegration. The convex upright in situ samples become rounded by the de-edge effect when they are disintegrated and eventually tend to be relatively stable with nearly circular geometry.

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