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Distribution loess landslides triggered by the 1920 Haiyuan earthquake and their formation mechanisms

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The 1920 Haiyuan Earthquake (M=8.5) is one of the strongest earthquakes in Chinese modern history, and directly resulted in more than 200,000 people dead. The Earthquake induced a large number of landslides. Among them, we investigated 544 landslides in the meizoseismal area, and found that the distributions of the landslides are mainly concentrated in the southeastern part of the seismogenic fault, but the relationship with the NW-trending seismogenic fault is not noticeable. Further investigation indicated that such distribution is mainly controlled by two types of factors. One is the nearly SN-trending secondary faults concealed under the loess cover. The other one is the thickness of the loess. The landslide is more intensive in those areas with thicker loess and the density of the landslides decreases with the decreasing in the loess thickness, while landslides occurring in the bedrocks are very rare.

Investigation shows that the sliding surface of a large number of loess landslides is extremely gentle with the apparent friction angle ranging between 8 -11 degrees. Liquefaction phenomenon was found on a large number of areas in loess tableland along both sides of the river in the meizoseismal area. This is likely one main reason for the occurrence of landslides with very gentle sliding surface angle. Laboratory testing of undisturbed loess of these regions indicated that the sand content ranges from 3% to 15%, silt content is about 65% - 85%, clay content between 10% - 20%, and thus this kind of soil belongs to silt. But the sand content showed uneven distribution and high sand content occurred in local area. Dynamic triaxial tests showed the saturated loess could suffer from liquefaction failure.

However, there existed a large number of low angle slip surface, large runout and high mobility loess landslides in the slope zone with low underground water level. Loess is characterized by large pores with high compressibility and low strength. Scanning electron microscopy revealed that cement of loess particles were dispersed particulate, distributed discontinuously attached to the particle surface or accumulated at the point of the contact in the skeleton, the adhesive strength is very low. The earthquake occurred in December of that year’s winter. Due to very low water content of loess, relatively dry shallow loess easily shattered and collapsed under strong shaking of extreme earthquake. Therefore this caused occurrence of the high-speed and long runout landslide.

Finally, we conclude that because of the special geological characteristics of loess, there are more than two types of landslide mechanism: one is the liquefaction occurring on the loess layer affected by the groundwater level; the other one is the collapse of loess structure under strong earthquake.