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# Prediction of the loess soils collapse sensitivity classes by application of ordinal logistic regression, northeastern Iran

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**Abstract**
The current study evaluates ordinal logistic regression (OLR) for assessing collapse sensitivity classes of loess soils. Collapse sensitivity (Is) is the critical parameter to predict pseudokarst sinkholes occurrence in Golestan Province in northeastern Iran. A database containing 62 records of soil's physical and mechanical properties is used in this study. By performing oedometer tests, the parameters of collapse coefficient, the time required for 90% settlement (T90%), and collapse sensitivity were determined. To gather this goal, a database was prepared based on experimental datasets, consisting of ten inputs (grain size analysis, porosity, initial water content, precipitation, climate, liquid limit, calcium carbonate, vegetation, and degree of soil saturation) and one output (collapse sensitivity classes). This task is complex due to the difficulty of preparing and carrying out such experiments in a laboratory. Using OLR, the probability of soils being placed in classes with severe, moderately severe, moderately, and slight sensitivity was estimated. This study showed that the OLR method could correctly distinguish more than 70% of different categories. Experimental data obtained from Semnan, Sarakhs, and Mashhad areas, has shown the accuracy of the proposed OLR model.

***Keywords:*** *collapse sensitivity, ordinal logistic regression model, loess, Golestan Province*

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## Extended Abstract:

### 1. Introduction

Loess collapse is one of the most severe environmental problems in Golestan Province in NE, Iran. This soils have an open structure and high water sensitivity, and collapsibility properties. As a result, this specific loess inappropriately can pose severe environmental difficulties, such as channel erosion, loess caves, ground cracking, water supply channel walls collapse, sudden and asymmetric subsidence, house wall cracking, pasture destruction and soil erosion, road and bridge destruction. Loess collapse causes the formation of landforms that are very reminiscent of the typical karsts (dips, loess caves, gullies, circuses, tunnels, etc.). In the previous studies regarding the effect of loess soil behaviour on the occurrence of destructive phenomena such as pseudokarst sinkholes, the coefficient of collapse (Ic) of loess soils has been noted to be the most critical parameter in addressing the susceptibility of this phenomenon. However, recent research has shown that the risk of destructive phenomena in areas with higher collapse coefficients may be lower than those with lower collapse coefficients (Zhang et al. 2018). Therefore, the new concept of sensitivity collapse (Is), based on the intensity and speed of collapse, is defined (Zhang et al. 2018). This parameter has correctly explained the density and geographical distribution of loess caves in Golestan province (Zalaghaei et al. 2022). The conventional method of obtaining this parameter is laboratory investigations performed on soil samples acquired from site/field through borehole sampling. Although it is preferable to determine Is directly through the laboratory consolidation tests data, borehole sampling is generally time-consuming and expensive. By considering the potential of fragility and disturbance of dry loess soils during sample preparation for consolidation test and spending much time determining the intensity and duration of soil settlement at different stresses, this study was tried to employ indirect methods such as Ordinal Logistic Regression (OLR) to find the collapse sensitivity category.

### 2. Materials and methods

After some explanations regarding the case study under examination, the principles of OLR has be described. Then, finally, an evaluation of the developed OLR equations were given in detail. Ordinal logistic regression models arise in contexts where the response variable belongs to one of several ordered categories, such as 1=Sever, 2= Moderately sever, 3=Moderate, and 4= Slight. OLR is a form of regression used when the dependent variable is categorical (the independent variables can be of any type). To evaluate the physical and mechanical parameters controlling the distribution of loess caves, we prepared undisturbed block samples from 62 points in Zones II, III, and I. Based on ASTM standards, some physical, mechanical, and chemical properties were carried out. In addition, an odometer test was performed based on (ASTMD5333-03 2003) standard. Seven samples with a diameter of 75 mm and a height of 20 mm were obtained and prepared from each sampling site to determine the collapse intensity (Ic), collapse rate, and initial stress required for collapse. These samples were subjected to 25, 50, 100, 200, 400, 800, and 1600 KPa. However, in the present study, the coefficient of the collapse of the soils was determined under different pressures. Loading steps were 25, 50, 100, 200, 400, and 800 KPa, respectively. The amount of deformation at each stage of loading was read at intervals of 0.1, 0.25, 0.5, 1, 2, 4, 6, 9, 12, 16, 20, 25, 30, 45, and 60 min. Then it was continued at intervals of 30 min until reaching a stable state (deformation value less than 0.01

mm per hour). Then based on the two parameters of collapse intensity (Ic) and collapse speed (T90%) defined by (Zhang et al., 2018), the classification of soil collapse sensitivity is determined.

## 3. Tests results

In general, it can be deduced that the collapse coefficient of loess soils decreases from the north (sandy loess) to the south (clayey loess). In addition, the percentage of fine clay particles, liquid limit values, moisture percentage, and initial saturation degree of soils rise as one travels south in this province. Nonetheless, the CaCO3 percentage decreases from north to south in the Golestan province. These results are consistent with those of previous studies (Rezaiy et al. 2011; Salehi et al. 2015). To assess the efficacy and precision of this classification, Ic and T90% values were derived for 62 locations in the province of Golestan, and the experimental collapse sensitivity classes of loess soils were determined. The ordinal logistic regression model is used to compare the collapse sensitivity classes of loess soils in the Golestan province measured by the direct method. Evidently, over 70% of the class's predictions are accurate. The direct measurements collected from the loess investigations in the regions of Sarakhs, Mashhad, and Semnan were utilized to assess the validity of the relationships derived from the logistic regression technique.

## 4. Conclusion

The collapse sensitivity classes of Golestan province loess soils measured by the direct method are compared by the ordinal logistic regression model. Test results show that, more than 70% of the class predictions are correct. To evaluate the validity of the relationships extracted from the logistic regression method, direct measurements obtained from the loess investigation of Sarakhs, Mashhad, and Semnan regions have been used. The results of the ordinary logistics method show good compatibility with the direct method results, as the results of the OLR method has been able to correctly determine the more than 85.70% categories of soil collapse sensitivity.

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