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PECULIARITIES OF DEGRADATION IN LOESS SOILS' DEFORMATION AND STRENGTH PROPERTIES ON THE EXAMPLE OF DNIPROPETROVSK CITY

(Reviewed by the editorial board member B. Maslov)

Presentation of mathematical modeling results for the deformation and strength properties degradation process using the group method of data handling. Testing of this method had been applied to longitudinal data on the variability of the properties of the geological environment as an element of regional level natural – technogenic system.

Research Objective: to establish the peculiarities of massif degradation on the example of the longitudinal data research on periglacial formation soils' properties using methods of stochastic and inductive modeling.

Solution methods and software: stochastic modeling performed with methods of correlation and multiple regression analysis; inductive modeling – with group method of data handling. Software: STATIST (O. Honchar DNU), trial version of STATISTICA, customized program by Koryashkina L.S. (Candidate of physical-mathematical sciences, Associate Professor at O. Honchar DNU)

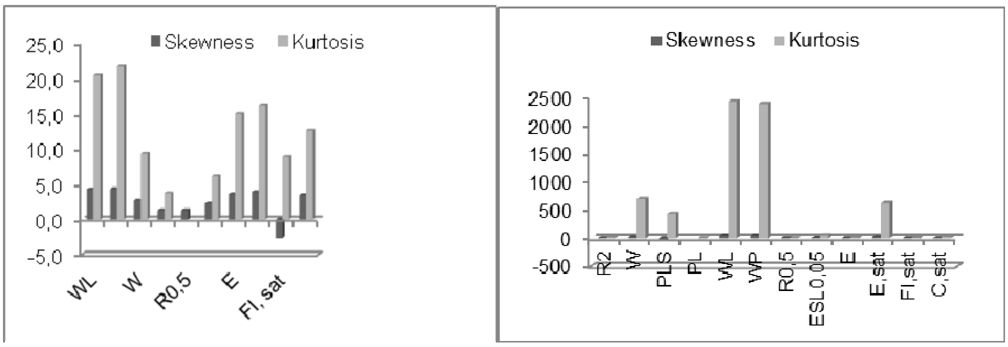
Results. These peculiarities indicate that there is subordination between subsidence properties degradation and changes in aggregate content: this confirms the A.K. Larionov's theory about consecutive destruction of rock's aggregate system and decrease in coagulation-dispersion type connections as a result of increase of water film thickness during subsiding.

Scientific innovation. Methods of inductive mathematical modeling applied to the description of change pattern in loess soils' exposed to technogenesis allows to objectively establish factorial variables whose changes affect the intensity of the process. Coordinates, soils' physical properties indicators were set as the factor variables. The evaluation of technogenic impact intensity is not performed, which greatly simplifies the solution.

Practical significance. Inductive Modeling will enable more accurate predictions of strain.

Presentation of the basic research results. Peculiarities of the loess soils' deformation and strength properties have been the subject of scientific research for a long time (Krokos V.I., Abelev Yu.M., Larionov A.K., Lysenko M.G.). The nature of subsidence as a physical-chemical process is explained from the view point of theories by Denisov N.Ya., Sergeev E.M. and Minervin A.V. Subsidence change patterns as a result of properties change in rocks exposed to technogenic factors are researched insufficiently and represent a current scientific problem. A lot of attention is drawn to the problems of subsidence properties degradation in soils massifs' exposed to technogenesis [1, 4, 5].

There is a shortage of works dedicated to the change patterns of loess-type and loess soils exposed to the simultaneous influence of high intensity transient physical fields, for instance, in cities. To study the real processes in subsiding soils' composition changes, conditions and properties under their exposure to complex factors' impact one needs to research longitudinal data series. Such sampling is time-consuming. In some cases it is very difficult to restore the data about technogenic impact intensity. Methods of permeability experimental modeling, consolidation in the process of argillaceous soils formation are in the stage of development [6]. Special attention is dedicated to the study of the relationship between the soils' structural-textural features and development of hazardous and unfavorable processes [7, 8]. The study of soils' deformational behavior as a result of microstructure peculiarities – is one of the trends which has been both traditional and fast growing in recent years [9, 10, 11]. Physical experimental modeling methods contribute to the solution of forecasting problems on condition that mechanical similarity criteria are strictly adhered to. Due to the development of the nonlinear dynamics methods, the theory of dynamic systems [12] and their application in tackling practical tasks in geology there is a need to change modeling methods used for engineering-geological processes forecasting.



a b

Figure 1. Skewness of average values (in a year) (a) and particular values of periglacial formation properties' indicators (b)

Methods of inductive mathematical modeling allow to solve a wider array of tasks in massif's condition evaluation. To characterize the periglacial formation properties, the total number of 3,104 monoliths was selected from the aeration zone. The foundation is comprised of the standard measurements of the properties' engineering-geological indicators – materials of State Enterprise "UkrGIINTIZ, OSC "DneproGiprotrans", "Ukrjuzhgeologija" that were included into the common database (1956-2007 years).Stochastic analysis of average values (by the measurement year) and particular values showed that data skewness and kurtosis in the second case is several time higher (Figure 1).

The rank correlation of year's average values showed that linear correlation with indicator's measurement year was discovered for fraction composition 0.25-0.1 mm (rank correlation coefficient r equals = 0.42); the negative correlation – for deformation module and specific cohesion (r =-0.57; -0.72 respectively). The correlation was not confirmed by regression. The particular values' rank correlation showed that indicators have a sense of the spatial variable, there is correlation of values with the sampling depth z.Thus, the rank correlation coefficient for soil density ρ with sampling depth z equals 0.57, natural humidity w 0.21 and deformation module E 0.61.

Positive correlation with sampling year t was discovered for the following indicators: content of particles bigger than 2 mm with natural humidity w. per unit, (r=0.288). Positive correlation with sampling year t was discovered for absolute deformation value in case of compression testing of naturally humid soil at the stage of normal compression 0.15 mPa (r=0.43), the internal friction angle Fi (r=0.66). Negative correlation with sampling year t was discovered for values distribution of specific cohesion c, mPa, (r=-0.697), deformation module E, mPa, (r=-0.25). Rank correlation values between the indicators are not high (Table 1).

Table 1

Correlation matrix for periglacial formation properties' indicators (particular values)

	WL	***WP***	***W***	***PLS***	***PL***	***R 0,1***	***DEF0,15***	***ESAT***	***FI***	***C***
WL	1.00	0.49	0.36	0.47	0.19	-0.14	0.10	-0.12	-0.40	0.48
WP		1.00	0.36	0.14	0.11	0.09	0.33		0.24	
W			1.00	0.18	0.53	0.26	0.38		-0.16	0.16
PLS				1.00	0.14	0.11	0.12	-0.12		
PL					1.00	0.16	-0.33	0.49		0.30
R0,1						1.00	0.32		0.62	-0.42
DEF0,15							1.00	-0.30	-0.22	-0.23
E, sat								1.00	0.29	0.32
FI									1.00	-0.64
C										1.00

Notes to Table. 1-5: 1. Only meaningful values of rank correlation coefficient are presented. 2. Empty cells mean the absence of meaningful values of rank correlation coefficient. 3. WL, wl, WP,wp – plasticity limits, per unit; W,w – natural humidity, per unit; ρs – soil particles' density, gr/cm3; PL, ρ- soli density, gr/cm3; R 0,1 – fraction particle content 0,25-0,1 мм; DEF0,15 – absolute deformation during naturally humid soil compression test at the level 0,15 mPa; E, sat – deformation module in water saturated condition, mPa; FI – internal friction angle, degree; C,c – specific cohesion, mPa. 4. Symmetrical matrix elements are not displayed.

Multiple regression of indicators properties' particular values in the inhomogeneous sample showed that correlation models are standard in the set of the dependent and independent variables irrespective of the multi – colinearity signs (Table 2).

The multiple regression analysis method requires adherence to strict conditions regarding the homogeneity of selective distribution; these conditions can not be fulfilled in this case. To find the optimal model of correlation between the indicators of subsidence, deformation and strength properties, group method of argument handling was used[4]. Standard, most often measured indicators were chosen as variables characterizing the inner properties of the formation. Testing numerous possible variants allowed us to define the optimal fraction of particle size content that determines the values of relative subsidence. On the compression level approximately equal to the common urban one, particle size content is not a factor for subsidence degradation due to the fact that fraction content is used as a nonlinear component in the model which does not include time as a factor variable.

In the compression interval 0.05–0.1 mPa, with the linear variable t the coefficient is high, the fraction interval for which the time changes act as the subsidence factor is bigger. Fraction content changes in time act as subsidence factor on the compression levels which correspond to extra load (0.3 mPa), for fraction content 0.5-0.25 mm. It is possible to find correlation between changes in certain fractions content, pressure and micro aggregates' size (Table 3).

Table 2

Regression model for particular values of loess formation (particular values)

The dependent variable	Regression Model	Model's parameter AR^2
PL	ρ=0,0008year+0,01z+0,0267w	0,992
WL	WL=0,103*ρ_s	0,97

Table 3

Coefficients for models' factor variables in loess type loams' subsidence

Compression mPa	Fraction, R, mm	Coefficients for variables' linear elements						
		Year, t	***WL,***	***WP***	***W***	***PLS***	***PL***	***R***
	0.25-0.1		0.0015	+				+
	0.05-0.01	0.0011				+	0.0017	
0.05	0.01-0.005	+	0.01		0.005	+	+	
	1.0-0.5				+	+		0.107
	0.5-0.25		+	256.42	91.836	0.005	1.173	1.807
	0.25-0.1	+	+			0.0055	-0.048	-0.028
	0.1-0.05	0.867	24.604	+	0.135	0.0317	-0.016	0.986
0.1	0.05-0.01	+		-0.053		+	0.0025	+
	1.0-0.5			+	0.177	+	0.001	0.0057
	0.5-0.25	+		0.07	-0.831	0.004	+	0.002
0.3	0.25-0.1		0.03	0.006	0.378		0.006	

Notes to Table 3-6: (+) – the variable is included as a factor one, as non-linear element: an empty cell means that variable is not included as a factor one. R – content of a fraction in the range 0.25-0.1; 0.1-0.05; 0.05-0.01; 0.01-0.005 mm

Results analysis shows: the higher the compression, the bigger is the aggregates' size whose changes in time act as a factor in subsidence properties' degradation. Linear relation between functional and factor variables is due to the controlling impact of the destruction process. In the loads' interval 0.05-0.1 MPa which are nearly equal to structural strength, accumulation takes place – slight increase in fraction content 0.25-0.1 mm, because the increase signs of relative subsidence (in the process of degradation) and fraction content are not identical. The reason for that is the destruction of big aggregates sized 0.5-0.25 mm and of the fraction sized 0.1-0.05 mm, this is indicated by the sign "+" or " –" in front of the coefficient. At the compression level of 0.3 MPa takes place the destruction of sand aggregates sized 0.5-0.25 mm. Coefficient analysis at linear factor variable "fraction content" indicates, that linear relation between relative subsidence coefficient and fraction content predominates at compression level 0.05–0.1 MPa. This level is nearly equal to structural strength limit. With linear variables at other compression levels coefficients are lower or non-existent. Linear relation between fraction content and subsidence degradation appears in the dispersion range from 1 to 0.05 mm, which corresponds to the sizes of macro- and microaggregates in loesses [2, p. 146]. Non-linear relation of increase appears in fraction 0.05-0.01 mm and subsidence degradation. These peculiarities indicate hat there is subordination between subsidence properties degradation and changes in aggregate content: this confirms the A.K. Larionov's theory about consecutive destruction of rock's aggregate system and decrease in coagulation-dispersion type connections as a result of increase of water film thickness during subsiding [2, p. 225]. Fraction content 0.1-0.25 mm has the biggest impact on the values of plasticity's lower limit, natural humidity and density.

All the functional variables – deformation properties indicators have the spatial pattern (Table 4). Correlation between time and physical properties is more evident in the models created for the undisturbed condition.

Values of the internal friction angle increase in time, module's values – decrease. Increase in internal friction angle values and the deformation module with depth reflects the relationship between values in their natural condition and the changes due to technogenic impact.In some cases values' decrease (increase) in time does not negate relationship with the sampling depth; this affects the results of the regressive analysis: models for properties regression and the coordinate have not been received. Deformation and strength properties' change in time are connected with changes of medium's dispersion, they reflect degradation's direction and intensity.

Table 4

Coefficients at linear elements of models' factor variables for the physical-mechanical indicators of loess loams' properties

Variable	Factor variable (upper line) and their values (lower line)						
	z	*t*	*WL*	*WP*	*W*	*PLS*	*PL*
E	0.863	-0.543	0.226	-12.05	11.577	-0.832	-
	t	*z*	*WL*	*WP*	*W*	*PLS*	*PL*
Fi	-	0.781	-7.316	-	56.953	0.101	14.639
	z	*t*	*year*	*WL*	*WP*	*W*	*PLS*
E, sat	0.705	+	0.001	-	0.358	4.654	-0.035

Notes to table 4-6: (+) – the variable is a factor one, the relation is non-linear; (-) – the variable is not a factor one; 0.705 – coefficient of the linear polynomial element of *ai Xi* type, where *a* – is a coefficient at factor variable; *X* – factor variable, year – indicator's measurement year

Table 5

Coefficients at linear factor variables in models of paleosoil horizons' relative subsidence

Compression MPa	Fraction R	Coefficients at linear factor variables t. year						
	R	t. year	z	WL	W	PLS	PL	R
	0.01-0.005		+	0.069			0.006	+
0.05	менее 0.005		+	-0.119		+	-0.004	+
	1-0.5	+	+		0.13	0.0016	0.0018	
	0.5-0.25	+	+		0.13	0.0016	0.0018	
	0.25-0.1			+	+		-0.009	-0.011
	0.01-0.005			+	-0.018		+	0.001
0.1	менее 0.005		0.217	0.289		+	0.055	-0.001
	0.25-0.1				+	+	-0.106	
0.15	0.1-0.05				+	+	-0.106	
	0.01-0.005				-0.693	+	0.001	+
0.2	менее 0.005				-0.693	+	0.001	+
	0.5-0.25		+		17215	56.86	+	0.031
0.3	Менее 0.005	0.071	+	+	+	0.069	0.0197	+

Table 6

Coefficients of linear factor variables in models of paleosoil horizons' physical-mechanical properties

Variable	Coordinates		Physical properties indicators				
	t	***z***	***WL***	***WP***	***W***	***PLS***	***PL***
C		-0.085	5.046	-1.063	-0.097	+	-0.398
C. sat				1.111	-1.694	-8.26	0.9
E	0.0048			24.528	-1.194	-0.192	1.676
E. sat	+	0.94		80.57	-26.71	0.104	
Fs. sat	+	+	-126.23	67.23	270.17	1.111	

Notes: Fs – internal friction angle, degree, complete water saturation condition

Result analysis of paleosoil horizons' changes study shows that soil density is a linear factor variable, while soil particles density is non-linear in the majority of models (Table 5). Linear relation between the sandy and silt fractions' content and subsidence degradation is discovered in the compression interval 0.05-0.1 MPa; this points out to the relationship change between the compressions' interval in which aggregates' destruction is a factor for subsidence degradation. Linear relation between clay fraction content changes in time appears only at the level of 0.3 mPa, in all other cases linear relation is poorly defined or absent. Subsidence models' spatial pattern is confirmed at the initial compression levels. In this model selection factions act as factor variables. Coefficient values are smaller than in loess-like loams' models. In paleosoil horizons microaggregate content changes are less defined than in loess-like loams.

Linear connections with measurement year are confirmed only for the deformation module values (Table 6), the tendency does not correspond to mechanical properties indicators' changes for subsiding loess-like loams. In the process of subsidence degradation in paleosoil horizons fine sand aggregates' and fine clay aggregates' accumulation is accompanied by a decrease in the fraction content 0.01- 0.005 mm.

Conclusions:

* For loess-like loams and paleosoil horizons the aggregate composition changes in the process of subsidence

degradation are characterized by different trends, which leads to the decrease in massif's anisotropy.

* Indicators of loess-like loams deformation properties do not lose the character of spatial variables. The internal friction angle values increase in time, while module values – decrease; but with depth – they increase.

* For loess-like loams, deformation and strength properties' changes in time are connected with the medium's dispersion changes which reflect direction and intensity of degradation.

* Result analysis of paleosoil horizons' changes study indicates that soil particles' density is present as non-linear factor variable in the majority of models.

* Compression intervals in which aggregates destruction is a subsidence degradation factor depends on the type of soil, because for loess-like loams and paleosoil horizons the difference in coefficients at linear factor variable "fraction content" is one order of magnitude or more. Microaggregate content changes in paleosoil horizons are less defined, than in loess-like loams.

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ОСОБЛИВОСТІ ДЕГРАДАЦІЇ ДЕФОРМАЦІЙНИХ ТА МІЦНІСНИХ ВЛАСТИВОСТЕЙ ЛЕСОВИДНИХ ГРУНТІВ НА ПРИКЛАДІ м. ДНІПРОПЕТРОВСЬКА

Наведено результати математичного моделювання деформаційних і міцнісних властивостей в процесі деградації з використанням методу групового обліку аргументів. Цей метод був застосований для опису мінливості властивостей геологічного середовища як елемента природно – техногенної системи регіонального рівня.

Мета дослідження: встановити особливості деградації масиву на прикладі тривалого дослідження даних про властивості перигляціальних ґрунтів з використанням методів стохастичного та індуктивного моделювання. Методи рішення і програмне забезпечення: стохастичне моделювання виконано методами кореляційно – регресійного множинного аналізу; індуктивне моделювання – методом групового урахування аргументів. Програмне забезпечення: STATIST (ДНУ ім. О. Гончара), STATISTICA (trial – версія), авторська програма (канд. фіз.-мат. наук, доцент ДНУ ім. О. Гончара Л.С. Коряшкіна). Результати підтверджують підпорядкованість деградації властивостей і змін агрегатного склад, що підтверджує теорію А.К. Ларіонова про послідовне руйнуванні агрегативної системи породи і зменшенні зв'язків коагуляційно – діспергаційного типу в результаті збільшення товщини водних плівок при осіданні [2, с. 225]. Наукова новизна. Методи індуктивного математичного моделювання застосовуються для опису зміни властивостей лесових ' ґрунтів , що піддаються техногенезу, дозволяє об'єктивно встановити факторіал змінних , зміна яких впливає на інтенсивність процесу. Координати, фізичні показники властивостей були обрані факторними змінними. Оцінка інтенсивності техногенного впливу не виконується, що значно спрощує вирішення. Практичне значення. Індуктивне моделювання дозволить виконувати більш точні прогнози деформації.

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ОСОБЕННОСТИ ДЕГРАДАЦИИ ДЕФОРМАЦИОННЫХ И ПРОЧНОСТНЫХ СВОЙСТВ ЛЕССОВИДНЫХ ГРУНТОВ НА ПРИМЕРЕ г. ДНЕПРОПЕТРОВСКА

Приведены результаты математического моделирования деформационных и прочностных свойств в процессе деградации с использованием группового метода учета аргументов. Этот метод был применен для описания изменчивости свойств геологической среды как элемента природно – техногенной системы регионального уровня.

Цель исследования: установить особенности деградации массива на примере длительного исследования данных о свойствах перигляциальных грунтов с использованием методов стохастического и индуктивного моделирования. Методы решения и программное обеспечение: стохастическое моделирование выполнено методами корреляционно-регрессионного множественного анализа; индуктивное моделирование – методом группового учета аргументов. Программное обеспечение: STATIST (ДНУ им. О. Гончара), STATISTICA (trial – версия), авторская программа (канд. физ.-мат. наук, доцент ДНУ им. О. Гончара, Л.С. Коряшкина). Результаты указывают на соподчиненность деградации просадочных свойств и изменений агрегатного состава, что подтверждает теорию А.К. Ларионова о последовательном разрушении агрегативной системы породы и уменьшении связей коагуляционно-диспергационного типа в результате увеличения толщины водных пленок при просадке [2, с. 225]. Научная новизна. Методы индуктивного математического моделирования применяются для описания изменения свойств лессовых 'грунтов, подвергающихся техногенезу, что позволяет объективно установить факторные переменные, изменение которых влияет на интенсивность процесса. Оценка интенсивности техногенного воздействия не выполняется, что значительно упрощает решение. Практическое значение: индуктивное моделирование позволит выполнять более точные прогнозы деформации просадки.