International Journal of Engineering Science Invention
ISSN (Online): 2319 – 6734, ISSN (Print): 2319 – 6726
www.ijesi.org Volume 2 Issue 4 ǁ April. 2013 ǁ PP.27-31

The phase portrait and degradation in soil.

Mokritskaya Tatiana

Department geology and hydrogeology. University Dnepropetrovsk Oles Gonchar, Ukraine

ABSTRACT: *The compaction coefficient of loess is a nonlinear function which is coupling the porosity coefficient and two parameters: pressure and humidity. The compaction coefficient is the main characteristic of the subsidence soil. A scatter diagram constructed in coordinates {the coefficient of porosity; the difference between the coefficients of porosity (or non-normalized difference between the absolute deformations of the soil)} is a likeness of the phase plane.*

Keywords: *Loess, phase portrait, degradation.*

I. INTRODUCTION: ANALYZE OF PREZENT THEORY AND CONSEPTIONS.

The ability of polygenetic continental deposits of Quaternary per glacial formations to a singular behavior, as conditions are changing, is a study subject throughout the history of the geology development. The first experiments on subsidence properties were obtained in 20-30 years of the last century in the works of Yu.M. Abelev,it were supplemented inresearches byN.Ya. Denisov , A.K.Larionov,V.A. Priklonsky, V.P. Anan , N.I. Krieger, V.T. Trofimov, T.G. Ryashchenko , and others. Subsidence means "loess deformation under its own weight when it is getting wet " [1, p. 226], "a flop - step subsidence deformation in loess rocks" [2, p. 49]. A classical paper by Krieger N. [3, p. 252] specifies the most important features of the loess:"adaptability of loess properties to the surrounding geological environment "," self-defense "," degradation ", wherethe degradation means " loss of specific seal properties, loss of the subsidence property, loss of a characteristic texture, leaching." Investigations of relations between the deformation behavior and the characteristics of the microstructure of loess soils were conducted byV.I. Osipov, V.N. Sokolov,T.G. Ryashchenko, N.N. Grin, and others.

The results of the study of loess and loess-like rocks indicate the high structural vulnerability of their textural features in the process of technological impacts, leading to their degradation. The process of properties changing as a result of the subsidence degradation can be studied from the standpoint of the theory of dynamical systems. Mechanics is a classical field of application of the theory of dynamical systems [4] where Hamiltonian systems with no dissipation and no supply of energy are very important. Evolution of such a system is described by the movement of a point on the phase plane with coordinates p (generalized coordinates) and momentum q (generalized momentum). Trajectory is a movement of points on the phase plane which is successive in time. Reduction of the phase space and contraction of the domain to the attractor are characteristic fornon-Hamiltonian systems with dissipation. The attractor structure determines regular or chaotic dynamics. If the one-dimensional sequence of system parameters is given then the trajectory of a dissipative system is described incardinates $(x;\dot{x})$, where x is the parameter of the system, and $\dot{x}$ is the velocity of changing of the parameter. Time is implicit and it allows us to ignore changing of the parameter in timeforcharacterization of the points cloud (basin of attraction).

In geology, the geological environment has traditionally been viewed as a Hamiltonian system. The compaction coefficient is used as the main parameter of deformed soil ground in soil mechanics (N.A. Florin, N.N. Tsytovich,N.N. Maslov, M.N. Goldstein and others). By N.A. Tsytovich [5, p. 134], the seal law expresses relations betweenporosity coefficient changes and pressure changesina narrow range in the following form:

$$d\varepsilon = -a dp \qquad (1)$$

where$dp$is a pressure differential , $d\varepsilon$isadifferential of the porositycoefficient on the range of normal tensiondp and$a$isthe compaction coefficient.

The compaction coefficient is a nonlinear function which is coupling the porosity coefficient and two parameters: pressure and humidityThe compaction coefficient is the main characteristic of the subsidence soil [6]. The subsidence is characterized by a soil deformation difference in full water saturation conditions and natural moisture conditions, on each stage of standard compression tests, normalized with respect to natural conditions.

Disablingof the normalization with respect to natural conditions does not affect the form of relations between the porosity coefficient and its differential because the factor used for the normalization is constant for a given sample and has the following form:

$$\frac{1+e_0}{h_0} \qquad (2)$$

where e_0 is an initial value of the coefficient of porosity, h_0 is the height of a soil sample in conditions close to natural.Factor is constant for a given sample.

A scatter diagram constructed in coordinates {the coefficient of porosity; the difference between the coefficients of porosity (or non-normalized difference between the absolute deformation of the soil)} is a likeness of the phase plane with coordinates $(x; \dot{x})$. The second coordinate is the difference between soil deformations in different soil moisture conditions undera given level of pressure. Each point of the diagram describes the relationship between the main soil parameter and its differential as a result of changes in the thermodynamic conditions. Analysis of the trajectory (time series of points of the phase plane) is needed for characterization ofsubsidence degradation of the massif in time and for choice of a theoretical model of the system.

Results of properties determinations in different locations over a long period of time form a heterogeneous set of random data. Analysis of the subsidence dynamics (average, calculated bythedata array ordered in time)allows usto characterize the form of the attractor.

II. METHODS OF RESEARCHING.

We assume that subsidence capacity meansabilityfor specific mechanical reactionsto changing of thermodynamic parameters of the environment which was formed during the soil formation time. Capacity parameter is a measure characterizing a reaction to changingof thermodynamic conditions during the experiment which depends on initial conditions. Process of consumptionof capacity parameter means the rate of degradation of subsidence properties in functioning of a natural-anthropogenic system. Evolution as "unlimited sequence ... self-organization ... from an unstable to a stable state "[see 9, p. 9]appears in an irregular geological environment degradation. Marginal subsidence properties degradation of amassif will correspond to a transition to the second stationary state in which the consumption will be zero because of the system capacity exhaustion.Now, there are three main approaches to modeling of nonlinear processes [7]:

(i) applying of stochastic models;
(ii) constructing of models based on physical properties of considered processes;
(iii) Constructing of a mathematical model as an evaluable equations with further identifications.

Applying of stochastic modeling techniques to laboratory experiments data handling (formation is the study level) allows us to analyze a variability of loess properties in a city aeration zone over a studied period of time. Parameters are introduced on the ground of physical premises of nonlinear subsidence processes. The capacity of a subsidence soil massif is calculated as the mean value of the coefficient of porosity of the loess massif (in a city influence zone over a given studied period of time). The capacity parameter is defined as the average difference of the absolute soil deformation caused by changes of the humidity under compression tests. Analysis of the time series of the massif capacity and the capacity parameter allows us to characterize the form of the attractor.

III. RESEARCHING REZULTS.

The approbation of constructing techniques of the phase portrait of the subsidence properties degradation is based on a database of properties of per glacial formation soils in an aeration zone (Ukraine, 1964 - 2007.). Data sets corresponding to the intervals 1978-1991 and 2001-2007 are continuous and uniform. Samples of medium and large volumes characterize the distribution of properties of theextra glacialformation subsidence soils in an aeration zone of a built up area. Building density is high, the values obtained beyond areas of mechanical effects of low-rise buildings.

Our statistical analysis confirms the uniformity and symmetry of physical properties of the formation in the volume of the aeration zone defined over one year despite random choice of data in the spatial coordinates. We have calculated the coefficient of porosity of the formation which characterizes the porosity state of the massif in the aeration zone over the selected years. The mechanical reactions heterogeneity has appeared essential in tests with steps of pressure close to natural (0.05 and 0.1 MPa with the state of the natural moisture). Asymmetry for two distributions has become statistically essential since 2004.

Visual analysis of changes in average values of the coefficient of porosity and average values of absolute deformations over time (Fig. 2) indicates that there is periodicity in changes of formation properties and their heterogeneity. The periodicity is a result of self-organization of the massif in the process of degradation in the volume of a natural-anthropogenic system of local level (city). Static and dynamic mechanical stress, flooding and groundwater level reducing result compaction and decomposition and it leads to periodic changes of the coefficient of porosity. Quasiperiodicity is regarded sometimes as a chaotic motion sign which is unpredictable and "forgetting" about the initial conditions [8, p. 14].

Using testing results of certain monoliths it is possible to analyze subsidence properties of the massif via constructing a diagram of points $(e, \dot{e})$ where **e**is the coefficient of porosity and $\dot{e} = \boldsymbol{f}(\boldsymbol{e})$is the difference of the absolute soil deformation caused by changes of humidity under a given level of pressure. Our analysis of the diagrams shows that the area of the states domain increases during compression tests (with increasing pressure from 0.05 to 0.25 MPa) in both samples. The increase of the basin of attraction under pressure increasing of in both total samples is a sign of some trajectories divergence.

During the compression test there may appear adestructionof thesoilstructureif thetransmited pressure isexceedingthestructuralstrengthand itleadsto a chaoticstate. Comparisonofthe points positionscharacterizingscatterintheperiods 1978-1991 and 2001-2007.

showsthatattheinitialstageofcompressiontestsatlevel 0.05 MPathereisa compressionofthe points cloud bybothcoordinateaxes. Reductionofthe capacity and the capacityparametercanbeexplainedbycompaction and degradationof subsidencepropertiesof the massif duringeverydaystresses (seeFig. 2 a and b).On pressure steps higher than the natural pressure (0.25 MPa) the sign of the differential of the coefficient of porosity is opposite to the sign of the difference of deformations. In the period 2001-2007 the point cloud area defined in coordinates "capacity - setting capacity" on the step of 0.25 MPa is much bigger than in the period of 1978-1991 years. The capacity values decrease and the capacity differential values increase. The trajectories scatter on steps of pressure above the structural strength indicates a chaotic prognostic state.

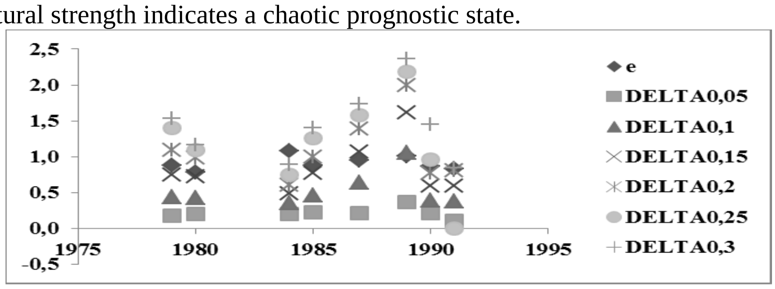
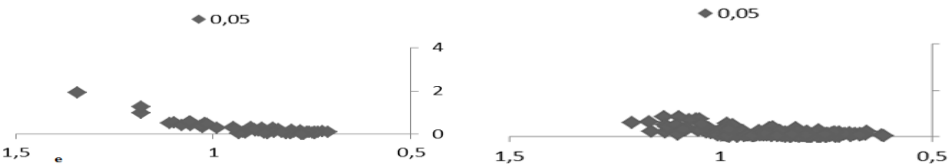
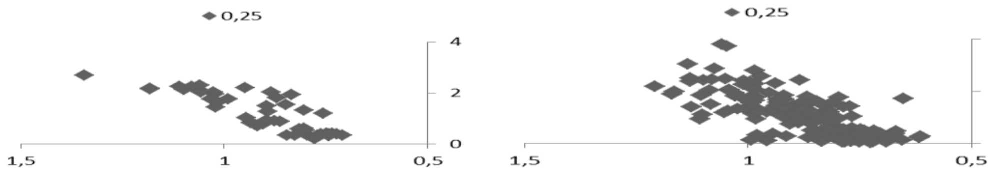


Figure 1. The mean values of capacitance (void coefficient e), h u, and setting capacity (absolute increments of strain when the state of humidity DELTA 0,05-0,3) formations, 1978 - 1991.

Notes: 1. DELTA 0,05 - 0,3 - absolute strain increment when the state of the humidity on the steps of DELTA pressure of 0.05-0.3 MPa in compression tests.



a) *b)*



c) *d)*

Fig2. Diagram of phase states of the massif on the plane e; $\dot{e} = \dot{f}(e)$ under the pressure of 0.05 MPa and 0.25 Mpa.

Notes: 1. Values of the coefficient of porosity are represented on x- axis and values of the differential of the coefficient of porosity are represented on the y-axis.

2. a) diagram of phase states under pressure of 0.05 MPa in the period 1978-1992;
b) diagram of phase states under pressure of 0.05 MPa in the period 1992-2007;
c) diagram of phase states under pressure of 0.25 MPa in the period 1978-1992;
d) diagram of phase states under pressure of 0.25 MPa in the period 1992-2007.

Changing of the position and the area of the point cloud on the phase plane within time and pressure increasing proves that the process of subsidence degradation of the massif is chaotic.

During the selected time periods raising of underground water has changed to decreaseing of the water level.So,changing ofthelink "capacity - parameter" trend cannot be caused by reducionof the aeration power, exception oflow-subsidence grounds and,as a result, apparent increase of the subsidence. We studied grounds located within boundaries of an urban area with a similar developmentdensityand hence the change can not be a corollary ofsome data heterogeneity caused bya different intensity of the anthropogenic influence.

The theoretical limit of the subsidence properties degradation is a stable balance either in a point or on a segment of the x-axis because a special property (subsidence capacity)acquired in a rock formation is consumedirreversibly. The theoretical limit is achievable in the ideal case of complete degradation of subsidence properties. In reality, some close to zero values remain and a limit cycle is more plausible. On the diagram (Fig. 3)there are "jumps" where trends of the capacity and the parameter are opposite.

Alternation of segments with different increment trends indicates the presence of zones of an "intermittent" connection of physical and mechanical parameters of the system at strains close to natural. Intermittent movements (bursts) are asign of achaotic motion [see 8].The position of a point on the phase plane, i.e. in the domain of states of a given massif with special properties (subsidence), is defined by coordinates:the capacity and the maximum forecast value ofthe differential of the capacity parameter under the specified conditions.

Capacity values are calculated as the average coefficient of porosity of a loess massif (in a city influence zone within a set time). The capacity parameter is defined as the average absolute difference between the deformation of the soil as a result of changes in the humidity state in compression tests. The tracking order was given with the time series of monitoring. Constructedtrajectories ofthe system dynamics characterize the soil evolution (degradation) which has nonlinear properties. The trajectoriesdiagrams (Fig. 4) show the subsidence degradation for containing no data gaps periods 1978-1991 and 2001-2007depending on the pressure levels (from 0.05 to 0.3 MPa)separately. Analysisofthetrajectories confirms our conclusion onthe existence of chaos signs: the phase portrait is shrinking , there are signs of closure- i.e.a limit cycle in the equilibrium state. Closed orbits are a sign of a periodicity and walking is a sign of a chaotic process.

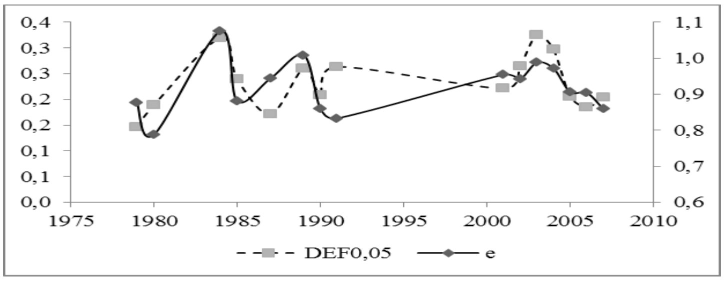
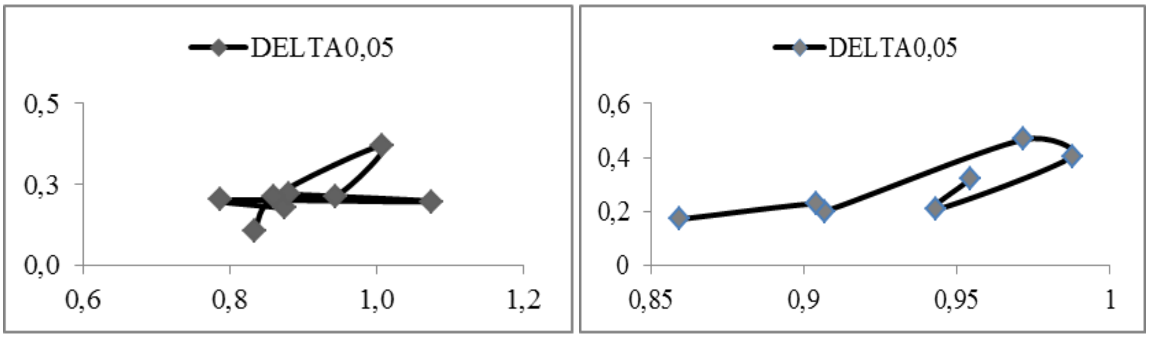
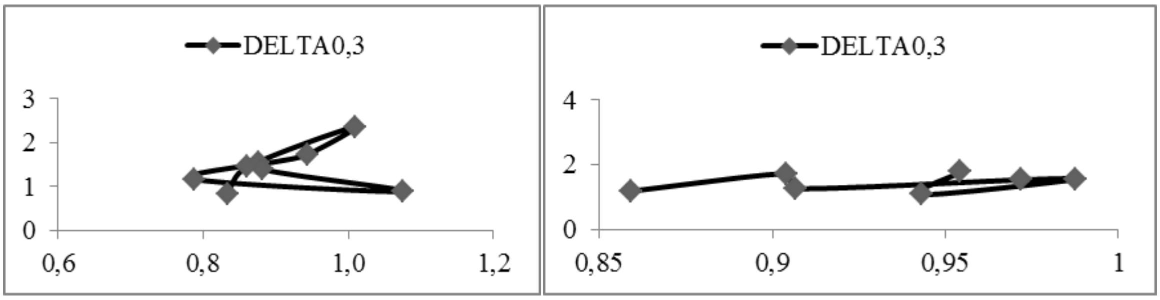


Fig. 3 Diagram of changes of average values of the massif parameters in time.

Notes: e –the coefficient of porosity; DEF0, 05 –the absolute ground deformation of the natural moisture on the pressure level 0.05 MPa.

The phase diagram of the degradation trajectory of subsidence properties of a formation based on the results of the study of the subsidance properties of periglacial formations in a zone of influence of an industrial agglomeration for 1979-2007 years (Fig. 5) confirms that the system dynamics is chaotic. The positions of the points with the coordinates: the subsidence capacity (the initial value of the coefficient of porosity), the capacity parameter (the differential caused by changes of the pressure and the humidity) in 1979 (the beginning of the trajectory) and in 2007 (the end of the trajectory) are almost identical on the pressure stage 0.05 MPa and very close on the level of 0.3 MPa.

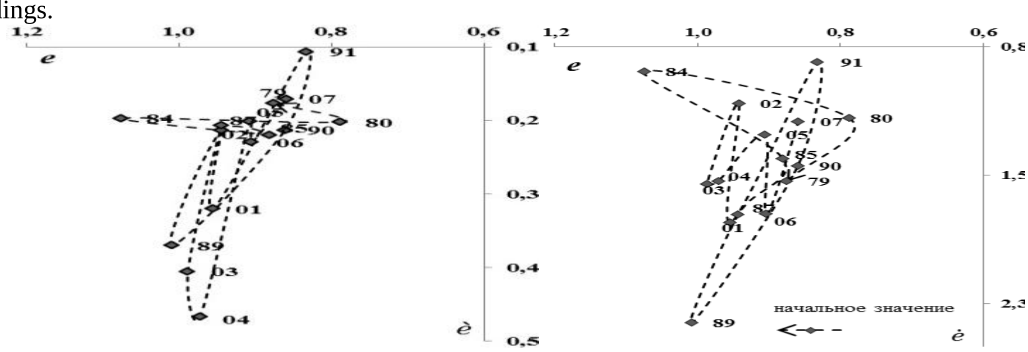




a) 1978-1991 ***б) 2001-2007***

Fig. 4. Diagram of the phase trajectories of the massif of subsidence soil (periglacial formations, pressures of 0.05 and 0.3 MPa, 1978-1992.)

Thetrajectorycharacterizesperiodical changes of the compaction state and the subsidence state of the massif.The reduction of the size of the area in the period of 2001-2007 years in comparison with the period of 1979-1991 years is characteristic for the stress state of the massif which is close to the conditions created at the base of buildings.



a) *b)*

a) Phase portrait of the subsidence degradation in the area of stresses 0.05 MPa.

b) Phase portrait of the subsidence degradation in the area with additional stresses 0.3 MPa.

Fig. 5 Phase portrait of the massif subsidence degradation in the area of stresses close to the natural (a) and additional (b) (Dnepropetrovsk, 1979-2007 years.).

Notes: ***89*** *- The point (capacity e, capacity parameter $\dot{e}$) position on the phase plane in 1989.*

IV. CONCLUSIONS

- the diagram of the massif subsidence degradation in the local natural and man-made system influence zone (city) constructed in the coordinates (e; $\dot{e}$) is an analogue of the phase portrait of a dynamic system;
- the process of the massif subsidence properties degradation has signs of a chaotic process;
- the phase portrait of the subsidence soil degradation allows us to ascertain the attractor form.

REFERENCES

[1]. A.K. Larionov. *Forests and rock construction properties*.(Moskow.Gosgeoltechizdat, 1959).
[2]. V.F. Krutov. *Building properties of clay soils of Ukraine.(*Kiev.: ND, 1980)..
[3]. N.Krieger*Loess, its properties and relation to the geographical environment.*(Moscow.Nauka,1965),
[4]. Ebelinr Werner,Enrel Andreas Faystel Reiner. *Physical processes of evolution*. URSS, 2001.
[5]. N.A Tsytovich*Soil mechanics*. (Moscow: Ministry of Construction, 1963).
[6]. Mustafayev A.A. *Calculation of the foundations on collapsible soils*: (M: HS, 1979). –
[7]. Nikulchev E.V. *Geometric approach to modeling of nonlinear systems based on experimental data:* - (Moscow: MSUE, 2007).
[8]. Moon F. *Chaotic Vibrations: Introduction for Scientists and Engineers*: Trans. from English. (M, New York, 1990).