13th World Conference on Earthquake Engineering
Vancouver, B.C., Canada
August 1-6, 2004
Paper No. 1588

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EARTHQUAKE TRIGGERED COLLATERAL HAZARDS ON THE TERRITORY OF UZBEKISTAN

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SUMMARY

The analysis of consequences of strong and destructive earthquakes occurred in Uzbekistan and neighboring countries has show of development of residual deformations on loess soils such as subsidence, landslides and liquefaction. Loess soil covered a big part of the territory of Uzbekistan. Earthquakes of rather moderate intensity can cause a large number of human victims if in the zone of earthquake there are wetted loess soils. Earthquake-trigger influence for landslides in Central Asia was investigated. The main property of loess soil is collapsibility. The paper presented the result of research of the influence of seismic shaking on the development collapse processes.

INTRODUCTION

Various type of ground failures are associated with moderate-size or large earthquakes. Several data sets have been used by many authors for the study of landslides and soil liquefaction triggered by earthquakes. These date sets cover different seismogenic areas of the world like Japan, California, South America, Italy, Turkey, etc. Uzbekistan located on the Asian continent in the basin of the great Amudarya and Syrdarya rivers, in the desert subtropical zone, taking the part of Turan Lowland in the West and mountainous highlands in the East. Natural environment of the Republic is characterized by high seismic conditions. There are many cities such as Tashkent (the capital, population 2,3 million), Samarkand, Bukhara and others have expected seismic intensity YIII and IX (MSK). The earthquakes on the territory of Uzbekistan are the most frequent and dangerous. In the period 1955-2000 year in territory of Uzbekistan happened 81 earthquakes with M>5. M=5 – 56 times; M=5.5 – 14 times; M=6 – 4 times; M=6.5 – 4 times; M=7 – 3 times [1]. The territory of Uzbekistan covered by loess soil. By comparison of the map of seismic zoning to a map of distribution of loess soils it is easy to be convinced that the territory of the majority of seismic areas are covering by collapsible loess soils with significant thickness (50-100 m).

The analysis of consequences of strong and destructive earthquakes, occurred in Uzbekistan and neighboring countries has show a wide range of development of residual deformations on loess soils: landslides, fractures, liquefaction, surface faulting, subsidence. Loess soils are a specific media for propagation of seismic waves and sensitively react to external dynamic influences. Development of seismodynamical processes in loess soils necessitates analyzing the stability of buildings and structures.

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This analysis must taken account of seismic processes when designing buildings and structures in seismic areas. Therefore, of the important stage of seismic microzonation is taken account of ground conditions. Change in site intensity due to influence of local soil conditions can be determined by consideration of the following factors as:

- Type of soils composing upper part of the ground cross-section;
- Thickness of the soil stratum;
- Seismic properties of soils and their seismic response;
- Level of underground water;
- Possibility of manifestation of seismogeological effects.

Estimations of these factors allow the specification of settlement seismicity in area under study to be made. This paper to present data collected by Institute of Seismology of Academy of Sciences of Uzbekistan since 1977, which examined both hydrocollapse and seismic subsidence in loess soils for the Tashkent region in Uzbekistan and result of research of landslides triggered by earthquake.

DISTRIBUTION AND SEISMIC PROPERTIES OF LOESS SOILS ON THE TERRITORY OF UZBEKISTAN.

Loess is a widespread phenomenon in the Quaternary sedimentary record. The loess is homogeneous, without bedding, is more dust (contents of fractions 0.005 - 0.05 mm more than 50 %), porous (porosity more than 42 %), frequently having macro pore, collapse after wetted Trofimov V. [2]. Loess is subdivided on collapsibility at natural pressure, and manifested the collapsibility at additional loadings. If loess soils have not of listed characteristics, it is view as loessial soils. Loess soils meet on all continents, but it is widest they are distributed in Europe, Asia and America. Loess can cause a number of engineering problems. These problems result because loess undergoes structural collapse and subsidence due to saturation when both the initial dry density and initial water content are low Rogers [3]. Generally, soils that possess porous textures with high void ratios and relatively low densities have the potential to collapse. They have sufficient void space in their natural state to hold their liquid limit moisture content when saturated. At their natural moister content these soils possess high apparent strength but they are susceptible to large reductions in void ratio on wetting, especially under load. In other words, the metastable texture collapses as the bonds between the grains break down when the soil is wetted. Hence, the collapse processes represents a rearrangement of soil particles into a denser state of packing Jefferson [4]. The particles, which make up loess deposits, although principally of silt-sized quartz, consist also of feldspars and micas. Clay-sized particles within the loess structure consist of quartz, feldspar and carbonates in addition to true clay minerals. As result of their genesis and constitution, loess deposits form remarkably open structures with the interstitial clay-sized particles congregating at the quartz particle contacts. A process of inter-particle bonding, the strength of which can in certain circumstances increase with time, maintains this open structure. Stability of loess soils depends on their moistening. Therefore at change of moistening the engineering - geological and seismic properties of soil vary. There are numerous cases around the world where loess collapse on inundation, when under load, has resulted in damage and considerable cost. Usually, loess has high shearing resistance and withstands high stresses without great settlement, when natural moister content is low. However, upon wetting, the clay bond tends to soften and cause collapse of the loess structure inducing large settlement under low level of stresses. Therefore, it is dangerous to construct on these soils without improving their characteristics Abdrabbo [5].

Loess soils in territory of Uzbekistan observe on various climatic, geomorphologic zones: on flat surfaces of mountains, their slopes, foothills, foothill plains and valleys of the rivers. The big thickness (from 5-10 up to 80-100 m) and the continuous covers loess soils are characteristic for foothills, foothill plains and intermountain hollows. The faltering and island covers loess soils by capacity from 0.5-3 till 10-18 m meet above than these marks. The distribution of loess soils on the territory of Uzbekistan divided on three zones Mavlyanov [6]:

I - zone of continuous distribution of non-collapsing and weak collapsing loess soils - plain part of the territory. Here basically are observed alluvium loess soils .

II - continuous distribution of collapsible loess soils - foothills and foothill plains. It basically are proluvium loess soils.

III- zone of island distribution of collapsible and non- collapsible loess soils - mountain part. Prevail here eluvial and deluviam (slide rocks) loess soils.

The age of loess may be Early Quaternary (Q_I stony loess), Middle Quaternary (Q_{II} , proluvium loess and proluvium- diluvium loams), Late Quaternary (Q_{III}, alluvium, alluvium-proluvium, diluvium, fluvioglacial), Recent (Q_{IV}, alluvium loess). Are most distributed proluvium loess soils of Pleistocene age, which cover foothill plains and top part of ancient river terraces. It is Tashkent region, Golodnay and Karshi steppe, Samarkand hollow, Fergana and Shahrisabs hollow, slopes of mountains of Nuratay, valley of the Kashkadarya and Surhandarya rivers. The capacity of proluvium loess soils changes from 20-30 m up to 80-100 m.

Macroseismic observations of consequences of last strong earthquakes shows that the seismic effect on different sites is manifestation not equally. On increasing of seismic intensity basically the following factors influence: age and genesis of loess soils, depth of a level of underground waters, the ruggedness of a relief and gradient of a slope, thickness of loess soils and lithological composition, property of soils. On the data of macroseismic researches, character and degree of influence of these factors in different parts of area are various. In mountain and foothill zones the determining influence on change of seismic intensity is rendered lithological composition of soils, and relief of district. In plain territory increasing of seismic intensity depends from lithological composition and level of underground waters. Seismic zonation, the taking into account the probable change of seismic intensity depending on engineering-geological conditions was conducted for Tashkent and Chirchik. The sites with distribution of dry loess soils (the thickness more than 5 m), occupying the top terrace of Chirchik river estimated such as average seismic effect with change of seismic intensity “0” . The sites with distribution of rocks and area of distribution dry and wetting gravel estimated as a territory with reduction of seismic intensity “-1 “. To sites with increase of seismic intensity “+ 1” the high slopes (20-30 м) fifth terrace of the Chirchik river and area of wetting loess soils (where the level of underground waters is higher than 5 m.) are referred.

For studying of seismic properties of loess soil the field researches near to city of Tashkent on loess massive with capacity of 40 m were conducted. The change of engineering - geological and seismic properties of loess soils after wetting were determined (Tab. 1).

Table 1. The changing of physical - mechanical and seismic properties of loess soil after wetting.

The condition of loess massiv	Natural density g/sm^3	Porosity, n %	Natural wetting W (%)	Seismic wave Vp m/sec	Seismic wave Vs m/sec
Natural	1.5	50	7	700	350
After artificial wetting	1.9	40	18	450	280

The analysis of results of the conducted researches has shown that after artificial wetting of loess soils all physical - mechanical properties were changing. With increase of wetting the porosity and distribution of seismic waves decreases. All this reduces the seismic stability of loess massive.

Many researchers investigated the dependence of intensity of shaking of loess soils from their capacity, hydro-geological and geomorphologic conditions Medvedev [7], Musaelyan [8].

The change of engineering - geological, hydro-geological and in this connection engineering - seismological conditions occurred in loess distribution territories when processes of construction is finished. In built up territories process of flooding that is increase of a level of underground waters is observed. Thus, main tasks for engineers are: an estimation of seismic influences on stability of ground foundations, a study of conditions of development of these processes, and prediction of probable consequences of such seismodynamical processes.

SEISMIC SUBSIDENCE IN LOESS SOIL

Collapsibility of loess soils at Tashkent region.

The major city in the Central Asian region is Tashkent, and this is founded on loess, near to the slopes of the Tien Shan range. Tashkent is a leading " loess city " and its location and construction factors relate very strongly to the loess. The flooding processes in Tashkent are responsible for moistening of building foundations located in zones with loess soils having hydroconsolodation properties. As result of moistening there takes place decrease in bearing capacity of soils and subsequently deformations of buildings occur. It might be supposed that in the city of Tashkent with its 2000 years history loess soils could have realized their collapsibility, especially in central parts of the city. However experience shows that subsiding abilities still show in case of moistening of soil foundations. On the loess territories take place collapse, weathering, erosion, suffusion, landslides. Collapses in loess are the most widespread engineering-geological process complicating of a condition of construction of buildings .The urban and industrial construction changes also the soils under the foundation of various structures. The basic reasons of these changes are additional dynamic and static loadings on soils, and for loess soils still change of wetting and saturation. The dynamic pressure arises in addition to static. And under influence of static pressure from weights of buildings and structures during condensation of soils there is an increase of their density, resistance to shift, module of deformation and reduction of porosity and compression.

The wetting of loess soils occurs as a result of outflow of water from a sewer and water network, and also at watering the sites near the buildings. For this reason buildings located in various parts of city are deformed. The average level of underground water in Tashkent is 5 - 10 m, but on the sites of local – flooding processes is observed the level of underground water table is on depth of 1.5 –3.0 m. The cause of flooding processes is result of filling up of ancient drainage channels in Tashkent. The thickness of loess soils in territory of city varies from 2 up to 70 m. On the basis of generalization and statistical accounts of the large number of laboratory definitions (1500 samples) and field investigations of the forecast of collapsibility of loess soils of area is made. The territory of Tashkent divided to 4 categories of loess soils with expected collapse are allocated at wetting and external loading of 1.5 kg/sm^2 : up to 5 sm., 5-50 sm., 50-100 sm., more than 100 sm. Khudaybergenov [9]. The collapsibility of loess soils is increased basically in the water divide sites especially there, where is not present irrigation channels and the soils are not wetted, and also in a southwest direction.

Seismic subsidence process.

Seismic subsidence is the additional deformation of loess soils as a result of weakening of structural links and destruction caused by seismic vibration. This kind of subsidence is displayed in sands, in various filled grounds and, with moistening, in loess soils. Seismic subsidence as a component of common subsiding deformation can has taken place under seismic excitations both during the subsiding process and after stabilization as well Kriger N. [10].

A study of the development of seismic subsiding processes by field investigations has conducted on the territory of Tashkent where there are collapsibility loess soils widespread. Many buildings and structures in the city were designed with consideration of the hydro-consolidating properties of loess soils, however there is buildings designed and constructed without proper consideration of these factors, and as a consequence under moistening of the foundations deformations occurred causing damage to these buildings. Such deformations were observed in buildings of AUTOVAZ venture, administrative buildings of Sovplastital company, Institute of Civil Protection, Tashkent State Conservatory, etc. For these

buildings the institute TashGIITI carried out geodetic observations, recording the settlement of the marks positions on the walls and foundations of buildings. The continuous observations the settlements of the damaged buildings were conducted during 3-5 years with frequency of every 3-4 to about 15 months depending on intensity of the settlement process. For the study of development of seismic subsidence the data from geodetic observations were analyzed with seismometric records registered on the Tashkent region for the same period.
The analysis of these diagrams (Fig.1) shows that the intensity of development of deformations in damaged buildings depends on a number of factors. The main factors are:

1) the engineering-geological properties of loess soils,
2) the degree of moistening,
3) the static loads and intensity of seismic shaking.

Observations on the administrative building of AUTOVAZ, where the cracks had been observed since 1977 were made because of the deformation was irregular due to wetting of loess soils in foundation. Deformations over period of 1977 to 1982 were recorded 37 cycles over 74 settlement marks. Loess soils in the active layer had initial subsiding pressure 0.2 - 2.5 kg/cm^2. Under there conditions the subsidence from y weight of the structure made up 70 cm and the subsidence from the self weight of the ground - from 21.8 sm up to 59.8 cm. The total calculated subsidence under full wetting of loess soils under the building was up 110 cm. For the period of observations from March of 1977 to December of 1983 maximal settlement value observed equaled 265 mm. On the Figure 1 the settling progresses of a mark for the interval of time of 1978 - 1981 years is shown. For this period on the territory of Tashkent the following seismic shaking intensities (by MSK) from far and close earthquakes were felt:
intensity VI - once (Nazarbek earthquake on December 11, 1980 with magnitude M = 5.2, and depth of source H = 16 km); intensity IV - 3 times; intensity III - 6 times; intensity II - 4 times.
The diagram shows that the process of development of deformations depends on intensity and frequency of seismic events.

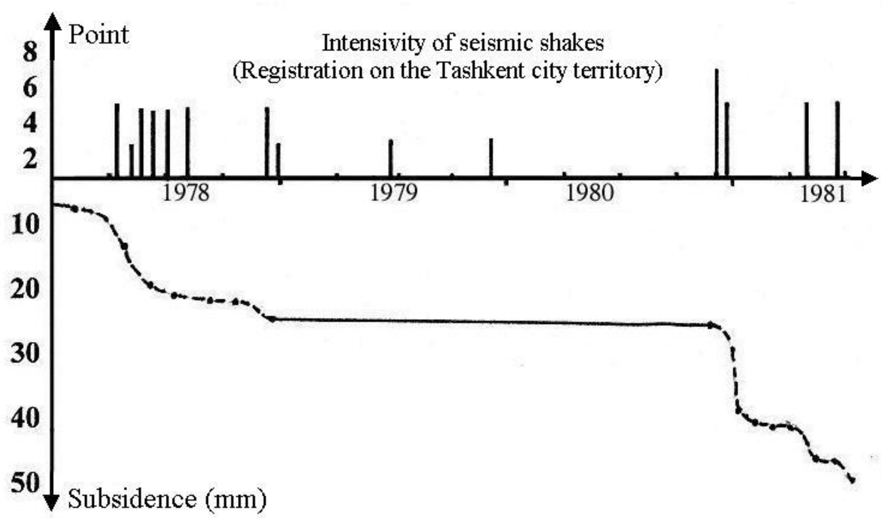

Figure 1.Diagram of the settling course of a mark and seismic shaking for the interval of time of 1978 - 1981 years.

Loess soils in the foundations had water contents from 20.1 up to 23.3 %, so it could be concluded that the additional settlements were not due to wetting of loess soils of the foundations, because when deformation of building started all sources of humidifying of loess soils in foundation were liquidated. In Figure 1 a clear the stepped configuration of the curve of the settlement process with respect to time can be seen. Each of the steps corresponds to seismic events. Initially the speed of the settling process was 0.046 mm/day, after three earthquakes as shaking intensity III this had increased up to 0.14 mm/day. However, the further seismic excitation of intensity III that occurred in June and July of 1978 had no

significant influence on the development of deformation. It is considered that the first intensity III event destroyed the major structural links between particles consolidation of soil caused reorganized the soils.
Further seismic events of the same intensity were unable to destroy structural links. However, seismic influence of intensity III and intensity II occurred in December of 1978 increased the speed of settlement up to 1.77 mm/day. It is felt that structural destruction of soils under previous earthquakes did not take place over the whole thickness of the stratum but was localized places where the structural links were weakened most. As result of reorganization of particles there was weakening of structural links in other parts of the stratum. It is necessary to take into account also possible influence of duration of seismic shaking, which is essential for manifestation of ground failure. During the period of 1979-1980 a settlement as 2 mm, was observed and in essence deformation of buildings was not significant, even though for this period two earthquakes producing intensity II were registered.
Under Nazarbek earthquake (M=5.2) on December 11, 1980 the building was subjected by shaking of intensity VI and IV, which resulted in development of a deformation with rate of 0.35 mm/day. The value of settlement after the earthquake was 17 mm and for the period of February - May, 1981 - 2.5 mm. At the end of May there was an earthquake of intensity IV and this accounts for most of the observed settlement. If for the four previous months the building deformed on 2.5 mm, after the earthquake the additional settlement 8 mm was observed. Analysis shows that components of seismic subsidence could be revealed in the course of the common subsiding process even under II-III shaking intensities (MSK). After full "conventional stabilisation" correspond to statical conditions in moistened loess soils, seismic subsiding deformations could only occur in case of seismic intensity of more than VI.

SEISMO LANDSLIDES.

Landslides have been one of the major causes of damage and casualties in many recent earthquakes [11, 12]. Earthquake triggering landslides range in magnitude from M=5.3 to 7.9, with peaks at M=6.4 and 6.7 [13]. The largest known landslide in Central Asia was the Sarez earthquake (February 18, 1911. M=7, H=26, I=9) on the Pamir mountains. This earthquake triggered the biggest landslide with volume 2 milliard m^3. This landslide has blocked the valley of the river Murghab and as a result was formed the Sarez lake.The Institute of Seismology conducted research for investigation the manifestation of ancient landslides in epicenter zone of known historical earthquakes on the Chirchik river valley. Researches used the field investigation and also air photo. On geological-geomorphological, to hydro-geological and other attributes faults (Karjantau, Brichnulla, Koksu, Kenkol) are determined.
In investigated area the strongest earthquakes have taken place in April 3,1868 with magnitude M = 6.5, and November 29, 1886 with magnitude M = 6.7, the formation of large Achikul landslide by the Surentantin fault was probable has taken place at this time. In 1946 has taken place Chatkal earthquake with M=7., H=30 km, I=9. This earthquake triggered the formation the big cracks around Sari Chelek lake (200-300 m), and as result of cracks triggered many landslides. In 1969 within the limits of crossing Alizar fault and Kumbel fault occurrence the two big landslides on the right side of Karankul river and near the Hodjikent city. The most part of earthquakes has taken place in the spring or autumn period when soils were strongly wetted. Occurrence of large landslides is connected with modern tectonic movements Kasimov [14].
Annually in Uzbekistan occur about 500 landslides in volume from 1000 up to 10 million m3. The majority of them occur in loess soil. In extreme years when there is a plenty of an atmospheric precipitation that their number reaches up to 3000. (Karankul landslide April 20, 1969, volume 5 million m3, Sulisay lanslide November 11,1994, volume 2 million m3 and etc.)
The mudflows in mountain regions of Central Asia are widespread in loess soils, take place in water rich years, presenting the greatest damage and threat to the life of people. From 165 sites with volume from 0.2-1.0 up to 5.0-40.0 million m^3 on 30% has taken place casualties. The mudflows are most dangerous because of sudden formation the movement takes place in a few minutes, high speed of displacement and large extent of propagation Nyazov [15].

Often, development of landslides was also related to the influence human activity, construction of roads in mountain areas where occurs the cutting of slopes, particular from water reservoir, irrigation, industrial explosions. For last 20 years a share artificial landslides has increased up to 20 % from total Nyazov [16].
Earthquake-trigger influence for landslides in Central Asia was investigated. Often these landslides were formed under influence human activity, particular from water reservoir, irrigation and industrial explosions. There are the example of earthquake and earthquake + human induced landslides observed by Institute of Seismology.

Sharora landslide. In January 23 1989 the Gissar earthquake initiate a landslide in loess soils. The earthquake took place with the following parameters: magnitude M=5.2; depth of the source – H=5-7 km; intensity – I=7 (MSK scale). This earthquake triggered the landslides and mudslides.

The first landslide, called the Sharora landslide took place in the bottom of the Orta-Boz plateau. The slope consisted of loess soils (highness 60-140 m), under a gentle gradient 4-6°. The landslide assisted of 5 million m^3 of material and caw a width 1000 m, length 250 m and was up to 20 m deep. Under the body of the landslide 200 people were killed. The duration of movement of the landslide was 1 minute. The top part of the fallen ground was formed by dry loess soils of the broken structure.

The second landslide on the site of a dairy farm together with the first landslide took place on the northern slope of the hill cut with a road. Volume of the landslide was 1 million cubic meters. On the farm 13 people died.

The mudslide Okuli-bobo with length 3-7 km, wide was 0.6-0.7 km, the thickness was 25-28 m, volume was 40 million m^3 located The mudslide was on distance of 700 m to a southwest from landslide Sharora. The surface of top part of landslide was covered by water. In the pre 20 years steady irrigation of the slope area occurred for cotton field. This moistening has increase and the water content of the soil to wet 24-28%, up to a depth of 20-30 m. The epicenter zone was located at the distance of 25-30 km to the east of Dushanbe city under the loess massif. The loess soil was saturated on slopes, which had been watered as result of irrigation of cotton fields. It is here were liquefied under earthquake influence began.

In the zone of the mudslide covered a part of the village Okuli-bolo. The seismic mudslides covered numerous houses and 70 people left under the liquefied soils Zerkal [17].

It took the mudslide about 30 minutes to reach the neighboring village Okuli-poen located at the distance about 2 km. The local people heard the noise of collapsing structures and had time to escape to a safe place.

All the residual deformations observed took place in the limits of epicentral zone of the earthquake, where the loess soils had thickness of 5-20 m. Local people said the development was started in 1970. Cotton fields covered about 100 hectares and gardens - 30 hectares. The irrigation channels were built in loess soils without waterproofing layers. The volume of water used for irrigation purposes made up 12-15 million cubic meters a year. In 1968 underground water on loess hills were not observed up to depth of 20 m. Thus, as result of human activity a suspended watered layer was formed in the loess massif, which became one of the main reasons of the catastrophic mudslide phenomena. The natural disaster occurred in result of Gissar earthquake showed, that even earthquakes of rather moderate intensity can cause a large number of human victims if in the zone of earthquake there are moistened loess soils.

Djigiristan landslide.Monitoring over this landslide were conducted before displacement because it was above settlement Dzhigiristan on the left side of Djigiristan river. The top part of a slope was covered with loess soils with capacity of 10-15 m. The gradient of slope was 30-35^o. The researches earlier conducted in the top part of a landslide at height about 130-140 m from the river were found out cracks in loess soil by extent of 100 m, width up to 0.2-03 m and amplitude of moving on a vertical up to 0.5 m^3. The crack limited the block of a ground in volume up to 100-150 thousand in m^3 which was prepared for displacement. May, 4, 1991 in the central part of a slope there was the landslide in volume of 170 thousand m^3. Borders of it coincide about earlier fixed crack. The probable reason of formation of a landslide was earthquake May, 1 1991 г with intensity 4-4.5 (be MSK-scale). The massive of loess soil was already prepared for earthquake, these spring days a plenty of an atmospheric precipitation has dropped out. The sizes of cracks after earthquake have increased. But catastrophic displacement of a landslide began when 2 bulldozers rose on a slope, one after another. It has caused resonant liquefaction of the saturated loess soils Niyazov [18]. Landslide has fallen upon settlement Dzhigiristan, 56 people were killed.

Mechanism of formation

The mechanism of formation of seismic mudslides differs from seismic landslides. Seismic landslides are formed in result of separating of loess massif from its basis under strong seismic shocks and sliding downwards on a slope under action of gravitational forces. On the other hand, formation of seismic mudslides is related to liquefaction of loess soils as result of complex oscillatory movements.

Liquefaction of soils occurs when three major factors were presence: soil, pore water and dynamic high-frequency vibrations. During intensive dynamic vibrations (usually 20-30 sec) water in loess soils separates from modular particles and transforms in free state creating positive pore water pressure in soils. This raises the process of accumulation of free water. When the pore water pressure has a critical value, structural links of the soil ground begins to collapse, thus free water upwards after the seismic wave, forming "wet sites" on the surface of grounds. If the surface has a gradient, there is a flow of liquefied soils as seismic mudslides

CONCLUSIONS.

Due to seismic influence on loess soil the various types of seismic deformations take place, the scale and intensity of which depend on a number of engineering-geological and seismological factors. The geomorphologic and geological peculiarities associated with loess soils, e.g. slope steepness and relief, thickness of stratum and engineering-geological properties: density, porosity, moistening, collapsibility, deformation-and-stress properties and depth of the ground water table together with also static loads. The dynamic parameters of vibration: amplitude, frequency, duration are related to the engineering-seismological factors. The special combination of these factors also determines character and intensity of development of seismodynamical processes in loess soil.

Seismic subsidence in loess soils is a component of the common subsidence. It can be displayed during development of subsiding processes even under seismic intensity of II-III. After conditional stabilization of the subsiding process in moistened loess seismic subsiding deformations occurred under intensity of VI and higher. The research showed that investigation of probable seismogeological effects is an important stage of assessment of ground behaviors under seismic influence.

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