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On Determining of the Ultimate Strain of Earth Crust Rocks by the Value of Relative Slips on the Earth Surface After a Large Earthquake

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Abstract: The value of the Earth crust rocks ultimate strain together with other physical-and-mechanical characteristics plays an important role in problems on setting maximal values of displacements, velocities and accelerations of grounds in the course of quakes, in determining of the value of potential strain energy accumulated in the medium when a process of a large quake maturation runs, in prognostication of a quake by "ultimate strain of rocks" forerunner as well as other problems, are related to the soil bearing resistance and behaviour. The paper represents a developed method for determining the magnitude of ultimate strain of soils thickness of the Earth crust in natural conditions by the relative slips on the earth surface after a large earthquake. Are obtained the empirical dependences of the value of ultimate strain from magnitude of earthquake, relative slips, the rupture length, and seismic moment by analysing values calculated by the proposed method for the 44 strong earthquakes with a magnitude of 5.6-8.5. A comparative analysis of the ultimate strain values is given which is obtained by other authors by the method of geodesic triangulation.

Keywords: Earthquake, Slip, Rupture, Ultimate Ground Strain

1. Introduction

The value of an ultimate strain of any material, including rocks, is established on the basis of mechanical testing of their samples to the point of destruction stage. For tough materials the method of such testing and processing their results now is essentially unified and are beyond any doubt. Establishment of strength characteristics of rock and hard soils is made according to the foresaid standard procedure. As for other loose and mild soils, then they show some resistance under tension, compression and shear. However, strength of soils, basically, is determined by their capacity to resist shear, since resistance to compression in rare instances turn out depleted, and soils in real conditions are almost unaffected by tension. At that in all testing procedures standard laboratory small-sized soil samples undergo testing. Since assessment of shear stresses level is much difficult than that of angular deformation, then as parameters of strength or ultimate strain is assumed the magnitude of distorted angle γ_{lim} under pure shear, based on known ratio of elasticity theory $\tau_{lim} = \gamma_{lim} G$ where τ_{lim} is ultimate shear stress, G is shear module of the ground. On the basis of laboratory tests it is thought that the magnitude of crust rock can be taken equal to $\gamma_{lim} = 10^{-3}$.

The value of a ground ultimate strain can also be determined by differences of triangulation points displacements in epicentral region, established by their measurements before and after earthquake.

Magnitudes γ_{lim} measured in the same way according to K. Tsuboi for a considerable number of earthquakes in Japan, in particular, for 1927 Tango earthquake with M=7.5 was about 10^{-4}, according to the results obtained by T. Rikitake was $0.5 \cdot 10^{-4}$ on the average, K. Mogi obtained from $0.1 \cdot 10^{-4}$ to $1 \cdot 10^{-4}$ depending on an earthquake.

Considerable difference between magnitudes γ_{lim} found by laboratory tests and making use of geodetic surveys of triangulation points is explained in that the real crust in comparison with laboratory samples contains a great number of fine discontinuities, cracks and weakening, which essentially decrease microscopic strength of the rock crust. The articles [1-3] are devoted to various aspects determine

γ_{lim} using geodetic observations and laboratory tests of fragments of soil, and also their uses for establishing the probability of earthquake occurrence.

In contrast to usual impacts during an earthquake not a uniform layer of a certain ground is affected by the quake but an entire soil thick layer of various grounds of great strata, equal to the depth of the earthquake source. Therefore, the real magnitude of the ultimate strain of the crust composed of such strata can be determined only by strain parameters of the source in the final stage before happening of the quake. In the present work an attempt was made to determine the magnitude γ_{lim} of the ultimate strain of ground strata of the Earth crust in natural conditions by parameters of consequences on the earth surface made by a large earthquake: rupture length, the source depth and magnitude of a relative slip. It is assumed that the maximum value of the long-term static deformation of the medium is equal to half the relative slips, formed on the surface of the earth after a large earthquake.

2. Statement of the Problem

In the process of a long maturing of a large earthquake in regions around future rupture occur considerable static shear stresses and shear deformations. At the moment of earthquake burst the latter reach to their ultimate values τ_{lim} and γ_{lim}, and take place crack of the crust with formation of a new rupture of L length and relative slip of $\bar{u}$ length on the earth surface, i.e. destruction of crust rock of great volumes in natural conditions takes place. The earthquake, as if, becomes a natural test equipment of tremendous dimensions for establishing strength characteristics of earth crust soil power. Static shear stress-strain condition of the medium before the very beginning of crack (earthquake), in regions directed perpendicularly to the future rupture, naturally, is of diminishing character. In our works [4, 5] analyzing the results presented in the work of T. Rikitake [6] on measurement of ground deformation in the epicenter zone by differences displacements of triangulation points before and after the earthquake for a great number of large earthquakes boundaries $R(\bar{u})$ of these regions were evaluated depending on the magnitude of the average slip $\bar{u}$ at the rupture shown in Fig. 1. as a result the following $R(\bar{u})$ dependence [4] has been suggested:

$$R(\bar{u}) = (5\bar{u} + 15)\cdot 10^3 \tag{1}$$

where:

R and $\bar{u}$ are in meters.

From the catalog of 244 large earthquakes during 1853 to 1993, represented in the work of D. Weels and K. Koppreschmidt [7] data on 44 large earthquakes have been chosen (Table 1), of which there are all necessary parameters in the catalog: the length L of rupture, depth h of the source (rupture), maximum u_{max} and average slips $\bar{u}$. The magnitude of the relative slip along the rupture usually has a irregular distribution [7].

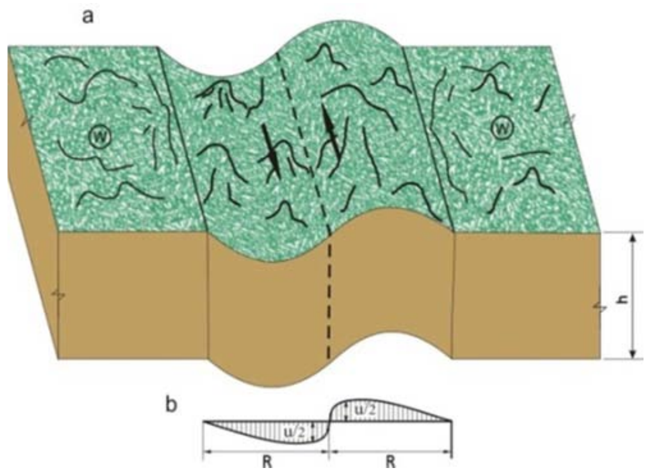

Figure 1. Schematic illustration of a slow and lengthy deformation of the medium over a long period of an earthquake maturing, a. deformed condition of the medium before development of the rupture, b. distribution of displacements of the medium in the direction perpendicular to the rupture before the earthquake, h is the depth of the future rupture, u/2 is static deformations of blocks the moment crack occurs, R is length of the deformation area perpendicular to the rupture, W are regions suggested as not deformed by maturing earthquakes because of comparatively smallness of deformations as compared with u at the rupture. Arrows show directions of slow slips of blocks, dashed line shows line of future rupture.

The concept of an average slip was suggested by authors of the paper [7] averaging is performed along the length L of the rupture for each earthquake individually. Authors of [7] consider that the magnitude of the average slip can be assumed constant along the entire length of the rupture. Moreover, in authors [7] opinion, just by magnitude of the average slip $\bar{u}$ constant relative shear takes place along the whole length L of the rupture and depth h of crack of rupture planes.

Thus, it is suggested that stress-strain condition of the crust while an earthquake is matured is presented in Fig. 2 [4] by hatched area, limited by some closed graph C before he rupture in Fig. 2a, and after it – in Fig. 2c.

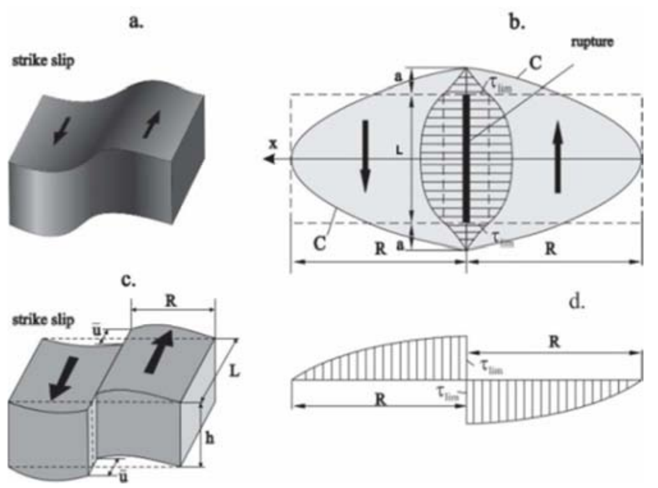

Figure 2. Schematic illustration of the medium stress condition a- before formation of the rupture, c-after formation of the rupture, b-equivalent areas of stress conditions, d-distribution of shear stresses, (τ_{lim} -limit resistance of rocks).

It is assumed that outside that closed graph magnitudes of stresses and deformation medium are substantially small in comparison with their values at the rupture, and therefore can be neglected. It is seen from Fig. 2 that the region accountable for stresses and strains limited by C curve can be replaced by an equivalent rectangle area with 2R and L sides shown by a dashed line. In other words it is regarded that the starting moment of earthquake the static stress condition of the medium was distributed in two rectangular parallelepiped of R, L, and h sides, where h is the depth of the actual rupture, L is the length of the actual rupture, R is the distance of the actual rupture beyond which the W medium (Fig. 1) can be regarded as no stressed by maturing earthquake. Values of static displacements of parallelepipeds near rupture is suggested equal to, where is the actual average slip after earthquake.

Table 1. *Key parameters of earthquakes [7] and calculated values of ultimate deformation* $\gamma_{\lim}$ *by formula (8).*

No	Country	Earthquake location	Date of earthquake occurrence	Type of slip	Earthquake magnitude M_s	Rupture length L, [km]	Rupture depth h, [km]
1	USA	Fort Tejon	09.01.1857	RL	8.3	297	12
2	USA	Owens Valley	26.03.1872	RL-N	8	108	15
3	Japan	Nobi	27.10.1891	LL	8	80	15
4	Japan	Rikuu	31.08.1896	R	7.2	40	21
5	USA	San Francisco	1/13/1906	RL	7.8	432	12
6	USA	Pleasant Valley	10/3/1915	N	7.6	62	15
7	China	Kansy	12/16/1920	LL	8.5	220	20
8	Japan	North Izu	11/25/1930	LL- R	7.3	35	12
9	China	Kehetuohai	8/10/1931	RL	7.9	180	20
10	Turkey	Erzihcan	12/26/1939	RL	7.8	360	20
11	USA	Imperial Valley	5/19/1940	RL	7.2	60	11
12	China	Damxung	11/18/1951	RL	8	200	10
13	USA	Dixie Valley	12/16/1954	RL-R	6.8	45	14
14	Turkey	Abant	5/26/1957	RL	7	40	8
15	Mongolia	Gobi-Altai	12/4/1957	LL	7.9	300	20
16	USA	Hebgen Lake	8/18/1959	N	7.6	45	17
17	Iran	Dasht-e-Bayaz	8/31/1968	LL	7.1	110	20
18	Turkey	Gediz	3/28/1970	N	7.1	63	17
19	USA	San Fernando	2/9/1971	R-LL	6.5	17	14
20	China	Luhuo	2/6/1973	LL	7.3	110	13
21	Guatemala	Motagua	2/4/1976	LL	7.5	257	13
22	Turkey	Caldiran	11/24/1976	RL	7.3	90	18
23	Iran	Bob-Tangol	12/19/1977	RL	5.8	14	12
24	Greece	Thezzaloniki	6/20/1978	N	6.4	28	14
25	Iran	Tabas-e- Colshan	9/16/1978	R	7.5	74	22
26	USA	Homestead Valley	3/15/1979	RL	5.6	6	4
27	Australia	Cadoux	6/2/1979	R	6.1	16	6
28	USA	El Centro	10/15/1979	RL	6.7	51	12
29	Iran	Koli	11/27/1979	LL-R	7.1	75	22
30	Algeria	El Asman	10/10/1980	R	7.3	55	15
31	Italy	South Apennines	11/23/1980	N	6.9	60	15
32	Greece	Corinth	2/25/1981	N	6.4	19	16
33	Greece	Corinth	3/4/1981	N	6.4	26	18
34	USA	Borah Peak	10/28/1983	N-LL	7.3	33	20
35	Algeria	Constantine	10/27/1985	LL	5.9	21	13
36	Australia	Marryat Creek	3/30/1986	R-LL	5.8	13	3
37	Greece	Kalamata	9/13/1986	N	5.8	15	14
38	New Zealand	Edgecumbe	3/2/1987	N	6.6	32	14
39	USA	Superstition Hills	11/24/1987	RL	6.6	30	11
40	Australia	Tennant Greek	1/22/1988	R	6.3	13	9
41	China	Lancand Gengma	11/6/1988	RL	7.3	80	20
42	Armenia	Spitak	12/7/1988	R-RL	6.8	38	11
43	Canada	Ungava	12/25/1989	R	6.3	10	5
44	USA	Landers	6/28/1992	RL	7.6	62	12

Table 1. *Continued.*

No	Country	Maximum slip u_{max}, [m]	Mean slip $\bar{u}$, [m]	Seismic moment $M_o x10^{-26}$, [dyne*sm]	Value of R from (1), [km]	Ultimate deformation from (8) $\gamma_{lim}x10^4$
1	USA	9.4	6.4	114.0	50.84	1.07
2	USA	11	6	48.60	45	1.05
3	Japan	8	5.04	30.24	40.25	0.98
4	Japan	4.4	2.59	10.88	27.95	0.73
5	USA	6.1	3.3	85.54	31.5	0.82
6	USA	5.8	2	9.300	25	0.63
7	China	10	7.25	159.5	51.25	1.11
8	Japan	3.8	2.9	6.090	29.5	0.77
9	China	14.6	7.38	132.8	51.9	1.12
10	Turkey	7.5	1.85	66.60	24.25	0.60
11	USA	5.9	1.5	4.950	22.5	0.52
12	China	12	8	80.00	65	1.15
13	USA	3.8	2.1	6.615	25.5	0.65
14	Turkey	1.65	0.55	0.880	17.75	0.24
15	Mongolia	9.6	6.54	196.2	47.7	1.08
16	USA	6.1	2.14	8.186	25.7	0.65
17	Iran	5.2	2.3	25.30	26.5	0.68
18	Turkey	2.8	0.86	4.605	19.3	0.35
19	USA	2.5	1.5	1.785	22.5	0.52
20	China	3.6	1.3	9.295	21.5	0.47
21	Guatemala	3.4	2.6	43.43	28	0.73
22	Turkey	3.5	2.05	16.61	25.25	0.64
23	Iran	0.3	0.12	0.101	15.6	0.06
24	Greece	0.22	0.08	0.157	15.4	0.04
25	Iran	3	1.5	12.21	22.5	0.52
26	USA	0.1	0.05	0.006	15.25	0.03
27	Australia	1.5	0.5	0.240	17.5	0.22
28	USA	0.8	0.18	0.551	15.9	0.09
29	Iran	3.9	1.2	9.900	21	0.45
30	Algeria	6.5	1.54	6.353	22.7	0.53
31	Italy	1.15	0.64	2.880	18.2	0.28
32	Greece	1.5	0.6	0.912	18	0.26
33	Greece	1.1	0.6	1.404	18	0.26
34	USA	2.7	0.8	2.640	19	0.33
35	Algeria	0.12	0.1	0.137	15.5	0.05
36	Australia	1.3	0.5	0.098	17.5	0.22
37	Greece	0.18	0.15	0.158	15.75	0.07
38	New Zealand	2.9	1.7	3.808	23.5	0.57
39	USA	0.92	0.54	0.891	17.5	0.24
40	Australia	1.3	0.63	0.369	18.15	0.27
41	China	1.5	0.7	5.600	18.5	0.30
42	Armenia	2	1.22	2.550	21.1	0.45
43	Canada	2	0.8	0.200	19	0.33
44	USA	6	2.95	10.97	29.75	0.78

Note: RL is right lateral slip; LL is left lateral slip; R is reverse movement; N is normal faulting.

Considering that the length L of the rupture according to Table 1 for all analyzed earthquakes is larger than the length R, may be presumed that in the process of static deformation both prismatic spaces with L x h x R dimensions were affected by pure shear as shown in Fig. 2 for left hand shear (LL).

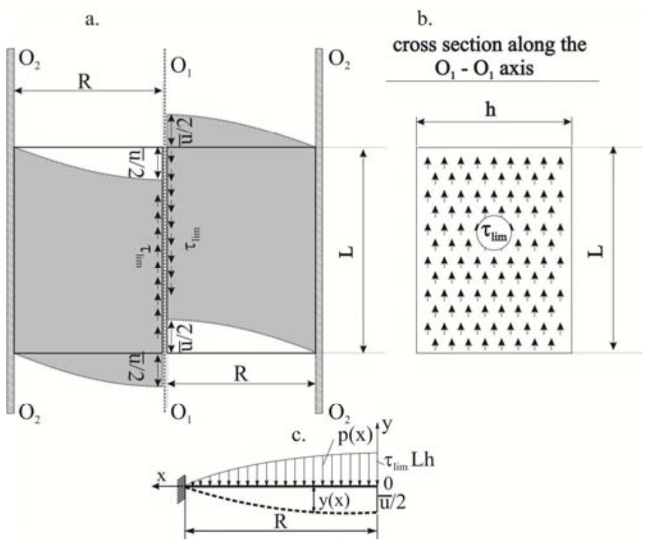

Figure 3. *Conventional design scheme of deformed medium. a – conventional scheme of the medium deformation after the earthquake b – distribution of ultimate shear stress along the rupture plane c – conventional design scheme of the beam under pure shear.*

In all other types of the crust rupture, presented in the Table of earthquakes, rupture occurs by reason of the soil's loss of shear resistance in different planes of the crust. Values of maximum and average slips u_{max} and $\bar{u}$ correspond with deformations of shears in that planes, and the distance $R(\bar{u})$, are perpendicular to directions of discontinuities for all earthquakes irrespective rupture type. Therefore, conventional design scheme illustrated in Fig. 3, can be considered acceptable for all 44 earthquakes.

Two symmetric planes of rupture at distant R, are assumed fixed and parallel to the rupture plane O_1-O_1. Displacement of the rupture plane O_1-O_1 relative to fixed planes O_2-O_2 are assumed equal $\bar{u}/2$.

3. Solution of the Problem

Since before the earthquake burst both deformed parts of the medium are in statically equilibrium state, according the generally accepted law of mechanics, each of these parts will also be in equilibrium state if to the part under consideration is applied influence of removed part in the form of distributed forces. In our case these $p(x)$ forces will be shear stresses $\tau(x)$, multiplied by the cross-section area L x h as shown in Fig. 3c. At that the force at the rupture plane will be maximum and equal to $\tau_{lim}Lh$, and at O_2-O_2 planes – equal to zero.

As an optimal dependence of forces $p(x)$ along the length R, on the analogy of [4, 5] can be assumed the following dependence:

$$p(x) = \tau_{lim} Lh \cos\frac{\pi x}{2R}, \tag{2}$$

which satisfies the foresaid conditions:

when: x=0 $p(x) = \tau_{lim} Lh$,

when: x=R $p(x) = 0$.

Since it was assumed that both parallelepipeds undergo pure shear, for their calculation a scheme shown in Fig. 3c can be used in the form of a cantilever beam which undergoes pure shear by distributed variable load p (x). Differential equation of an bend axis of such a beam under pure shear is of the following form [8]:

$$\frac{dy}{dx} = \frac{p(x)}{FG} \quad \text{or} \quad \frac{dy}{dx} = \frac{\tau_{lim} Lh}{FG}\cos\frac{\pi x}{2R}, \tag{3}$$

where:

F=Lh is the area of the beam cross-section,

G is shear modulus,

p (x) is the distributed load by formula (2).

Solution of (3) is:

$$y(x) = \frac{\tau_{lim}}{G}\frac{2R}{\pi}\sin\frac{\pi x}{2R} + D, \tag{4}$$

where:

D is integration constant, which can be determined by the following condition:

when: x=R then $y = 0$.

Therefore: $\frac{\tau_{lim}}{G}\frac{2R}{\pi} + D = 0$ *or* $D = -\frac{\tau_{lim}}{G}\frac{2R}{\pi}$

Substituting values of D into (4) for the bend beam axis y (x), we have:

$$y(x) = \frac{\tau_{lim}}{G}\frac{2R}{\pi}\left(\sin\frac{\pi x}{2R} - 1\right). \tag{5}$$

According to the problem statement

when: x=0 then $y = -\frac{\bar{u}}{2}$.

Therefore, from (5) we get

$$-\frac{\bar{u}}{2} = -\frac{\tau_{lim}}{G}\frac{2R}{\pi}. \tag{6}$$

Taking into consideration Hook law $\tau_{lim} = \gamma_{lim} G$ for ultimate deformation γ_{lim} the following simple formula

$$\gamma_{lim} = \frac{\pi}{2}\cdot\frac{\bar{u}}{2R}. \tag{7}$$

Substituting R values, obtained by formula (1), into (7) for ultimate deformation we get the following relationship (where is the relative slip measured in meters).

$$\gamma_{\text{lim}} = \frac{\pi}{2} \cdot \frac{\bar{u}}{\bar{u}+3} 10^{-4}. \tag{8}$$

4. Results and Analysis

In the bottom row of the above Table 1 values γ_{lim} for all 44 earthquakes of 5.6 to 8.5 magnitude computed by the formula (8) are presented. Graphical distribution of values γ_{lim} for the earthquakes being under consideration is shown in Fig. 4

It is seen from the Table 1 the minimum value $\boldsymbol{\gamma_{\text{lim}} = 0.03 \cdot 10^{-4}}$ took place for 1979 Homestead Valley (USA) earthquake with magnitude ranging from M=5.6 to 15.03 with minimum rupture length (6km) and minimum depth of the source h=4km, and minimum slip $\bar{u} = 0.05\,\text{m}$. The maximum value of ultimate strain $\boldsymbol{\gamma_{\text{lim}} = 1.15 \cdot 10^{-4}}$ (in 36.5 times) took place for 1951 Damxung (China) earthquake with a magnitude from M=8.0 to 18.11 with sufficient large rupture length L=200km, of the source depth h=10km, and $\bar{u} = 8\,\text{m}$ slip which can also be considered logical. The average value γ_{lim} for all 44 earthquakes is $\boldsymbol{\gamma_{\text{lim}} = 0.52 \cdot 10^{-4}}$. Taking into account that the majority of real earthquakes with M<7.0 magnitude the probability of the rupture coming out to the earth surface (cracking) is very small, and that of considerable errors in the rupture length L, especially the length of the average slip $\bar{u}$, noticeably great To get more real picture of ultimate strain γ_{lim} values of 18 relatively small earthquakes with M<7.0 magnitude have been excluded from the above table. These earthquakes are hatched in the table. As can be seen from Fig. 4.b in this case ultimate strain γ_{lim} values have been noticeably stabilized and the difference between maximum and minimum values of γ_{lim} is all in all 5 times, as opposed to 44 earthquakes, when this difference comes up to 36.5 times. The average value of γ_{lim} for 26 earthquakes with M≥7.0 magnitude came up to $\boldsymbol{\gamma_{\text{lim}} = 0.71 \cdot 10^{-4}}$.

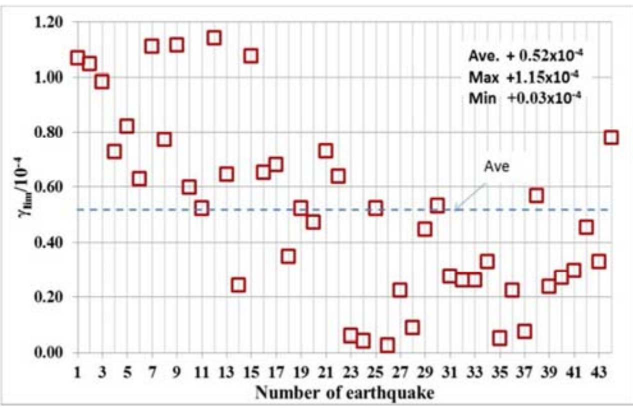

Figure 4a. *Distribution of γ_{lim} ultimate deformations values a- for 44 earthquakes with 5.6≤M≤8.5.*

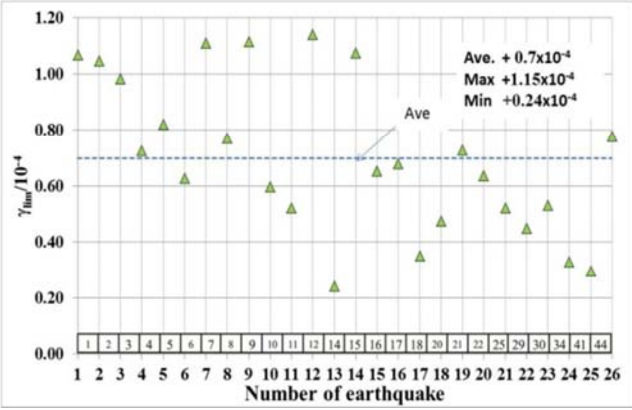

Figure 4b. *Distribution of γ_{lim} ultimate deformations values b- for 26 earthquakes with M≥7.0.*

As shown in Fig. 5 the dependence of γ_{lim} on earthquake's magnitude for 44 earthquakes with 5.6≤M≤8.5, as well as for 26 earthquakes with magnitude range 7.0≤M≤8.5.

From the above figure is seen that both dependences are well interpreted with the following empiric dependences:

$$10^4\gamma_{\text{lim}} = 0.39\text{M} - 2.23 \quad \text{for } 5.6 \le \text{M} \le 8.5,$$

$$10^4\gamma_{\text{lim}} = 0.58\text{M} - 3.67 \quad \text{for } 7.0 \le \text{M} \le 8.5. \tag{9}$$

Also there is good correlation between γ_{lim} and the average slip $\bar{u}$ (m) length, rupture length L (km), and seismic moment $M_0 = LhG\bar{u}\,(dyne\ x\ cent)$, for G=5 x 10^{11} dyne/cent^2 represented in Fig.6.

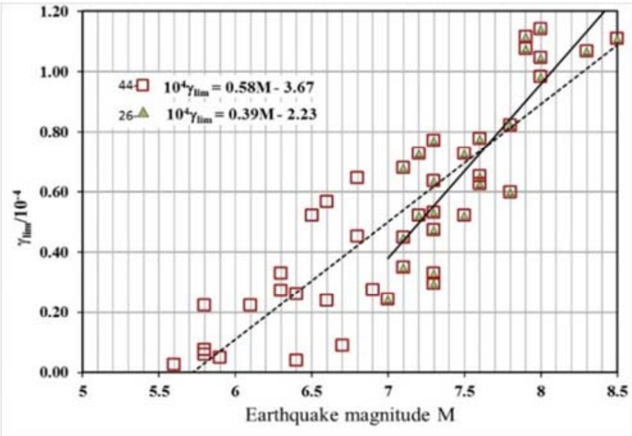

Figure 5. *Dependence of ultimate strain γ_{lim} on earthquake magnitude M.*

These dependences can be interpreted by the following way:

for 5.6≤M≤8.5

$$10^4\gamma_{\text{lim}} = 0.56\lg\bar{u} + 0.48$$

$$10^4\gamma_{\text{lim}} = 0.47\lg\text{L} - 0.25$$

$$10^4\gamma_{\text{lim}} = 0.28\lg\text{M}_0 + 0.06$$

For.

$$7.0 \le M \le 8.5 \qquad (10)$$

$$10^4 \gamma_{\lim} = 0.81 \lg \bar{u} + 0.39$$

$$10^4 \gamma_{\lim} = 0.55 \lg L - 0.42$$

$$10^4 \gamma_{\lim} = 0.39 M_0 - 0.19$$

Analysis of the obtained results shows that between $\gamma_{\lim}$ and rupture depth h, as well as between $\gamma_{\lim}$ and rupture area L·h there is no determinate correlation, however for large areas of a rupture within $2000 \le Lh \le 6000$ (km^2) values of $\gamma_{\lim}$ tend to be stabilized around $\gamma_{\lim} = 1.11 \cdot 10^{-4}$.

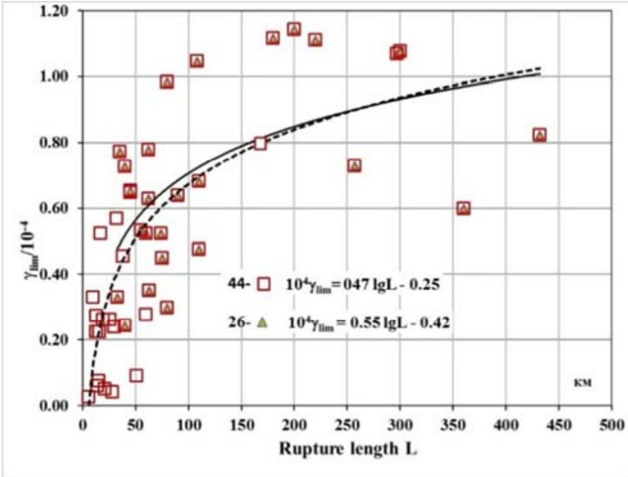

Figure 6b. *Dependence between of γ_{lim} rupture length L (km).*

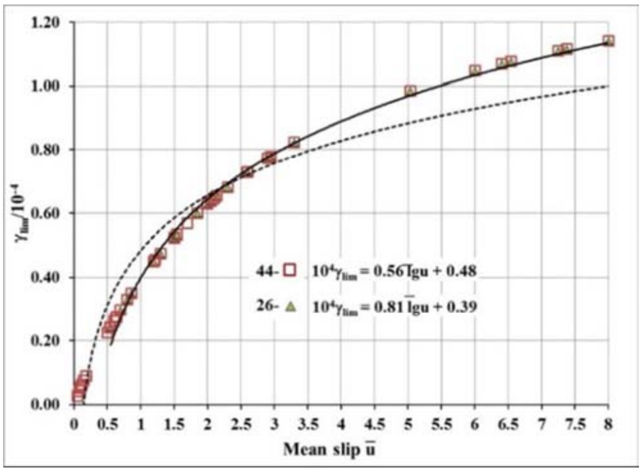

Figure 6a. *Dependence between of γ_{lim} and average slip $\bar{u}$ (m) length.*

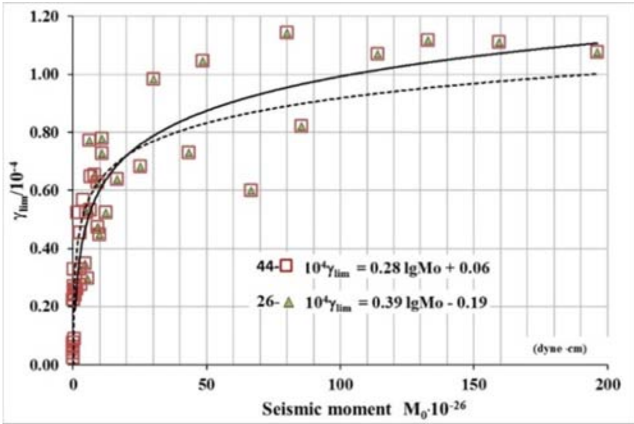

Figure 6c. *Dependence between of γ_{lim} (m) and seismic moment M_0.*

In table 2 values of $\gamma_{\lim}$ found by various researchers and obtained by the present study show that values obtained by computation on the basis of the formula (8) well correlate with those obtained earlier by other scientists.

Table 2. *Values of γ_{lim} [6], [9], [10].*

Quantity of earthquakes	Magnitude	Values of ultimate strain of γ_{lim} x 10^4				
		According to present research and formula (8)	K. Tsuboi (1933)	T. Rikitake (1976)	K. Kasahara (1981)	K. Mogi (1985)
44	5.6≤M≤8.5	0.03÷1.15 average 0.52	1.0	0.5	1÷2	0.1÷1.0
26	M≥7.0	0.24÷1.15 average 0.71				

5. Conclusion

1. Developed a method for determination the values of the ultimate strain of soil strata thickness of the earth's crust relative to the value of the slip on the earth's surface by the author's proposed scheme of occurring of strong earthquake.
2. For 44 strong earthquakes with a magnitude 5.6≤M≤8.5 the values of the ultimate strain are obtained $\gamma_{\lim}$ and proposed their empirical dependence from the magnitude of the earthquake, the relative movement, the length of the rupture and seismic moment. A comparative analysis of the ultimate strain $\gamma_{\lim}$ with their values is given by the method of geodesic triangulation.
3. The value of $\gamma_{\lim}$ established for a last concrete earthquake can be used in monitoring designed to predict a new earthquake in the same area. If readings of values $\gamma_{\lim}$ are available by deformographs then the maturity time of a new earthquake can anticipated.

References

[1] Mogi, K., Study of elastic shocks caused by the fracture of heterogeneous materials and its relations to earth quake phenomena, Bull. Earthq. Res. Inst., 40, (1962), 125-173.

[2] Y. Hagiwara Ultimate Strain of the Earth's Crust and Rock Fracture Experiments. Journal of the Geodetic Society of Japan, Vol. 19, №4, 1973, pp.209-212.

[3] T. Rikitake Statistics of ultimate strain of the earth's crust and probability of earthquake occurrence, Tectonophysics Vol 26, Issues 1-2, March 1975, p 1-21,

[4] E. Y. Khachiyan On a Simple Method for Determining the Potential Strain Energy Stored in the Earth before a Large Earthquake. ISSN 0742-0463, Journal of Volcanology and Seismology, 2011, Vol. 5, No. 4, pp. 286-297. Pleiades Publishing, Ltd., 2011.

[5] E. Y. Khachiyan Method for Determining the Potential Strain Energy Stored in the Earth before a Large Earthquake. Science Publishing Group, USA Earth Science, vol. 2, 2, 2013 pp 47-57.

[6] T. Rikitake Earthquake Prediction. Elsevier, Amsterdam, 1976, 357p.

[7] D. L. Wells and K. I. Coppersmith New Empirical Relationship among Magnitude, Rupture Length, Rupture Width, Rupture Area, and Surface Displacement. Bulletin the Seismological Society of America, vol.84, N4, pp.974-1002, August, 1994.

[8] S. P. Timoshenko, J. M. Gere Mechanics of materials. NY: Van Nostrand Reinhold Company, 1972, 670p.

[9] K. Mogi Earthquake Prediction, Academic Press Japan, Inc.1985, 382p.

[10] K. Kasahara Earthquake Mechanics, Cambridge University Press, 1981.