TOPOGRAPHY SITE EFFECTS ON NUMERICAL AND EXPERIMENTAL DATA

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SUMMARY:

There are sites on the territory of Vladikavkaz city "unfavorable" for construction in accordance with Russian Building Codes (SNiP II-7-81*) - slopes more than 15°. Topography effect estimation requires detailed instrumental investigations, empirical data and creation of mathematical models of ground medium.
In the first stage of research slope on the right river bank was selected and microseisms registration performed. In the next stage seismic vibrations of case slope were modelled by final elements analysis (FEA).
As a result seismic intensity increments along the slope were calculated and spectral features of vibrations defined. The nature of topography effects was identified. Furthermore, features of topography site effects on the territory of Vladikavkaz city were indicated.

Keywords: site effect, topography, finite element analysis

1. INTRODUCTION

There are sites on the territory of Vladikavkaz city "unfavorable" for construction in accordance with Russian Building Codes (SNiP II-7-81*) - slopes more than 15°. Main zone of such conditions is terrace slope on right bank of river Terek. At the same time this region is characterized by high density of individual buildings (of high vulnerability). Hydroelectric power station constructions are also located here. All that assumes more precise account of geomorphological conditions on seismic intensity.
Topography effect estimation requires detailed instrumental investigations, empirical data and creation of mathematical models of ground medium.

2. INSTRUMENTAL INVESTIGATIONS

At the first stage slope on the right bank of the river Terek in Vladikavkaz city was selected for investigations. (fig. 1, slope angle 25-35°). Recording of microseismic vibrations was performed on this site.
Two seismic stations were simultaneously used; recording duration was 10 minutes and after one of the stations had been moved to the next point on the slope. Usage of such scheme allows accounting of temporal variations of amplitude level of microseismic field during performance of the work.
Before recording calibration tests were performed and amplitude adjustment coefficients were obtained (for second station relative to the first one): KZ=1.36; KX=2.19; KY=1.13. Due to large value of adjustment coefficient for X-component (> 1.5) this component was not used in analysis.
Considering that slope is oriented in West-East direction maximum relief influence must be registered on Y-component, oriented in the same direction

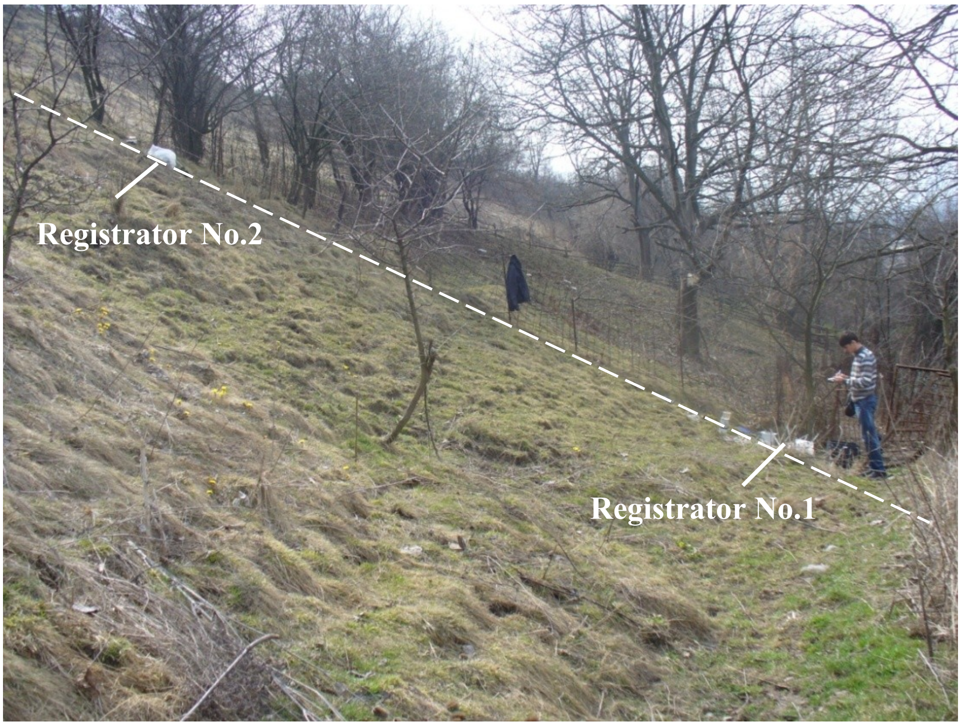


Figure 1. Part of slope during microseisms recording

Mean amplitudes of microseismic vibrations (microseisms amplitude level) were referred to the point at the base of the slope – Table 2.1. Corresponding scheme and curve are presented in figure 2.

Table 2.1. Maximum amplitudes of microseismic vibrations

Component	Distance *L*, m					
	0	20	40	60	80	100
Z	1.00	1.17	1.21	2.03	0.85	1.46
Y	1.00	1.28	1.78	2.96	2.97	2.22

Intensity variation of strong earthquake on data of maximum amplitude of microseismic vibrations was calculated by the next formulae [RSN 65-87, Recommendations on seismic microzonation, 1985]:

$$\Delta = 2\lg\frac{A\max_i}{A\max_e}, \qquad (2.1)$$

where $A\max_i$ and $A\max_e$ – maximum amplitudes of microseismic vibrations on investigated and etalon sites correspondingly.
Results of intensity increments relative to the base of the slope calculation are given in Table 2.2

Table 2.2. Intensity increments calculated on microseismic data

Component	Distance *L* m					
	0	20	40	60	80	100
Z	0,00	0,13	0,16	0,61	-0,14	0,33
Y	0,00	0,21	0,50	0,94	0,95	0,69

Calculations for vertical component (Z) show that there can be expected 1 point intensity increment at the distance of 40 meters from the base of the slope. Amplification at the top of the slope (*L*=100 m) is not so clear. Horizontal component (Y) analysis gives more stable and sustainable results.

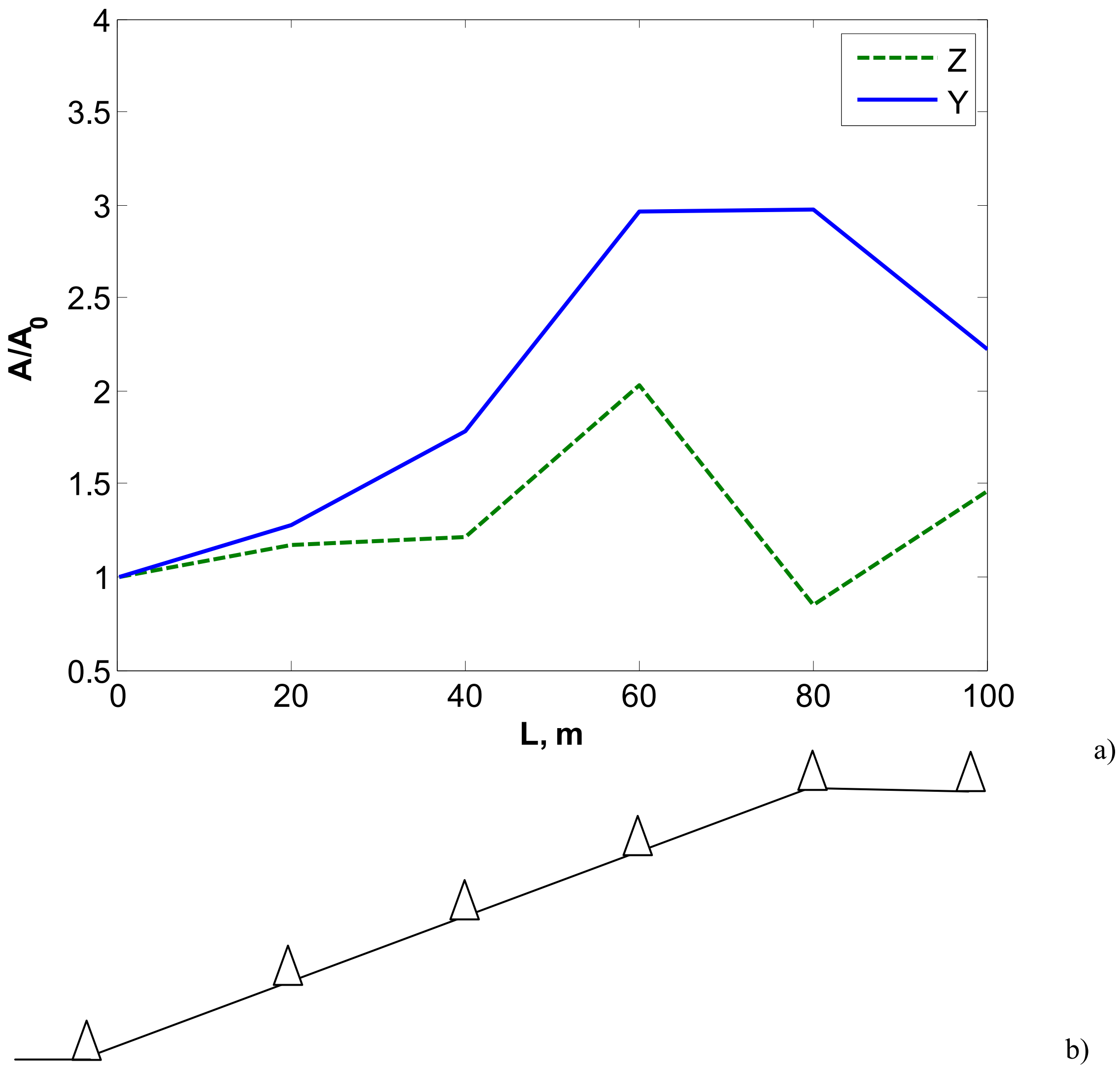


Figure 2. Amplification of microseisms amplitudes A/A_0 (a) along slope (b)

3. MATHEMATICAL MODELING

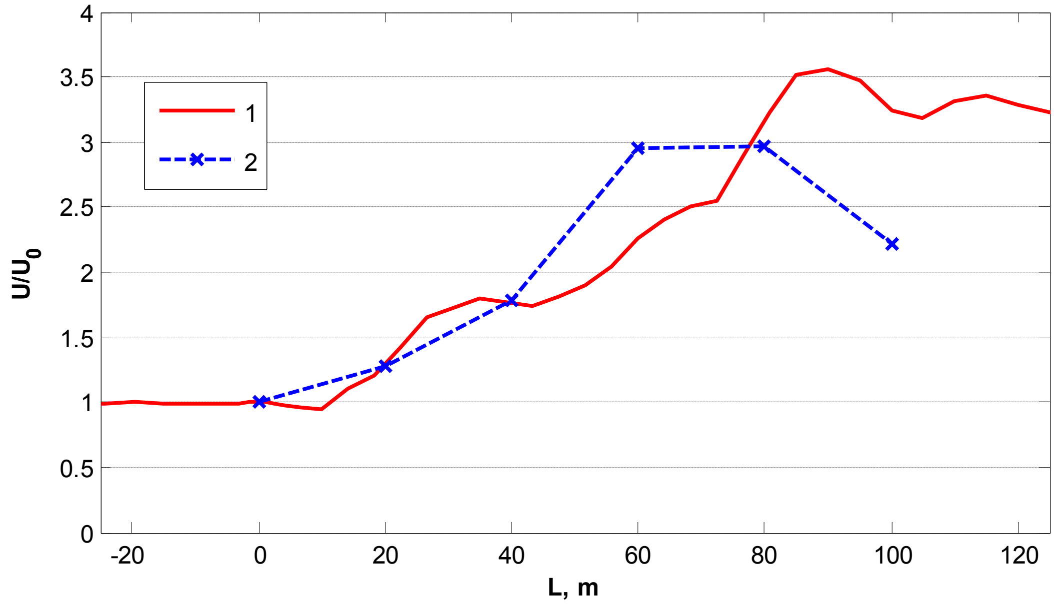
Finite element method (FEM) was selected for analysis as the most convenient tool for two- and three-dimensional soil medium modeling. Finite elements method allows describing geometry of real cross-sections in details [Zaalishvili et al., 2008]. Detalization level and model size are limited only by technical capabilities of computing facilities and practicability. Maximum size of elements depends on maximum frequency of interest sufficient for given problem solution.

Finite element method considers medium as complex of subdomains called elements connected with each other in node points and assumes that continuum response is described by response of these points.

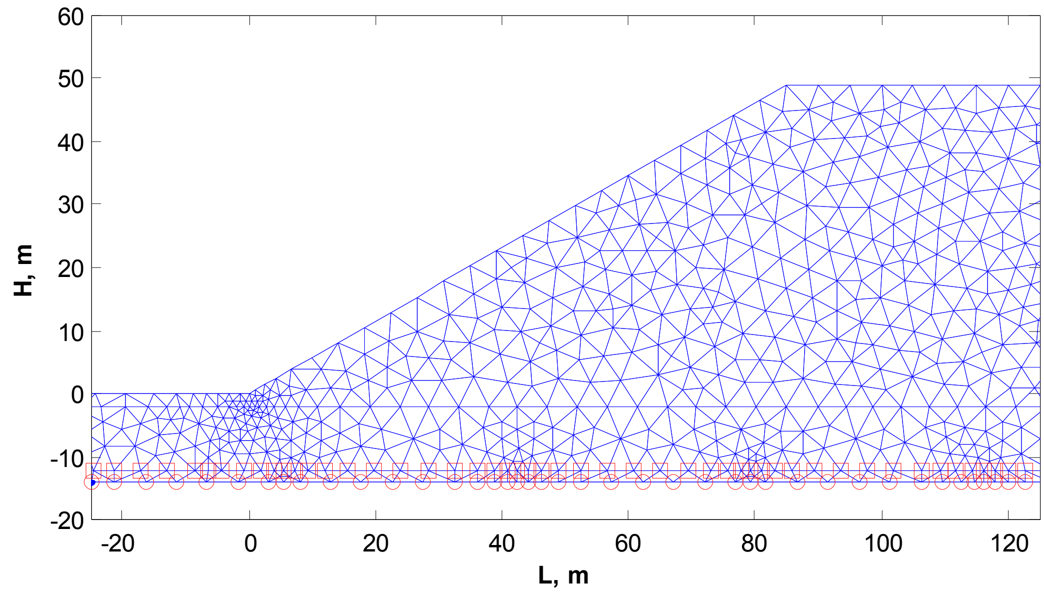
Matrix of displacements transformations and matrix of displacements to deformations transformation for each element are the main matrixes used in analysis. Law of displacements distribution within element depending on node displacements is attributed to each element and stress-strain relations depending on element material properties.

Rigidity matrix is calculated using virtual work principle. On the basis of d'Alembert's principle inertial forces are considered as consistent part of volume forces. After summing up on all degrees of freedom and taking into account damping forces one can obtain a system of linear differential equations of the second order. And solution can be obtained with the help of standard procedures of

solution of differential equations with constant coefficients. At the same time these procedures become ineffective for high-order matrixes. For this reason system was solved by Wilson method [Bathe, Wilson, 1982], which is essentially evolution of linear acceleration method.
Seismic forces were applied at the bottom of model in second layer of elements while lower nodes were fixed in both directions in accordance with [Jeremić, 2006]. Model was extended to minimize reflections from borders and damping forces were applied at vertical borders of model on both sides.
Model of slope with angle of 30° equivalent to site used for instrumental investigations was constructed (fig. 3b). Next parameters were used for the slope material Vs=300, ρ=1800, μ=0.28 and for bedding gravel soils – Vs=900, ρ=2200, μ=0.28. Loma Prieta strong motion record was used as input motion.



a)



b)

Figure 3. Amplification of vibrations along slope (1 – calculated; 2 -- instrumental) and calculational model of slope

Results of horizontal component amplification along profile are shown in figure 3a. Accordance of both curves is observed in all points except located in 60 and 100 m. It must be noted that impacts of different level and spectral content are comparing and this has effect on resulting amplitude level on the surface.

3. EMPIRICAL DATA

Similar results were obtained with the help of empirical equation [Zaalishvili et al., 2010a,b]:

$$\Delta I = -0{,}71 + 0{,}53\ \lg(\alpha H) + K, \qquad (3.1)$$

where α – slope angle;
H – relative height;
K – soil type dependent coefficient: K = 0.3 for coarse-grained soils with the content of sand and clay filler ≥ 30% , highly weathered rocks, clayey soils with consistency index $I_L \leq 0.5$ and porosity index e<0.9 for clays and loams and e<0.7 for sandy loams.
The product of slope angle and relative height is referred as “relief coefficient” R as it was introduced in [Zaalishvili, Gogmachadze, 1989].
Digital elevation model was constructed for the territory of Vladikavkaz city (fig. 4). Horizontals of engineering-geological map topographic base of scale M 1: 10 000 were used. Two layers were prepared for calculations – relative height and slope angles. Height of the central part of the city, where flattering of terrain is observed was used as initial value for relative height calculation. Calculated topographic intensity increments for whole territory are presented in figure 5. Red color corresponds to intensity increments of 1-1.5 points.

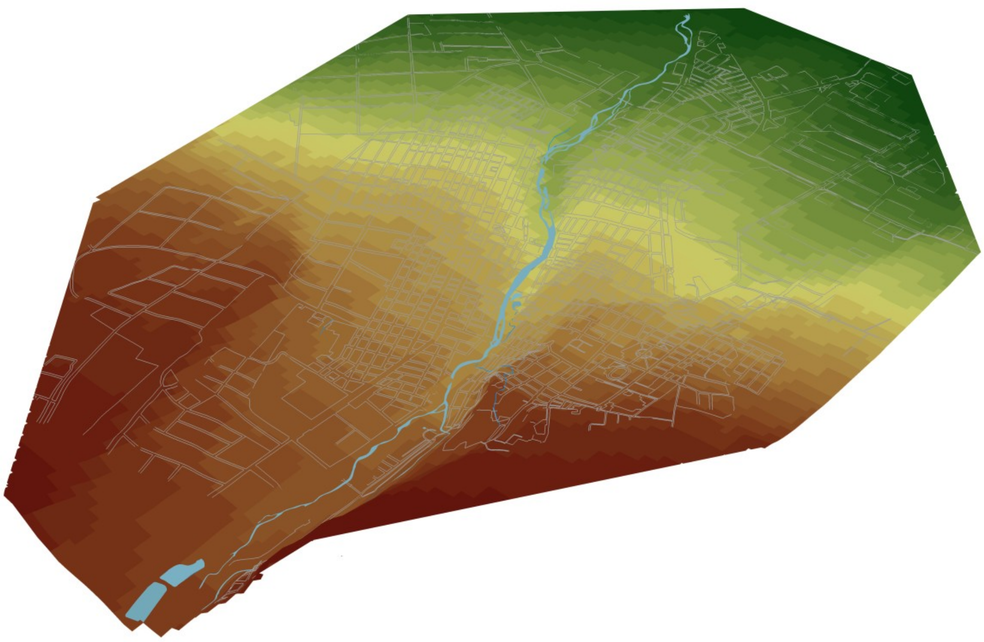


Figure 4. Digital elevation model of the territory of Vladikavkaz city (absolute height varies from 630 (green) to 750 meters (brown))

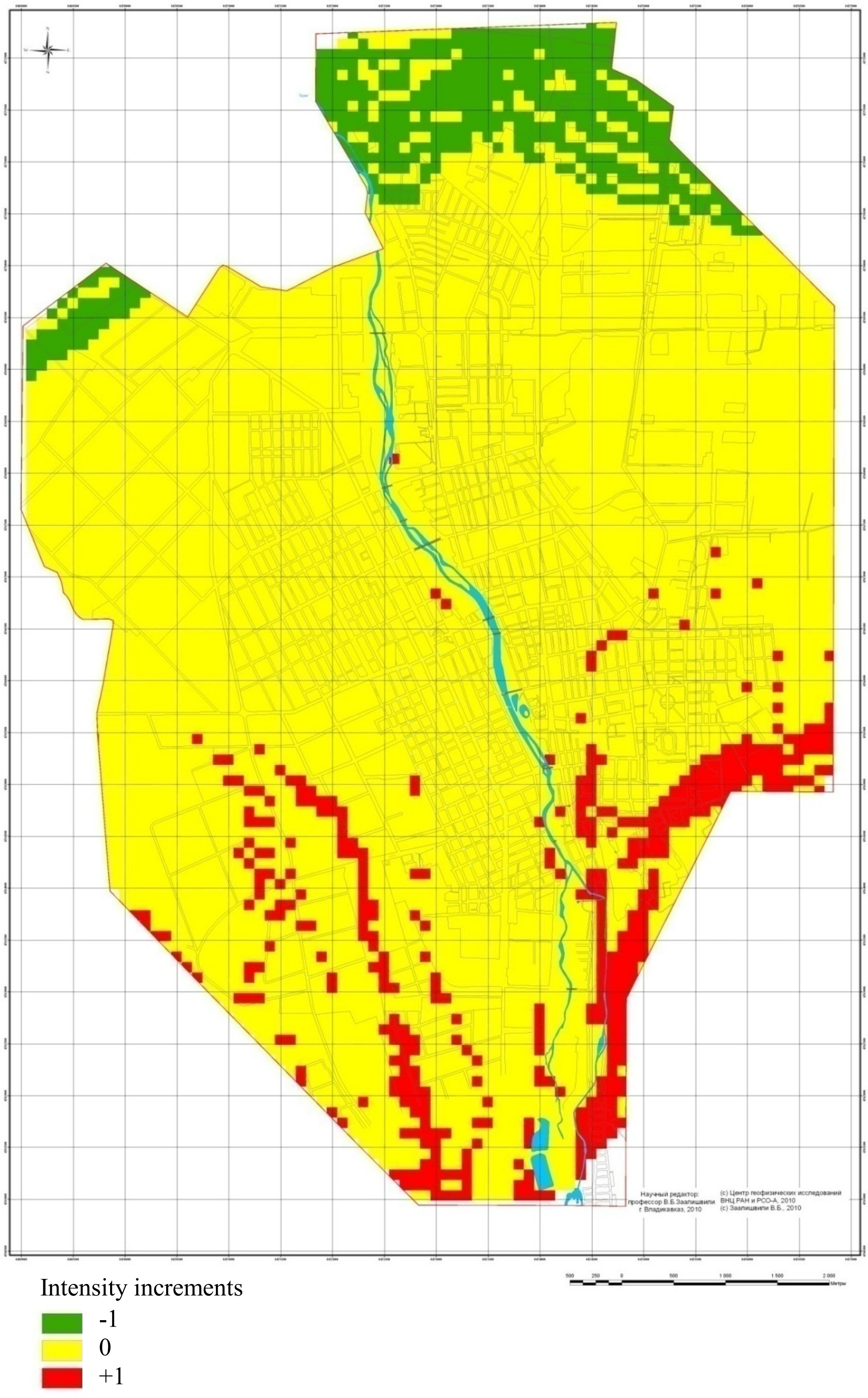


Figure 5. Topographic intensity increments for the territory of Vladikavkaz city

CONCLUSIONS

1. There are sites on the territory of Vladikavkaz city "unfavorable" for construction in accordance with Russian Building Codes (SNiP II-7-81*) - slopes more than 15°. Main zone of such conditions is terrace slope on right bank of river Terek with slopes of 25-35°.
2. Recording of microseismic vibrations was performed on the slope on the right bank of the river Terek for instrumental investigations of intensity increments on the territory.
3. Sesimic vibrations of slope were modeled by means of finite element method.
4. For the whole territory of Vladikavkaz city topography influence on seismic intensity was calculated by empirical equation
5. Topography influence on intensity increments can reach 1-1.5 points for some sites in Vladikavkaz city.

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