SEISMIC RISK OF CITIES WITH DIVERSE SITE DEVELOPMENT AND WAYS OF ITS REDUCTION

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ABSTRACT:

The urban growth of territories results in increasing of economic and social losses in a society from natural disasters. In these conditions there is an important problem of risk assessment and development of preventive measures for reduction of damage from earthquakes of design intensity. For solution of this problem for cities of Uzbekistan the types of buildings by constructive attributes have been classified. It is considered about 30 constructive types of buildings. The estimation of vulnerability of buildings is provided depending on their level of earthquake protection and seismic impact with definition of an average value of damageability index for each constructive type. On the basis of the analysis of seismic risk of the urbanized territories methods of seismic risk reduction which cover three directions of activity of a society are considered: risk assessment and action plan development; physical protection of existing buildings, new construction, lifelines, structural components; measures necessary for risk management.

KEYWORDS: seismic hazard, vulnerability, risk, earthquake resistance

In territories of the cities subjected to earthquakes, the problem of estimation of their impacts, prevention and protection is more important, than liquidation of their consequences. Well-known, that expenses for prevention of natural disasters in ten times less in comparison with size of the prevented damage.

In these conditions it is very important to reveal factors of increase or reduce seismic risk in city territories. As far as risk factors will be precisely determined and features of seismic hazard at sites are revealed, the estimation of expected economic damage in the urbanized territories from earthquakes of design intensity will be more objective.

In consideration of risk factors for buildings and constructions, complex of seismological parameters, seismotectonics and activity of faults, seismic zoning of territory are accepted as given. And risk factors in this case are considered in context of only correct use of this given information on earthquakes, i.e. their reliability and probability of earthquakes are not exposed to the analysis and doubt.

Risk factors can be grouped at stages of an estimation of seismic hazard, damageability (vulnerability) of buildings, gradation of cities, areas and settlements on reduction of risk. As we accept parameters of seismic hazard as given, risk factors in this sphere can be characterized by correctness of their application at an estimation of damage.

The factors raising or lowering economic losses due to earthquakes were considered by many authors engaged in an estimation of risk. Special development of work under the account of influence of these factors by size of damage have obtained in connection with necessity of definition of insurance division into districts of the territories subjected to natural and manmade disasters. Only names of these factors by different authors change in limits from 20 up to 50. Naturally, the account of all these factors qualitatively raises reliability of risk assessment.

As we consider concrete number of objects of vulnerability - civil buildings also factors which are the most important for taking into account, are dated for a considered infrastructure.

The analysis of the known factors raising or lowering risk, has allowed to reveal the most significant, in our opinion, parameters. To them are referred: seismicity; earthquakes of small and average intensity; repeatability of earthquakes; type of ground; level of subsoil waters; deficiency of seismic stability

of prevailing buildings; number of floors; quality of engineering - geological researches and their account; quality of design, quality of materials, quality of construction and maintenance.
In table 1 these factors with a rough rating (by three-point scale) and an estimation of their weight by two-point scale are given.

Table 1. Factors raising or lowering risk

N	**Name of the factor**	**Dimension**	**Interval values by groups**			**Weight of the factor**
1	2	3	4	5	6	7
1	Seismicity	Intensity units MSK-64	7	8	9 and >	2,0
2	Repeatability of earthquakes	once in 100 years	< 0,01	0,1	>1	2,0
3	Earthquakes of small and average intensity	MSK-64 intensity unit	4-5	5-6	6-7	1,5
4	Type of a ground by seismic properties	Type	I	II	III	1,5
5	Type of ground by settling properties	Type	Non settling	I	II	1,5
6	Level of ground waters	M	< 3	4-6	>6	1,5
7	Deficiency of seismic stability of building (prevailing building)	MSK-64 units	0-1	1	2-3	2,0
8	Number of floors (buildings)	Floor	< 3	4-5	>5	1,0
9	Quality of engineering - geological researches and their account	-	High	Average	Low	1,0
10	Quality of design of object (building)	-	High	Average	Low	0,5
11	Quality of the building materials, bearing material	-	High	Average	Low	1,5
12	Quality of construction	-	High	Average	Low	2,0
13	Quality of operation	-	High	Average	Low	1,0

These factors can be taken into account as at a level of a separate building, and district of city, settlement, region.
Value of a rating of damageability of building (Koff and Chesnokova, 1998) or group of buildings as first approximation can be defined by the formula:

$$r_c = \sum_{i=1}^{N} \frac{F_i \times W}{N}, \qquad (1)$$

Where: Fi - an expert estimation of i factor by 3-mark scale; W - weight (importance) of the factor by 2-mark scale; N - number of factors.
The given value of rating of influence of the specified factors on vulnerability of constructive type of building can be determined by the formula:

$$r_r = r_i / r_{max}, \text{ где } r_{max} = 57{,}0$$

Value of a rating, or its relative value, further will be taken into account at an estimation of parameter of vulnerability of building, and also at calculation of economic losses and definition of rating of cities by degree of risk.

Features of seismic hazard, for example in territory of Uzbekistan, are regulated by effective standards and rules КМК 2.01.03-96 "Construction in seismic areas» (КМК 2.01.03-96 ,1996).
At designing of new and reconstruction of existing buildings, and also at calculation of deficiency of seismic stability of buildings, are taken into account parameters of seismological regime of considered territory:
а) Expected intensity of seismic motions at site and accelerations (maximal and average);
б) Repeatability of seismic motions at territory of Uzbekistan;
в) Spectral content of seismic motions at site.
Intensity and repeatability of seismic motions in cities and settlements are accepted by obligatory appendices of design norms.
All territory of Uzbekistan is divided on four seismic regions which differ by value of spectral factor Wi. For each region characteristic samples of accelerograms of real earthquakes are determined.
The account of repeatability of earthquakes of various intensity is given in table 2.

Table 2. Account of repeatability of earthquakes

Interval of repeatability, Years	**Value of factor of account of repeatability of earthquakes at intensity**	
	7 and 8 units	**9 and more units**
<250	1,2	1,25
300-600	1,0	1,15
650-1000	0,8	1,0
<1000	-	0,9

Seismicity of construction site is taken into account by factor α. Value of factor is given in table 3.
Table 3. Value of factor of site seismicity

Seismicity of construction site, intensity units	7	8	9	> 9	9*
Factor α	0,25	0,5	1,0	1,4	2
The maximal acceleration, g	0,1	0,2	0,4	0,6	0,8

There is map of the general seismic zoning of territory of Uzbekistan OSR-78, according to which distribution of the areas (thousand km^2) zones of various intensity is shown in table 4.

Table 4. Distribution of areas (thousand km^2) zones of various intensity in maps OSR-78

Map title	Intensity units in MSK scale			
	6	7	8	9
OSR-78	71,0	168,6	50,2	8,2

However map OSR-78 appeared inadequate to real environment. For Uzbekistan in 1996 some amendments are entered in repeatability periods of the earthquakes, necessary for norms and was specified, that map OSR-78 for territory of Uzbekistan will be replaced by new one.

Table 5. Relation of areas of 8-and 9-intensity units in East Uzbekistan, (%)

Type of map	**7 < I < 8**	**8 < I < 9**
I	68,3	31,7
II	56,6	43,4
III	29,1	70,9

With reduction of risk up to 1 % almost 70 % of territory of republic becomes seismic active, with increase of risk up to 10 % - only 46 % (table 6).

Table 6. Relation of areas of zones of different maximal seismic motions to the general area of Uzbekistan, (%)

Risk, %	Type maps	Intensity				
		9 < 1 <10	8 < 1<9	7 < 1<8	6 < 1<7	< 6
10	I	-	1,61	13,51	31,32	53,56
5	II	0,25	4,55	29,11	29,82	36,27
1	III	0,49	10,00	38,81	20,31	30,39

Thus, for an estimation of seismic risk and the economic losses connected to it, in cities of Uzbekistan will be used not abstract information on the seismic hazard, based on deterministic parameters, but real maps of seismic zoning based on probabilistic approaches of the account of seismological information.

It is necessary to specify, that the account of maps with various level of excess of design intensity will be made for buildings of the various responsibility. Now these maps are not accepted yet as the normative document. However there is a confidence, that after their discussion and, if necessary, updating will be legalized as normative documents.

Use of materials of the seismological information over Uzbekistan will allow to solve the following tasks of the present research:

- Development and analysis of maps of seismic hazard, damage and risk;
- Assessment of seismic hazard of mass types of residential and public buildings of our cities;
- Modeling of scenario of earthquakes consequences.

The important value has revealing parameters of the urbanized environment, defining gradation of cities by degree of seismic risk.

Besides the factors given in table 1, it is possible to relate also:

- Density of buildings, m^2 / ha;
- Population density, person/km^2;
- Population;
- Percent of individual building;
- Percent of urbanized territory with soft soils;
- Percent of urbanized territory with high ability of soils liquefaction;
- Area of urbanized territory;
- Area of residential buildings.

If to accept mathematical model (Koff and Chesnokova, 1998) also it is necessary to give to above mentioned risk factors weight functions of importance and interval values by groups.

Risk factors can be grouped in three basic groups describing: hazard, susceptibility of this hazard of buildings and their vulnerability.

Gradation of cities is the important component of an estimation of risk as enables to open the reasons of the raised or lowered level of seismic risk and acceptance of measures on its mitigation.

Mathematical modeling of definition of an index of seismic risk of cities of Uzbekistan can be various. The index of seismic risk of city in all models should appear in relative sizes, that is it measures only change of size of an index of risk in time or its variations from city to city.

Weight factors of each factor can be accepted on the basis of expert estimations of the experts working in the field of seismic risk.

Methods of an estimation of seismic risk should reflect features of seismic hazard of territories, and also vulnerability of buildings and the constructions most widespread in the given territory.

Presence of a technique allows to solve the following tasks:

- Construction and the analysis of maps of seismic hazard, damage and risk of cities of Uzbekistan;
- Assessment of seismic hazard for especially important objects;

- Modeling of scenarios of consequences of earthquakes.

The economic losses at earthquake is determined, on the one hand, by intensity, spectrum, duration and the moment of time of seismic motion, and on the other hand, - stability of buildings to motions, dimensions and specific cost of constructions.

Table 6. An estimation of factors of definition of risk of cities

N	Name of the factor	Dimen-sion	Interval values on groups			W
1	Density of building	m^2 / ha	Low	Average	High	0,5
2	Population density	per/km^2	<100	101-1000	>1000	1
3	Population	person	<2000	2001-5000	>5000	1
4	Percent of individual building	%	<5	5,1¸15	>15	1
5	Percent of the urbanized territory with soft soils	%	<5	5,1¸20	>20	0,5
6	Percent of the urbanized territory with high ability of ground to liquefaction	%	<5	5,1-10	>10	0,8
7	Area of urbanized territories	km^2	<50	50-100	>100	0,06
8	Area of residential buildings	Thousand m^2	<1000	101-10000	>10000	0,14

Stability of constructions to seismic influence is set as the constructive seismic stability estimated in units by scale MSK-64. Vulnerability depends on constructive type of a building and parameters of seismic motions. It is equal to the average relation of expenses for restoration of the building destroyed at certain motion, to its initial cost.

Procedure of an estimation of vulnerability assumes performance of the following stages of work:

- Classification of objects of risk by their condition, structure and the properties, determining in aggregate character of reaction to seismic motions;
- Certification of objects of risk in the given territory, i.e. reference of each object to some, estimation of cost of object etc.;
- Definition of functions of vulnerability for each class of objects, i.e. an estimation of conformity between seismic motion and degree of damage (KMK,1996).

The economic losses are defined by cost estimation due to damage or destruction of building. Reason of losses at earthquake is the following three factors:

- Direct seismic influence (direct damage);
- Indirect consequences of destruction from earthquakes (indirect damage);
- Secondary natural and technogenous impacts induced by earthquake (secondary damage).

In our case parameters of seismic hazard may be given by building codes КМК 2.01.03-96, and also the developed new maps of zoning of territory of Uzbekistan with 10; 5 and 1 % risks of excess of seismic motions for 50 years at repeatability of 500 years. However can be used (at their presence) the seismic motions set by probabilistic parameters.

It is supposed, that seismic impacts distributed by Poisson law. Then the probability in time t in a point x will take place even one earthquake with intensity in an interval from I_{min} *(x)* up to I_{max} *(x)* (Gitis V.G., et all, 1997).

$$p(xt) = I - exp\{ -\lambda(x)t \}, \qquad (2)$$

and the probability of this seismic impact has intensity i is equal:

$$p(i/x_1t) = \lambda_i (x)/ \lambda(x), \qquad (3)$$

where: *l (x)* - intensity of a total stream of seismic influences of a class from I_{min} *(x)* до I_{max} *(x);*

λ_i *(x)* - intensity of stream of seismic events of class *i*.
Let's designate damage in point *x* through *D (x)*.
Damage from event of a class *i*

$$D_i(x) = \sum_{j=1}^{J} d_{ij} S_j(x), \qquad (4)$$

where: $d_{ij} = \lambda_i C_i$ - specific damage at seismic impact *i* for construction of constructive type *j* at influence *i*; C_i - cost of unit of the area of construction such as *j*; *Sj (x)* - density of buildings such as *j* in a point *x*.
Average damage from event in class from I_{min} *(x)* up to I_{max} *(x)*

$$\bar{D}(x) = \sum_{i=Imin}^{Imax} D_i(x) \frac{\lambda_i(x)}{\lambda(x)} \qquad (5)$$

The seismic risk is determined as probability of the social and economic losses connected to earthquakes in given territory during a certain interval of time. The developed technique of an estimation provides basically definition of economic losses at earthquakes at a level of separate buildings or urbanized territory (region, city, settlement of city type, etc.) . The estimation of damage or seismic risk can consist of two parts: passive and active. The passive part provides development of maps of distribution of damages and damage in considered territory. The active part of estimation of risk provides preventive actions for increase of safety as new constructed, as existing building. Knowing volumes of buildings by constructive types, having diagrams of damageability, economic damage, and also diagrams of economic losses from seismic motions depending on level of earthquake protection, it is possible to count up economic and material losses on each type of a building. At determined scenario earthquake economic losses will be the top risk level at probability of this earthquake P=1. At presence of probabilistic parameters of seismic hazard the estimation of seismic risk will have probabilistic character (Khakimov, 2000; Ibragimov et al, 2000; Khakimov and Nurtaev, 2003).
For an estimation of risk it is possible to take advantage of the formulas given in work (Gitis V.G., et all, 1997). Average limiting risk in a point *x* in time t we shall determine as mathematical mean of losses (damage) on unit of the area of building in a point *x*:

1 Average total risk from all events in time t:

$$r_s(x\ t) = \lambda(x)t\ \bar{D}(x), \qquad (6)$$

2 Average risk from the first event in time t:

$$r_1(x, t) = p(x_1\ t)\ \bar{D}(x), \qquad (7)$$

3 Average risk of the maximal event in time t:

$$r_{max}(x, t) = exp\{-\lambda(x)t \sum_{i=Imin}^{Imax} D_i(x) \cdot (exp\{\sum_{k=I\,min}^{i} \lambda_k(x)t\} - exp\{\sum_{k=I\,min}^{i-1} \lambda_k(x)t\}) \qquad (8)$$

It is necessary to point out, that at calculation of risk it is possible to take into account results of preventive antiseismic actions conducting for reduction of direct losses. Optimization of total risk by size of investments to reinforce of buildings is also possible.
Presented concept of assessment of seismic risk and economic damage enables to carry out preliminary protection of vulnerable city territories, to differentiate cost estimation of each region depending on features of territory and damage.

On the basis of the analysis of seismic risk of the urbanized territories seismic risk reduction methods which cover three directions of activity of a society are considered:
• risk assessment and action plan development;
• physical protection of existing buildings, new construction, lifelines, structural components;
• measures necessary for risk management.
All actions of mitigation of seismic risk were considered at three levels: small level - person or family, middle level - organization or neighborhood (mahalla), third level - regional and governmental. For each of these directions for three level actions the priorities have been developed. Realization of these actions is focused on mitigation of consequences of probable seismic disasters at the limited financial resources.

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