QUESTIONS OF NORMALIZATION OF DESIGN AND RULES OF REHABILITATION AND ANTISEISMIC STRENGTHENING OF BUILDINGS OF EXISTING SITE DEVELOPMENT

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ABSTRACT:
Attempt of formalization of characteristics of residual bearing capacity of elements of buildings, development of the design positions taking into account real characteristics of materials, specifications of limiting conditions, normalizations of constructive actions and their typifications, and also normalization of methods of strengthening was made to formulate conceptual bases of formation of optimized antiseismic reinforcement of existing buildings.

KEYWORDS: design, vulnerability, rehabilitation, earthquake resistance

With problems of restoration and antiseismic strengthening of buildings in earthquake prone areas for the first time seriously we have faced at liquidation of consequences of Tashkent earthquake of 1966. A number of recommendations, manuals, albums since then were developed with technological decisions on restoration and antiseismic strengthening of buildings and facilities.
Normalization of elements of strengthening of buildings and constructions of existing dwellings is regulated in a number of norms of the countries of the CIS in structure of norms and rules of design «Construction in seismic areas». Thus to a limiting condition reinforcing buildings the same requirements, as well as for again erected building are showed. If constructive and design requirements to new construction are strictly regulated, similar requirements to reinforcing buildings do not exist. Therefore the same purpose of strengthening, with other things being equal, different authors is achieved by various methods. Economic and technical feasibility of the accepted decision, as a rule, is not studied and not analyzed.
The analysis of projects of strengthening, for example of typical school buildings of the early constructions executed by different authors, shows, that with other things being equal, divergences up to two times in cost, the charge of the basic materials and in reliability of reinforcing schools are observed. It testifies to imperfection of normative base for antiseismic strengthening of existing buildings and constructions.
In this connection Joint-Stock Company " UzLITTI " works on preparation of positions and data gathering for development of the special normative document on restoration and antiseismic strengthening of buildings of existing building are begun.
The purpose of work is development of substantive provisions on designing antiseismic strengthening of existing buildings and constructions from diverse constructive systems, and also requirements to reinforcing to the buildings, the allowable levels of damageability based on positions of damage and seismic risk.
Effective standards and rules «Construction in seismic areas» basically are aimed at designing of again erected buildings and constructions. For existing buildings the recommendation of the specified norms are difficultly feasible or practically impracticable, as existing positions do not regulate methods of maintenance with a trustworthy information about existing buildings, an estimation of their real seismic stability, criteria of assignment of sufficient volumes and ways of strengthening, etc.

The analysis of results of technical inspection of some objects, carried out by many authors has shown, that the information stated in them and recommendations are based both on objective results of inspections, and on the subjective approach to interpretation of separate materials. Frequently subjective making expert estimations prevails above objective. Many questions of strengthening are connected to presence of difficulties at a design estimation of seismic stability of existing building as the accepted design models frequently do not correspond to the real deformed condition of a building and its originally given design schema.
Traditional physical methods of inspection of buildings carried out by researchers cannot be cancelled. They, certainly, are necessary and useful. At the same time, they can not give, for example, an estimation varying in time of dynamic characteristics of a building, frequencies of its own oscillation, decrements of attenuation and hazard of resonance with frequencies of relative spectral content of earthquakes etc. Ignorance of true dynamic

parameters of oscillation of building, in turn, can result to that accepted decisions on strengthening may be insufficiently correct.

At assignment of volumes of strengthening are not taken into account, so-called «natural seismic stability» of constructive system, the residual and again appointed service life of a building, a category of the responsibility of the strengthened building etc. Such position in one cases results in excessive expenses and stocks, in others - to essential lack of a level earthquake safety of reinforcing object.

It was established, that by consideration of questions of restoration and antiseismic strengthening of existing building it is expedient to normalize the following elements and parameters of examined buildings and constructions:

- kinds and volumes of the sufficient technical information on reinforcing object and its reliability;
- bases of estimation of actual seismic stability of reinforcing object before strengthening;
- criteria of assignment of constructive actions to reinforcing elements and a building in whole;
- basic design positions and constructive restrictions on limiting conditions of reinforcing buildings.

The initial information should include:

- the biographic data of object;
- engineering - geological data of a site of building;
- durability and deformational characteristics of underground and ground elements;
- dynamic characteristics of buildings;
- data on seismic hazard of site or area of building;
- operational characteristics of object;
- mapping of level of damage of bearing elements;
- spatial - planning data, and also the constructive data by measurements of building section of elements etc.

The new approach to reception and submission of the initial information on object of strengthening will allow to standardize and finish up to normative level of the requirement to the initial information, its volume and reliability. Realization of these requirements can be executed even by the expert of average qualification.

For an estimation of seismic hazard for reinforcing buildings it is necessary to take into account the following factors of seismic hazard:

- intensity of seismic influence in intensity units and acceleration;
- repeatability of seismic motions;
- spectral structure of seismic motions;
- category of soils by seismic properties;
- basic characteristics of buildings.

The basic characteristics, for example, of brick building, should include:

- data on actual constructive system of a building (in view of characteristics of ceilings, walls);
- sizes and characteristics of constructive elements of a building, basic and joint connections (in view of defects and damages);
- data on antiseismic actions and constructive restrictions;
- data about actual and forecasted loadings;
- actual period of the basic tone of own oscillation;
- design resistance of brickwork to compression;
- module of elasticity of brickwork;
- geometrical dimensions of constructive elements.

As against existing methods of an estimation of the seismic stability, the offered method provides:

- use of wider palette of the initial information;
- account of presence of defects of operational character;
- account of damages from past earthquakes;
- detailed account of properties of materials of a design (for example, for stone buildings: rigidity of mortar, presence of softener, kind of a brick - hollow, slot-hole, corpulent etc.);
- account of character of processes of destructions of building elements;
- account of the actual design schema of a building.

For example, design resistance of brickwork to an axial stretching on not tied up seams Rp can be determined by formula:

$$R_p^b = K_1K_2K_3K_4S \quad (1)$$

where K_1 - factor of influence of rigidity of mortar: at brickwork on rigid cement mortars without softeners K_1 = 0,75, in other cases K_1 = 1;

K_2 - factor of the account of brick and stone: at cladding from slot-hole brick and stone at conformity of hollowness to requirements КМК 2.01.03-96, K_2 = 1,25, at a corpulent brick of Kg = 1;

K_3 - factor of an operational condition of brickwork, is accepted by table 1 depending on a category of a technical condition;

K_4 - factor which is taking into account damages from previous earthquakes, is accepted by table 2;

S - the initial level of normative cohesion equal:

$$S = \frac{3.6}{1+50/R} \quad (2)$$

where R - strength of mortar (cube durability in kg / cm).

It is necessary to normalize parameters (criteria) of allowable limiting conditions for reinforcing buildings of various constructive systems in view of category of their responsibility. For this purpose it is necessary to solve the following problems:

• to define parameters of assignment of category of the responsibility of buildings and facilities;
• to compile terminology and requirements to limiting conditions of reinforced existing building;
• to define the basic characteristics of a technical condition of a building before (strengthening);
• to establish parameters (criteria) of allowable limiting conditions for reinforcing buildings in view of type of constructive system and a category of the responsibility of a construction.

Key parameters of assignment of a category of the responsibility of existing building at the decision of a question of provision their earthquake safety are:

• functional assignment of a building;
• amount of people constantly staying in a building, falling into unit of the area;
• presence of the valuable equipment in the cost expression, falling into unit of the area;
• residual (regenerative) cost of the building, falling into unit of the area;
• year of construction (term of operation of a building);
• residual service life of a building;
• type of constructive system.

Actions for buildings and new classification of a category of the responsibility can be subdivided as a first approximation into the following kinds:

I Restoration of buildings up to an initial design condition;
II Increase earthquake resistance in volumes, including obligatory application of constructive actions;
III Design antiseismic strengthening with constructive actions up to normative level of new construction.

The responsibility of buildings can be characterized, for example, by three classes:

Class I. Factor of reliability by destination η =1.

Residential buildings: in height of 6 floors and more;

- Public buildings, constructions and complexes: children's preschool establishments;
- Educational institutions of all kinds (school, colleges, liceums, high schools,etc.);
- Class II. Factor of reliability by destination η =0,95.
- The enterprises of retail trade with area up to 200 m^2;
- Public catering establishments with amount of places up to 200;
- Consumer services establishments of the population with amount of workplaces up to 150;
- Hospitals with amount of beds up to 100.
- Class III. Factor of reliability to destination η = 0,90.
- Apartment houses one-storeyed, two-storeyed;
- Buildings of auxiliary and economic assignment;
- Structure of complexes of public buildings and facilities.

Table 1. Factors of operational condition of brickwork

№№	Characteristics of damage	Category of state	Coefficient, K_3
1	Cracks are absent, unfreezing of brickwork < 1,0 cm	Serviceable	1,0
2	Vertical and inclined cracks, crossing no more than 4 lines of brickwork when number of cracks no more than 4 on 1 m of width of site; unfreezing of brickwork at depth of 15% of wall width, damage of some bricks of wall	Serviceable	0,9
3	Damage more than, pointed out in i.2	Limited serviceable	0,75
4	Continuous stratification of brickwork and deflection from plane more than 1/6 width of wall, unfreezing 25 % width of wall, collapse danger	Non allowable or dangerous	0

Table 2 Coefficient, taking into account damage from previous earthquakes

	Characteristics of damage grade by MSK-64 scale	Grade of damage, d	Coefficient
1	Absence of visible damage	0	1,0
2	Light damage (thin cracks in plaster, breaking of small parts of plaster)	1	1,0
3	Significant damage of non bearing elements of building (falling of plaster, damage of partitions, pipes, parapets), non significant cracks in bearing elements	2	0,8
4	Significant damage in bearing elements (large and deep through cracks in bearing elements, partition collapse, pipes, parapets), state of bearing elements «dangerous»	3-5	0

Minimal allowable level of actions for maintenance of seismic safety of buildings and constructions is given in the table 3.

Table 3. Minimal allowable level of actions for maintenance of seismic safety (fragment)

№№	Types of buildings and facilities	Level of reinforcement actions		
		I	II	III
	1. Residential buildings			
1	One-and two storey	+		
2	Buildings with height 3-5 storey		+	
3	Buildings with height 6 and more storey			+
	II. Public buildings and facilities			
1	Children pre-school buildings			+
2	Educational institutions of all types (schools, colleges, liceums, universities)			+
3	Enterprises with retail trade with area up to 100 m^2		+	
4	The same, with area more than 100 m^2			+

Terminology and requirements to limiting conditions of reinforced existing building, subject to increase of seismic safety which are subdivided on was developed:

- Terms on inspection and an estimation of technical condition of building elements;
- Terms and definitions on designing, calculation, restoration, antiseismic strengthening, reconstruction and modernizations of existing buildings and constructions.

The basic initial parameters of characteristics of building technical condition before strengthening may be:

- Year of construction and norms of designing of buildings working in this period in seismic areas;
- Constructive type of a building on classification of buildings and constructions by material bearing elements;
- Level of security of antiseismic actions or relative level in comparison with modern requirements;
- Residual service life of a building and of separate bearing elements;
- Category of the responsibility of a building existing and required after strengthening;
- Factor of seismic stability of building;
- Level of solidity of building;
- Relative bearing ability (durability) of the basic bearing elements;
- Design seismicity of building site, etc.

As criteria of allowable limiting conditions for reinforcing buildings in view of type of constructive system and category of the responsibility of a construction it is offered:

- relation of actual residual bearing capacity to required in KMK, so named residual factor of seismic stability which changes from 0 up to 1;
- index of damageability of building of the given constructive type by scale such as MSK, which changes from 0 up to 5;
- Relative displacements and skews for the given type of a building.

For the account of vulnerability and damageability of various constructive systems by assignment of volumes of strengthening their classification by a degree of the vulnerability, given below in the table 4 was developed.

Table 4. Classification of constructive types of buildings (existing and under construction in the Central Asia) by degree of their vulnerability and damageability at earthquakes (fragment)

Vulnerability grade	Type of buildings. Bearing elements	Average level of damageability index, d_{ij}
1	Residential buildings from local weak materials (non engineered)	3,96
2	One storey frameless adobe walls of type "gualyak, pahsa"	3,84
3	3-5-storey frameless brick buildings with wooden ceilings (constructed before 1958)	3,68
4	1-2-storey frameless brick buildings with wooden ceilings	3,15

For decision making about a level of antiseismic strengthening of concrete type of building it is necessary to define factor of seismic stability of building by the formula:

$$Ks = \frac{N_f}{N_r}$$

where: N_f -actual bearing ability of considered type of building or its elements;

N_r - required bearing ability which considered building and its elements should have according to effective standards.

Marginal levels of provision of seismic safety of existing buildings depending on their category of responsibility and vulnerability can be presented as in the table.

Table 5. Marginal levels of provision of seismic safety of existing buildings depending on their category of responsibility and vulnerability (fragment)

№№	Characteristics of buildings	Category of responsibility	Constructive solutions for buildings by level of damageability by table 4.1	K_s
1	Especially responsible facilities, which damage is connected with heavy consequences for environment	I	For all constructive systems	1
2	Buildings, which are responsible by purpose (some administrative objects of the state value, etc.)	II	For all constructive systems	0,9

As a whole the question of optimization of antiseismic strengthening of existing buildings is rather combined. Up to what level it is necessary to raise its seismic stability? Up to a level safe for residing if it is inhabited house, at motions of earthquake of design intensity? What this level means in physical understanding of non-failure operation of elements? This level can be characterized by damageability of concrete constructive type at design motions.

Attempt of formalization of characteristics of residual bearing ability of elements of buildings, development of the design positions which are taking into account real characteristics of materials, specifications of limiting conditions, normalizations of constructive actions and their typifications, and also normalization of methods of strengthening was made to formulate conceptual bases of formation of the optimized antiseismic reinforcement of the existing building, provided by concrete operations of calculation of seismic motions, acceptance of constructive decisions with use of the normalized ways of strengthening both separate elements, and buildings as a whole.

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