EARTHQUAKE SAFETY OF CIVIL BUILDINGS OF MODERN DEVELOPMENT IN CENTRAL ASIA AND INCREASING CONCEPTS

Shamil KHAKIMOV¹, Bakhtiar NURTAEV²

ABSTRACT
Over the past 20 years construction palette of civil buildings in Central Asia as in the cities as in the rural areas has changed dramatically, appeared new building materials, new structural systems, which previously were not used in construction. Some structural systems, not used previously such as: frame buildings of 9 floors and more with different filled masonry, stone and small-piece blocks, monolithic frame system without girders and joints, buildings with an incomplete frame, buildings with flexible first floor, frame - wall monolithic buildings without girders with different ratios of the volume of the walls and the frame. For these systems there are no complete recommendations on their design, construction and evaluation of seismic safety. The destruction mechanisms of various structural systems and their components in impact of earthquakes from global sample, and a summary of the reasons for the damage of various structural types in the urban and rural areas have been investigated. New concepts of design and construction, as well as technical solutions aimed for reducing the causes of damage of certain types of buildings of modern development under earthquake action have been developed.

Keywords: Civil buildings; Vulnerability; Damage; Safety; Technical solutions; New concepts

1. INTRODUCTION
Vulnerability to hazards and disasters has been investigated substantially in the past three decades by researchers from different fields using a variety of approaches, scales, models, and techniques (Arya et al., 2014; Eisenberg, 2000; Arslan & Korkmaz, 2007; Khakimov & Nurtaev, 2012; Nemchinov, 2008). Civil and housing buildings of modern construction in earthquake-prone areas of cities and settlements of Central Asia, may be divided into three groups according to their design features (Khakimov, 2009):
- rural houses of individual construction, erected with the use of low-strength structures of clay, light blocks, natural stones in bearing walls;
- buildings up to five stories, erected from brickwork and complex structures;
- civil and housing buildings in reinforced concrete frame and flat-wall structures and in small volume in metal frame structures.
Over the past 20 years, the construction palette of civil buildings in the Central Asian region, both in the city and in the countryside, has changed dramatically (Khakimov, 2014). There were used new building materials, constructive systems, previously not used in construction. Design systems like standard prefabricated reinforced concrete large-panel and volume-block apartment houses, assembled monolithic reinforced concrete frame-panel and frame-bond systems, brick buildings of the usual complex structure with a height of up to five floors were disappeared, which before tested by experimental and theoretical studies and real earthquakes. Practically it was disappeared standard design of civil buildings. Large-scale experimental works are not carried out. The quality of construction and materials used has been sharply decreased.
New construction systems, previously unused, have replaced the old ones: frame houses of 7-9 floors with different fillings from brickwork, small blocks and stones, according to the design scheme

¹PhD, Head of Department, JSV “ToshuyjoyLITI”, Tashkent, Uzbekistan, sh-khakimov@rambler.ru
²PhD, Head of Laboratory, Institute of geology and geophysics, Tashkent, Uzbekistan, nurtaevb@gmail.com
participating or not participating in the work of the frame; monolithic frame buildings of the girder
less system; buildings with incomplete frame; buildings with flexible first floors; frame-wall
monolithic buildings of girder less system with a different ratio of the volume of walls and frame. For
most of the listed constructive systems there are no full-scale recommendations for their design and
construction.
Owing to our own research and generalization of the work of a number of authors, the damage
mechanisms of various structural systems and their elements in earthquakes have been studied, and the
main causes of destruction of various structural types of buildings in the villages and in the cities have
been revealed (Arya et al.2014; Rzhevsky et al. 1989; Eisenberg, 2000; Blondet et al. 2007;
Nemchinov, 2008; Khakimov & Nurtayev, 2012; Khakimov, 2014). In the context of the existing
situation, a serious problem arises in conditions of limited funding for research in the field of
earthquake-resistant construction, assessing the seismic safety of civil and residential buildings of
modern construction and developing concepts for mitigating earthquake consequences (Khakimov,
2009).

1.1 Residential Houses in Rural Areas and Concepts of Their Seismic Safety Improvement

People used to make their houses by local materials and local construction technique without any
engineering philosophy especially in rural areas. Residential houses in Central Asian republics are
usually built by the residents themselves without use of recommendations of the building codes, with
rare exceptions, when the state itself builds standard residential houses, taking into account the
requirements of the norms. Majority of the rural population of the Central Asia are constructing
seismically dangerous housing almost unchecked by the states. A widespread presence of non-
engineered houses, owner self-built among these in particular, are potentially dangerous.
Recommendations for the use of low-strength local materials for construction contain only building
codes of Uzbekistan (KMK,1996). As shown by the analysis of the consequences of earthquakes
(Figure 1), in almost all rural settlements in the world, the largest number of victims falls on
residential buildings of individual construction (Arya et al.2014; Arslan & Korkmaz, 2007; Eisenberg,
2000).

![Figure 1. Consequences of Kan earthquake 2011 in Kyrgyzstan.](image-url)

The first serious problem is the provision of seismic safety of owner self-built housing. Currently, in
urban settlements, villages, in general in Central Asia, more than 40% of the population lives in
houses built by residents themselves using local low-strength wall materials without any anti-seismic
reinforcement. These houses are dangerous for living in earthquake conditions more than 6 intensity
units. This situation has happened for the following main reasons:
- construction of residential houses without elementary anti-seismic measures due to inaccessibility
and misunderstanding of the Building code provisions (KMK,1996);
- lack of awareness that buildings could be made earthquake resistant at small additional cost only, hence lack of motivation
- lack of skill in seismic design and construction techniques and unorganized nature of building construction;
- lack of concern about seismic safety due to infrequent occurrence of earthquakes;
- lack of simple and economical technical solutions available to the population, building rules with elements of seismic reinforcement;
- lack of a mechanism for influencing the population of engineering and legal activities of existing institutions oriented to the construction of seismically safe housing, etc.

Self-construction by the population of a seismically safe home requires other approaches. It is necessary to develop special benefits and so that the peoples can independently build a rural house without addressing to additional sources.

Lack of resources, particularly financial resources, and access to education and information play a major role in rural residents’ vulnerability to hazards. Especially in developing countries, rural residents are more vulnerable to hazards because they are less powerful to influence planning and policies and may not have access to safe land and housing, training and education, and financial resources and thus will suffer greater loss when disasters strike (Arya et al. 2014). Generally, because of the poor housing conditions in rural areas compared to cities, the bulk of disaster losses occur in rural areas. Thus, improving the quality of rural housing is very important for disaster risk reduction.

Building houses that are resistant to natural hazards, especially earthquakes, is perhaps one of the most important ways to minimize the human and economic losses. The most difficult is the question how to notify the public about these ways of strengthening and training. This is a fairly complex problem and the action schemes here can be many. It seems to us that we should start with the publication of colorful, attractive booklets, brochures, books. The next step can be the presentation of these printed materials in local community’s centers with a high level of presentation of material. The following steps may be:

• raising awareness how to educate communities and technicians about the importance of making safer houses. There is the necessity to use of media and periodicals. The experience of attracting periodicals for explaining the method of strengthening houses from clay materials was used by KazNIISSA in the aftermath of the earthquake in the village of Lugovai;
• development of methods for encouraging the population to build their homes in accordance with the requirements of earthquake-resistant construction. For example, subsidizing part of the costs, etc.;
• organization of interviews with the public with explanations of the nature of earthquakes, their consequences and ways to protect already built and newly built dwellings;
• provision of an experimental demonstration of earthquake-resistant residential building from adobe materials in a specific locality with the involvement of residents.

In the meantime, while the villagers build residential houses according to their understanding, they remain dangerous for the residence in earthquake-prone areas of the Central Asian region (Figure 2).

Figure 2. Rural houses under construction by the residents of the village.
1.2 State program to increase the earthquake safety of rural housing

The role of financial assistance for housing in developing countries has been discussed in a number of studies (ADPC, 2005; World Bank, 1993). The role of governments, both national and local, is enormous given the fact that they have to be technically capable to enforce the code as well as to be able to convince and motivate professionals and the public to comply with the building regulation. In order to increase the earthquake safety of rural housing, a new stage has begun with the announcement by the first President of Uzbekistan of the country 2009 as the Year of Development and Improvement of the Village. The state itself developed and began to implement the program at its own expense. In 2009-2016 throughout Uzbekistan more than 55 thousand modern rural houses designed by design organizations were built by standard projects. These masonry houses meet the requirements of modern standards, including seismic ones. This act of the state is unprecedented in the world practice for the construction of villages throughout the country with earthquake-resistant modern rural houses at the expense of the state, with their subsequent sale to the population on preferential terms. And this action is continues (Figure 3).

![Figure 3. Modern earthquake resistant rural houses.](image)

2. MULTI-STORAGE BRICK BUILDINGS

2.1 Performance of unreinforced masonry buildings in earthquakes

Damage to unreinforced masonry buildings and elements is a pervasive feature of many earthquakes. And studies have shown that buildings up to 5 floors, designed according to the norms and implemented strictly according to the project, satisfactorily resist earthquakes of design intensity. However, in real life this does not happen. The condition of most brick buildings after the earthquake, although there were no casualties, was such that the deformations were so significant that it was sometimes not economically feasible to restore and strengthen them. And this happened even under impacts below the calculated ones. Below are presented data on the impact on masonry buildings of moderate earthquakes in Central Asia on the basis of the results of their engineering analysis conducted under the guidance on of the authors (Table 1).

The reasons for the increased vulnerability of masonry buildings are determined by many factors, the main of which are:
- low quality of materials, violation of technology for erecting brick walls, poor quality of the adhesion of brick to mortar, seams between slabs of slabs, as a rule, do not get embroidered, etc. etc.;
- sharp decrease in the level of quality control of design processes, construction, production of building materials in the conditions of new economic relations established by business rules and private production;
- lack of research aimed at improving masonry construction and its components (brick and mortar).

In countries such as Japan, brick construction is prohibited. It is also forbidden in Uzbekistan, if it is impossible to obtain at the construction site the value of the temporary resistance to axial tension $R^b_\tau$.
equal to or exceeding 1.2 kgf/cm² (KMK 2.01.03-96). A survey of a number of brick construction projects showed that, as a rule, the value of $R^2$ is below the minimum allowable value. The practice of regulating and compensating for the poor quality of brick construction, the main type of construction of buildings in the Central Asian republics, for example, in the norms of Uzbekistan, due to the artificial increase in the seismic load by increasing the value of the reduction coefficient, did not give real results, although, possibly without this action, damage from earthquakes could be even more tangible (Figure 4).

Table 1. The impact of earthquakes in Central Asia in recent years on brick buildings.

<table>
<thead>
<tr>
<th>№</th>
<th>Earthquake, date</th>
<th>Intensity in epicenter, units</th>
<th>Intensity in area of investigation, units</th>
<th>Design intensity in units</th>
<th>Damage, MSK-64 scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Kamashi (Uzbekistan), 2000-2002, M=5,3</td>
<td>8</td>
<td>8</td>
<td>8</td>
<td>2.5</td>
</tr>
<tr>
<td>2.</td>
<td>Lugovaya (Kazakhstan) 23.05.2003, M=5,4</td>
<td>7</td>
<td>7</td>
<td>8</td>
<td>2-2.5</td>
</tr>
<tr>
<td>3.</td>
<td>Kan (Kyrgyzstan), 20.07.2011, M=6,2</td>
<td>8</td>
<td>6-7</td>
<td>8-9</td>
<td>2-2.5</td>
</tr>
<tr>
<td>4.</td>
<td>Tuyabuguz (Uzbekistan), 25.05.2013, M=5,6</td>
<td>7</td>
<td>6</td>
<td>8</td>
<td>1.5-2</td>
</tr>
<tr>
<td>5.</td>
<td>Mardjanbulak (Uzbekistan), 25.05.2013, M=6,0</td>
<td>8</td>
<td>6-7</td>
<td>8</td>
<td>2-3</td>
</tr>
</tbody>
</table>

Figure 4. Performance of brick buildings after Kan (2011) and Mardjanbulak earthquakes (2013)

2.2 Reinforced-concrete Frame Systems of Modern Civil Buildings

For all the above-mentioned constructive systems, most of the norms of the CIS countries do not contain full-rate recommendations for their calculation and design requirements. These constructive systems have not been practically studied experimentally and the construction is based only on calculated assumptions and all possible theoretical interpretations of their response, especially in nonlinear area of deformation. It should be pointed out that in a number of normative documents of the CIS countries for construction of new structural systems or buildings designed with deviation from regulatory requirements, or when the standards do not contain full-rate recommendations, preparation of project documentation and construction of buildings is allowed in accordance with special technical conditions (STU), developed and coordinated by special design institution in accordance with the established procedure. STU is a normative document for a particular projected building. However, practically in any normative document there are no requirements to their content and what measures are compensating for deviation from building code requirements. Recommendations STU, as a rule, comprise in increasing the class of concrete, increasing cross sections, reinforcement, loads, performing spatial calculation, selecting spatial models, calculating the effect of real or artificial
accelerograms. All listed recommendations are not sufficient, compensatory measures to reduce the negative consequences of the deviations in the building design from the requirements of the norms. How should we in conditions of practical absence of experimental studies, to assess the seismic safety of modern buildings? In JSC “ToshuyjoyLITI” the mechanisms of damage of various constructive systems and their elements in earthquakes of the world sample have been studied, and the main reasons for the destruction of various construction types in the village and in the city have been revealed. Work has begun to assess the seismic resistance of buildings of modern construction with the use of records of dynamic parameters for microseisms both on soils and on the structure under study. Modern frame buildings, especially with flexible first floor, are exceptionally vulnerable to earthquakes (Figure 5).

![Figure 5. Rigid building with first flexible floor. This type of construction by the norms of a number of Central Asian countries is not allowed.](image)

From the engineering analysis of the consequences of even moderate earthquakes in the performance of modern buildings (Khakimov, 2014), the main conclusion as follows: in practice, seismic resistance of modern buildings is lower than the claimed level of seismic resistance by 1-2 units. This means that the seismic risk of buildings of modern construction may be significant in the event of earthquakes of calculated intensity.

Another very important conclusion is that: it is not expedient at this stage to further increase the seismic load, as the artificial increase in loads on masonry buildings, as practice of Uzbekistan has shown, did not give the expected results. Approximate correlation between the design and actual seismic resistance of the building is presented in Figure 6.

![Figure 6. Approximate correlation between the design and actual seismic resistance of the building](image)
3. CONCLUSIONS

The weak parts in earthquake-resistant construction are:
- poor quality of design and expertise;
- low level of quality control of construction materials and site works;
- lack of research on the development of new structural systems and methods of seismic protection, as well as experimental studies;
- lack of a design system for special technical conditions.

It is proposed to introduce:
- institutions for support of construction projects;
- system of independent scientific expertise of technical survey reports and technical recommendations at the reconstruction sites;
- system of operational expertise of the facility under construction for compliance with the materials used, the methods of construction and the quality of the building elements to the requirements of the project and standards;
- system of seismic certification of reconstructed and newly constructed objects
- system of issuing to the customer the guarantee certificate of the facility when it is put into operation;
- certification system for construction industry workers on the basis of seismic resistant construction for the right to design and build on earthquake-prone areas, etc.

Objects with a height of more than 5 floors should undergo an independent examination at an early stage of design for compliance with the accepted architectural and planning parameters to the requirements of seismic norms, and, if necessary, the development of special technical conditions for the design of the facility.

Some measures to improve the earthquake safety of housing and civil buildings are proposed. Their implementation will significantly reduce seismic risk in the cities of the Central Asian region.

4. REFERENCES