Mitigation of Seismic Risk in Urban Zones of Uzbekistan as Path for Strengthening of Sustainable Development of Region

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Keywords: Risk, Buildings, Development of Region, Urban Zones.

Abstract: Population growth and active urbanization processes in Central Asia lead to seismic risk increasing in this region. Uzbekistan is most populated country in Central Asia. Along with the growth of civilian and earthquake engineering, many individual buildings remain in cities and also have trend for expansion. Sustainable development of region cannot be provided without safety resilience operating all civilian infrastructures. For mitigation of vulnerability of habitants during seismic event is the most important is housing safety. Assessment of stability for individual self-made, one and two storey residential structures are described in this issue. Measures for strengthening of such types of buildings are recommended in this issue.

1 INTRODUCTION

Territory of Uzbekistan located in seismic prone Central Asian region. Strong earthquakes with intensity of 8 points and more may happen in this area. Seismic risk for water work objects (Akhmedov, 2020) has the great importance and special State programme are developing nowadays. Measures against landslides or mudflows find their solution also (Sagdullayeva, 2020). Lesson from past events (Chan, E.Y., 2008) gives path for reliable solutions.

As urban densification occurs in Central Asian regions of high seismicity, there is a natural demand for seismically resilient not only for tall buildings and for residential sector also. Therefore, the great importance to minimise of human loses at probable seismic event with taking into account rapid urbanisation process and increasing of demographic growth. For sustainable development of region the preservation housing, industrial clusters, life line structures has importance also.

Traditional housing has cultural aspect and ecological friendly ones also. However safety and living standards need improving existing situation up to more comfortable level. Vulnerability of so structures and areas are high and doesn't acceptable nowadays.

Risk of destruction and hazard level for urban zones (Abirov, 2016) have to be estimated and measures should be developed for mitigation of earthquakes consequences. Below in Table 1 probable earthquakes intensity by MSK scale is provided for different regions of Uzbekistan.

Table 1: Probable earthquakes intensity in regions.

№	Regions of the republic	Earthquakes intensity
1	Andijan	8-9
2	Buhara	7-8
3	Djizak	7
4	Kashkadarya	7
5	Navoi	6-7
6	Namangan	8-9
7	Samarkand	7-8
8	Syrhadarya	7
9	Syrdarya	7
10	Tashkent	8-9
11	Tashkent city	8-9
12	Ferghana	8-9
13	Horezm	6-7
14	Republic of Karakalpakistan	5-6

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Akhmedov, M. and Abirov, R.
Mitigation of Seismic Risk in Urban Zones of Uzbekistan as Path for Strengthening of Sustainable Development of Region.
DOI: 10.5220/0010585400160022
In *Proceedings of the International Scientific and Practical Conference on Sustainable Development of Regional Infrastructure (ISSDRI 2021)*, pages 16-22
ISBN: 978-989-758-519-7

2 MAIN PART

Even nowadays most of the population lives in seismic dangerous territories of the republic in houses of individual construction, which are usually, one-storey buildings (two-storey if there are more than 4 rooms). The houses with dead longitudinal wall which looks at the street and longitudinal wall with door and window openings which makes front yard prevail (Figure 1, 2). That defends internal side from summer heat.

Total population of Uzbekistan now more than 35 mln. and at least third of them living in cities

Basis of the walls made from cobble, burnt brick and monolith concrete. Walls are built without any additional connection with corners and crosses, with obligatory installation of niche with depth up to 50cm which replaces installed furniture in butt-ends of house or in remote longitudinal walls. Laying of the walls with niches is made in one row according to the thickness and is the weakest part of barrier. Connection between longitudinal and cross walls is made by external and cross walls. There are two types of installed roofing, 1st level from loam and haulm or 2nd with garret on wooden roof timbers, which is covered with asbo-slate or iron. Historically there are traditional types of individual (private) houses with walls from local materials.

Figure 1: Longitudinal wall of house from air bricks (photo by P. Burton).

Figure 2: Front yard of house (photo by P.Burton).

Houses with loam and brick walls ("pakhsa") (Figure 3).

Houses with walls from air brick (Figure 4).

Houses with wooden frame that filled with air brick or guvala – clay lumps ("sinch") (Figure 5).

Figure 3: Incomplete houses from loam and bricks (photo by P. Burton).

Figure 4: Incomplete houses from air bricks (photo by P. Burton).

Figure 5: Incomplete houses with wooden frame filled with air bricks or guvala ("sinch") (photo by P. Burton).

Moreover, single buildings from burnt bricks with wood or concrete ceiling can be met. Nowadays, the approximate material structure of the housing in Uzbekistan looks like, (Table 2).

As seen on Table 2 houses from air bricks and loam continue to dominate by quantity in Uzbekistan. Most of the houses of this category in dense populated cities of the republic were built 50-100 years ago. Life times of these housing up to 30 years, but houses/buildings are still in use. As a rule they were built without any project and adhering to any seismic rules. Perhaps, exactly these facts were the reason of numerous destructions of buildings during strong earthquakes which happened in past period.

Table 2: Structure of living fund of the republic according to theirs walls (%).

Fabric/Material of walls	Sum	Urban	Rural area
From burnt brick	17.6	27.1	11.5
From reinforced concrete	13.2	28.0	3.8
From air brick	26.9	23.4	29.1
From loam	42.3	21.5	55.6

For instance, according to results of analysis of consequences of Tashkent earthquake at 1966 it was discovered that among all damaged buildings the individual housing, more than 67%. During Nazarbek earthquake at 1980 this result was more than 80%. During Chatkal earthquake at 1946 damage of the houses of individual building were marked at 6 points intensity by MSK scale.

The existence of intolerable amounts of salty inclusions, soil and atmospheric humidity are among main conditions that may lead to premature failure of the adobe housings. The endurance of the adobe housings is also indirectly affected by uneven base sediment, strong seismic vibrations and construction errors.

The adobe housings have been built for hundreds of years without being reinforced by housetops, plastering, foundation or socle. For example let's name 4-storey adobe housings the "Chodri Hovli", build back in XV century in Khiva (Khorezm) (Akhmedov, 2004). The building is situated on the 8x16m area and is 17m high. The thickness of the "pakhsa" is 80cm at the bottom and 40cm at the top of the building.

The aftermath of Kamashi (Kashkadarya region) earthquake of 20.04.2004 showed that "pakhsa" houses with difference thickness at the bottom and the top of the wall suffered less than the houses with "pakhsa" walls of the same thickness.

The results of the Tashkent (1966) (Raskazovskiy, 1967), Gazli (1976,1984) (Djuraev, 1985), Nazarbek (1980) (Rashidov, 1981) and other earthquakes obviously proved that "pakhsa" houses are destroyed faster and more intensely than others, ranking the last position by its seismic stability (Shamsiev, 1999).

Since the mentioned types of buildings are present in urban zones of the republic let's estimate their condition based on the example of individual housing in Tashkent. The territory of the city is 32850 hectares, from them apartments are on 15570 hectares (47,4%). According to the diagram of balance of the territory (Figure 6) part of individual buildings is more than 30% of the city territory, of which 20% are from air brick, 7 % are from burnt brick and 3% are from “sinch”/”pakhsa”.

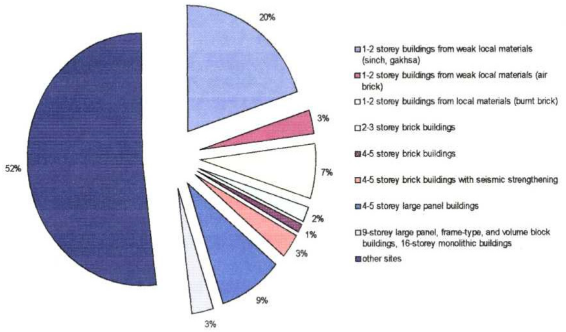

Figure 6: Various types of residential buildings.

We localize buildings in 7-8 and 9 point seismic intensity zones. In Table 3 we show the quantity of traditional 1-2 storey buildings of Shayhontour district of Tashkent before the earthquake between 26.04.1966 and 01.01.2001.

Before 1966 only 9 % of individual houses in this district were from burnt brick, 33,7 % of houses were from air brick, 30,3 % - had wood ceiling with loam and air brick. By 2001 we see a sharp increase in (4 times) houses from burnt brick and decreasing quantity of houses from “pakhsa” and wood ceiling as shown in 2nd part of the Table 3.

Table 3: Quantity of traditional residential structures according to their walls (sum and percentage).

Period	Sum	One storey	Two storey	Burnt brick	Air brick	Pahsa	Sinch
1966	5948 100%	5832 98.1%	114 1.9%	528 9%	2008 33.7%	1495 25%	1801 30.3%
2001	10115 100%	7786 72%	2329 23%	37.31 35.2%	3221 31.8%	1598 15.6%	1679 16.4%

The percentage distribution by total area is:

- 12 % of the whole territory built before 1948;
- 18 % before 1966;
- 70 % before 2000;

The Figure 7 shows graphs of allocation of damageability level for 1-2 storey individual buildings during the earthquake in 1966.

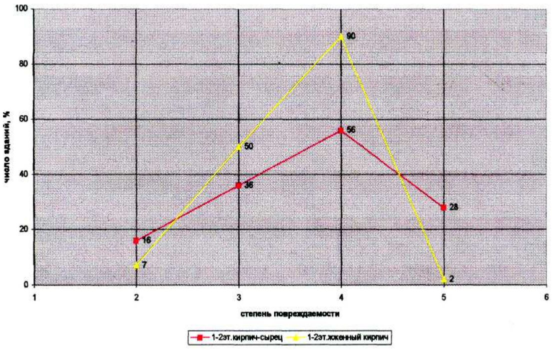

Figure 7: This caption has more than one line so it has to be set to justify.

From 682 inspected 1-2 storey houses of air bricks: 198 (28%) had fallen walls, 380 (56%) had huge cracks and fallen components and 104 (16%) had small cracks which were equal to 2.4 and 5 point level of damage. Out of 1251 objects from air bricks, the cracks were in just 19 cases (1.4%). Big cracks and fall of components happened in 1126 objects (90%). In 88 objects perforated cracks vertical, horizontal and “X” shape (7.6%) were detected. The level of damage was grouped according to the next characteristics:

1st level – well visible cracks by contour of house partition and plaster of ceilings, vertical cracks in places of coupling of walls and in places of weakened overlay by ventilation and smoke channels, channels for forming electric wiring, horizontal cracks in walls at the level of crosspiece and window-sill, cracks in frame walls, in places frame elements, width of cracks is 0.5mm. Horizontal and slanting cracks in smoke pipes and under bridle prop;

2nd level – crumbling and fall of plaster of walls and ceilings, partial collapse of laying of house partitions and modelled ledges, sloping and crossing cracks in partitions, bearing wall, damaging of laying sections of walls in places of relying beam of partitions vertical and transparent horizontal cracks in places of coupling of walls and from corner of apertures, partial collapse and fulfillment of frame, exfoliation and fall out of the parts of loam walls from "pakhsa", appearance of perforating vertical cracks with width of 2-5mm, partial collapse of pipes;

3rd level – laying exfoliation of brick partitions, total fall of overlay, modelled cornice and fulfillment of frame, transparent, bended and "X" shaped cracks up to 4-5mm. in walls, displacement and partial collapse of under roof timbers columns and stuffed aperture. Numerous sloping, transparent and horizontal cracks in embrasure and upper embrasure sections of walls with crosspiece movement and laying, total separation of walls sections vertically, movement of beam partition, "X" shape diagonal cracks in remote walls, separation of external walls from internal and movement of corner sites of walls, total broke of pipes, width of cracks in main constructions from 2-3 to 15-20mm;

4th level – total collapse of partitions, partial collapse of carrier and external carrier walls, break of aseismic belts, significant movement and partial collapse of partition beams;

5th level – collapse of single parts and the whole building.

Researches on these damages of one and two storey houses showed that houses from air brick, adobe blocks, "pakhsa" at 6 point earthquake by MSK scale in most cases get 2nd level of damage, and at 7 point earthquake completely lose their carrying ability.

However, if historically developed building technologies are saved and constructive arrangements during building the foundation, these houses stand seismic impact the intensity of 7 and sometimes 8 points ("sinch").

In Table 4 the results of the analysis and estimation of consequences of earthquakes according to typical damages which range within 1–5 degrees and the experience of building houses from local materials in the private sector are presented.

Table 4: Vulnerability of individual houses from local materials.

Type of individual houses	Level of vulnerability in intensity of an earthquake		
	7 points	8 points	9 points
I.	3-4	4-5	5
II.	2-3	4-5	5
III.	0-1	1-2	5-3

The vulnerability curve (Figure 8) based on the data on the Table 4 (Shamsiev, 1999, Akhmedov, 2006) are provided here.

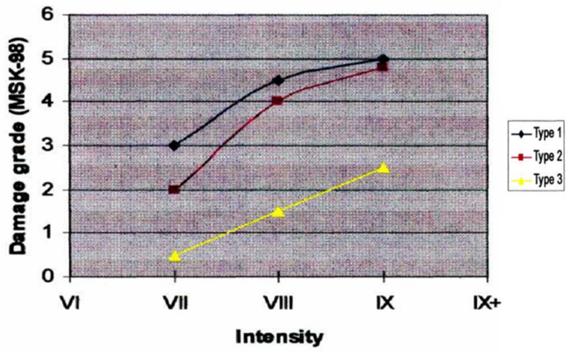

Figure 8: Vulnerability curves for residential houses from: 1 – Building of "pakhsa" type, 2 – Adobe buildings, 3 – Building with a wooden frame of a "sinch" type.

3 DISCISSION

The principal seismic design philosophy for repair and strengthening of structures are developed in some works and projects for different regions an as rule for RC buildings (Necevska-Cvetanovska, 2012), (Apostolska, 2020), etc. Asian traditional housing investigated widely (Tolles, 2002), (Shrestha, 2012), (Arya, 2000), (Ishiyama, 2018), etc. and proposed different path for solving strengthening problems. But for Central Asian traditional housing these approaches are not applicable.

Results of investigation and visual observation of post event situation in Uzbekistan can be described as regional results (Razakov, 2002). In some cases these results can be expanded for neighbouring regions.

Local material's using and traditional housing are reality and have to be taken into account. Investigation of housing from different types of traditional materials can give path for improving by using available approaches (Akhmedov, 2005).

4 CONCLUSIONS AND RECOMMENDATIONS

According to analysis expected the next results:

- structures from burnt bricks which were built by using aseismic measures and building codes, during strong earthquake will take only inconsiderable damages. To provide for seismic stability for houses from burnt brick the buildings in Uzbekistan are built in compliance with republican norms "KMK-2.01.03-96 – Building in seismic zones";

- residence from “sinch” will stand at earthquake with intensity of 8 points and will not collapse;
- houses from air bricks and “pakhsa” will collapse (destroyed). In order to enforce “pakhsa” houses during construction, first of all one should consider the historical experience of technology of clay preparation and keep the order of erecting the walls, secondly reinforce by laying rice straw reed stalks wooden chips or metallic net between the layers of “pakhsa”. These materials if correctly applied, ensure solidity of the walls, especially at conjugation points.

The vertical reinforcement of conjugation points with reinforced concrete mandrils, fitments of various classes, cement filled pipes are also used in so types of buildings nowadays. In all cases the elements of reinforcement at the overlaying layer are hardwired, creating a hard disk, ensuring the solidity of the whole construction. The idea of this method is that under seismic impact, the significant part of the load falls onto the reinforcement elements while the function of the building’s deformation tends to the function of the frame structure.

Another very efficient way of increasing the stability of “pakhsa” houses is the method of dispersed clay reinforcement with waste from carpet or rubber production and other fibrous materials which could increase the solidity of carrying elements.

The existence of the organized drainage system plays an important role in ensuring the solidity of the walls. Without a proper drainage system the precipitation affects the lower part of the walls and leads to erosion. In order to prevent such behavior we recommend plastering the cement solution onto the metallic net and covering it with water resistant paints on the plinth of the wall.

In order to reinforce the seismic stability of the air brick houses one can use the same building rules as for the “pakhsa” houses. Additionally we can recommend using the burnt bricks with sand-lime or complex solution in the most important parts of the construction such as socle, points of wall conjugation, overlay level, piers and jumpers, doorways etc.

During the construction of the air bricks houses it is recommended to use light materials in overlay and housetop elements in order to decrease the inertial load under the earthquakes.

The cheapest way to increase the flexural stiffness of the air brick walls is to use the pilaster-walls in the conjugation points. The “pakhsa” houses from air brick should not be more than one storey high. The minimum requirement to this type of houses is building the seismic belts at the overlay levels.

There are several special requirements to the foundation of the individual houses:

The depth of the foundation should be minimum 0,6m;

The width of the foundation should exceed the lower part of the brickwork by 10cm;

The part of the foundation above the ground should be minimum 0,4m;

If built on the weak soil, using the minimum 4 fittings of A11 or A1 class and wiring them with clamps from rod with diameter of 6mm and 0.7m increment;

After making the ditch for the foundation the ground requires packing in order to achieve the desired carrying capacity;

In sites close to ground water it is necessary to do the hydro isolation procedure of the foundation;

In sites where ground water may contain aggressive chemical elements we recommend using the special types of cement;

During the process of laying the foundation consider the fitting protrusions from the foundation which should be welded with reinforcement elements in the body of the foundation.

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