Classification of residential buildings made of local materials in the Kyrgyz Republic and the results of experiments on them

Zhanybek Mamatov [1,*], *Yzat* Sydykov[1], and *Samagan* Mamatov[1]

[1]Kyrgyz State Technical University named after I. Razzakov, Department "Design, construction of buildings and earthquake engineering",*720020* Bishkek, Kyrgyz Republic

Abstract. This article discusses the classification of houses built of local materials, taking into account the regional specifics of the Kyrgyz Republic and based on the analysis and generalization of the practice in the Central Asian region. Experimental and theoretical studies were conducted on the classified types, based on the results of which a rating was made on the economic component, construction technology and seismic resistance.

Key words: classification, simulation, experiment, local materials, model, wooden and concrete framework.

1 Introduction

The main part of the territory of the Kyrgyz Republic is located in the seismically active zone. Such location creates certain risks when buildings and structures may be affected by seismic impacts. Earthquakes occur very frequently in the Kyrgyz Republic. Their intensity can reach 8-9 points or even more. There have been many earthquakes in the Republic in recent times, the consequences of which have been loss of life, loss of shelter and huge material losses. The high seismicity of the territory imposes special requirements on the construction industry of the republic; the development and implementation of long-term and targeted State policy is necessary to increase the seismic resistance of existing and newly constructed buildings and structures [1].

More than 65 % of the population of the Kyrgyz Republic live in rural areas, where 90 % of the residential houses were built and are still being built with local materials. It should be mentioned that construction of individual residential houses is traditionally made of clay materials not only in rural areas but also in the Bishkek and Osh cities.

Depending on the region, certain construction methods have traditionally been established, based on the type of houses construction and on the technology of the production of materials. Therefore, there is a need to develop seismic-resistant structural and planning solutions for residential buildings using local construction materials.

When technical task was developed, it was decided to use simulation as the experimental-theoretical investigation method of the object. It consists of the following operations: construction of model, investigation of model parameters under the given

* Corresponding author: janybek@mail.ru

© The Authors, published by EDP Sciences. This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (https://creativecommons.org/licenses/by/4.0/).

conditions or effects, and transfer of the obtained data to simulated object. For this purpose, the centuries of experience in construction of houses from low-strength materials inherited from our ancestors was studied including earthquake-proof measures as well as reviving the methods and technologies of their construction [2-5]. Houses built from local materials of the Central Asian region [6-11], their constructive solutions and basic structures were studied and generalized, as a result of which they were classified into 4 (four) types, taking into account the regional specifics of the country, and experimental studies were carried out on them. They are classified into 4 (four) types according to the constructive solution and method of erection as follows [12-14]:

1) Houses made of raw bricks or blocks of regular shape;

2) Houses with a wooden frame, built using the "synch" technology;

3) Houses with walls built according to the "Sokmo" technology from clay material or irregularly shaped clay pieces.

4) Houses made of reinforced concrete frame filled clay material.

According to the results of the classification, the direction of mechanical modeling was chosen - research on models process with the purpose of transferring the research results to the full-scale structure. In this case the scale of the model, its elements, the mechanical characteristics of the materials are selected according to certain laws of similarity [15].

2 Results and discussion of experiments

Jointly with BOF “Habitat-Kyrgyzstan” a series of experiments were conducted on the seismic platform in the laboratory «Seismic Construction» of the Kyrgyz Civil Engineering Institute n.a. N. Isanov (KCEI). In this laboratory testing of 4 types of houses was done and comparison between them for seismic resistance was made [15-18]:

№1. In the Kyrgyz Republic, the method of building walls from clay materials using the “sokmo” and “pakhsa” technologies is widespread. For the construction of a clay wall, a specially made formwork 50-60 cm high is used. The laying is similar to that of a raw brick, but the joints are not strong enough. Clay was used in the construction of this type, although in practice the soil extracted from the site or surroundings of the house is most commonly used.

Fig. 1. General view of the model of the house «sokmo» after the experiment

Pakhsa is a 50-60 cm high clay wall, erected in layers with the help of a special formwork. The pre-mixed and seasoned clay mass is mixed with straw and manually formed so-called "gualak" - a round-shaped bar and laid in rows, filling the formwork along its entire perimeter. After one turn of the formwork, a certain amount of time must pass before the bottom layer has time to set. Only when the previous layer of wall can withstand the weight of the next circle, the formwork is placed on it and the process is repeated. As a result of the test, the model of the house collapsed when the seismic platform accelerated at 188 cm/s2, which means that houses built according to the Sokmo type are completely destroyed during a 5-6 magnitude earthquake (Figure 1).

№2. House structure with walls built of raw brick and blocks of correct shape are very often found in the countryside and new buildings in the suburbs of the city of Bishkek.

The peculiarity of this type of wall is that due to the fit of bricks and blocks in the corner joints the walls do not settle.

Masonry of this type is almost the same as brickwork. The wall thickness of raw bricks can be 1; 1.5 or 2 bricks, and from blocks of the correct form - 1 or 1.5 blocks. This type of wall without proper reinforcement is not earthquake resistant and needs to be reinforced. On the seismic platform of KCEI n.a. N. Isanov, we built a scale model of the house and made a relatively simple and inexpensive reinforcement before testing. A feature of this structure is that the walls were reinforced from the inside and outside with a mesh of propylene threads, after which shotcrete is applied to the surface of the wall under high pressure. The results of the experiment on the seismic platform showed that the model of a house built of raw brick with simple reinforcement has a much higher resistance to earthquakes compared to an unreinforced house built using the sokmo technology (Fig. 2).

Fig. 2. General view of the model of the house, made of brick raw, after the experiment

Figure 2 shows the benefits of model enhancement. As a result of the upholstery of the wall with a mesh of polymer threads and the application of shotcrete under high pressure, the adhesion of the mortar to the surface improves. With the acceleration of the seismic platform, corresponding to a 6–7 magnitude earthquake, the plaster remained stuck to the wall and did not fall off, which proves its relative seismic resistance.

№3. Houses with a wooden frame and filled with of clay materials, built using the "synch" technology most common in the Batken region of the Kyrgyz Republic and in the border regions of Tajikistan [5, 6, 9-11]. Timber framing is designed to provide dimensional rigidity and stability to the house against the load from the roof, timber ceiling and insulation materials. «Gualyak» is mainly used to fill the frame. Similar to «synch» homes can be recommended as a simple and reliable construction with local materials. Such timber-framed houses can be used as a model house in earthquake-prone areas, as well as housing for victims of natural disasters. The supporting pillars of frames made of sawn timber should have transverse dimensions of 100x50 mm, or Ø60-80 mm, braces - 50x30 mm, and the bed - 150x50 mm or 100x100 mm (Fig. 3).

Fig. 3. The process of construction of a model house of wooden frame "synch".

When filling the frame, it is necessary to ferment (real) clay to prepare shuttering the right size, add clay, various additives, such as straw, pour the dough around the perimeter, tightly tamping. When filling the wall, wait, let the clay dry and solidify the solution to a certain extent. The houses with wooden frame proved to be very resistant to earthquake compared to other constructions, and it is the houses of such construction that are recommended to be built in earthquake-prone areas. An external examination of the house model after the experiment showed that when the seismic platform accelerated, corresponding to a 7.8 magnitude earthquake, the clay filling collapsed, but the wooden frame remained intact (Fig. 4).

Fig. 4. General view of the model house of «synch» after the experiment.

It should be noted that in the event of severe earthquakes, these houses do not have the possibility of tragic consequences, and the collapsed filling is not difficult to recover in the future. Another factor that should be recalled - parts of houses, such as the foundation and wooden supports and the roof must be joined together and work as one.

Houses of this type are built on a poor foundation, which is laid out of rubble stone on clay mortar, and there is not even a bunch between the foundation and the frame. Therefore, the foundation must be made of concrete and connected to a wooden frame. In other words, when pouring the foundation into the formwork, it is necessary to install an embedded part in the form of a wire Ø 6 mm, with an outlet length of 0.5 m, in increments of no more than 1 meter, the more often, the better, and the beam laid on the foundation must be fixed with this wire. To fix in this way, the wire can be replaced with anchor bolts M 10mm-12mm (Fig. 3).

№4. The house of «reinforced concrete frame» with the filling of the raw bricks mainly are used in new built quarters around the city of Bishkek and in other regions. In the construction of houses of such construction, first of all, when the foundation is filled with concrete, it is necessary to lay reinforcement upright columns at the corners by four rods in each corner, in the openings of doors and windows (two bars). Secondly, at the intersections of the walls where there is a switch-reinforced, it should continue to the level beams. At the same time, every 60 cm in height, at least two reinforcements should go out at the junction of the supports with the wall. Thirdly, set the formwork, in the soaked clay should be added straw, and lay out of this clay-straw mixture around the perimeter of the formwork one row of wall height of 60 cm. Then, reinforcement grids are placed over the first row, which should be tied to the reinforcing bars released from the supports, then the formwork is repositioned, and thus the process of erecting the wall is repeated until the level of the transom. On top of the reinforced concrete supports and the wall being erected, install a reinforced concrete annular belt, which will perform the functions of a seismic belt. Then, insert the reinforcement protruding from the foundation along the edges of the door and window openings into the annular belt and tie it, install the formwork and pour it with concrete (Fig. 5). This element is called a monolithic or reinforced concrete core.

Fig. 5. The process of construction of model homes from the «reinforced concrete frame».

The results of the experiments show that when the seismic platform corresponding to a 7-8 point earthquake accelerates, in a house built in compliance with all building technologies and construction methods, only cracks appear in the plaster of the house and at the junctions of adobe walls with reinforced concrete elements at the level of window sills and jumpers (Fig. 6) [6].

Obviously, such a house construction is resistant to earthquakes, compared to the other listed three types of structures. Houses with reinforced concrete supports are much durable than houses made of the clay wall blocks. This fact must always be taken into account. For this purpose, horizontal grids linked to rods from reinforced concrete columns should be laid in the corners of the walls. If the proposed technology will not be respected, houses will not be able to withstand strong earthquakes.

Fig 6. A general view of the "reinforced concrete frame" model of the house, after the experiment.

Of course, there are other technologies to build buildings. For example, to erect walls with gaps at corners and intersections of walls for further filling of concrete columns and cores, and only then to install concrete elements. If this method is used, at the intersections of the grid left in the corners after 60 cm of the height of the wall, reliable connection shall be ensured by the concrete filling of the supports together with the grid protruding from the wall. In practice, in new built quarters around the city of Bishkek, it is common to have houses with reinforced concrete supports, the gaps between which are filled with large raw blocks. Construction standards are not fully complied in such cases and the earthquake resistance of such buildings is hardly foreseeable. There are also houses with a horizontal seismic belt, but without vertical columns. It is an obvious, flagrant violation and a waste of resources. The main components of seismic protection are the three main parts of the building (foundations, walls and roof), which must be bond in order to function as a unit during an earthquake. Poorly built seismic belt may even exacerbate the devastating effect of the earthquake. There are also buildings that, with columns, cores, and seismic belts, with low concrete quality and too thin rebar, cannot ensure the building's earthquake resistance. Therefore, developers should apply to architectural authorities and relevant design organizations for a detailed project, and in construction should strictly comply with design requirements.

3 Conclusion

A comparative analysis of the results of experimental studies of the presented buildings made it possible to draw up an objective picture of the preference for their seismic

resistance, taking into account the economic component, construction technology and seismic resistance:

-in the first place - houses with "reinforced concrete frame" - the frame of houses of such structure will assume all the burden if the recommended building technologies (techniques) are met.

-in the second place - houses built using “synch” technology, in which all elements interact with each other. Houses of this type are quickly erected compared to others and do not require extra transportation costs, therefore they are recommended for construction in areas prone to earthquakes;

-in the third place - houses made of raw bricks or blocks of the correct form, as well as houses built using the “pahsa” technology, are distinguished by the fact that at the junction of the corners, bricks and blocks are fitted to each other crosswise, thereby not allowing the walls to disperse. At the same time, the stability of bricks far exceeds the same characteristics of other structures made of clay.

-in the fourth place – houses with walls erected from mud-brick material or different ground (clay) pieces of irregular shape.

The reasons for the frequent destruction of such houses are the unbound structure, the absence of antisesmic measures and, of course, the improper exploitation of the houses.

Given that the Kyrgyz Republic is located in a seismically active zone and more than 93 per cent of its area is mountainous, the delivery of materials is a major obstacle. Therefore, we recommend the use of local materials, namely a wooden frame with clay filling or "Synch" constructions, as they are more earthquake resistant. Also, the construction of the houses must be carried out strictly in accordance with the project executed by the authorized project agency. The specific conditions of the construction should be taken into account and acceptance carried out in accordance with the requirements of the construction [17, 19-22].

References

1. State Programme «Seismic Security in the Kyrgyz Republic for 2012-2019» - 523 of 29 August (2011).
2. M.S. Tupolev «Constructions of buildings made of clay and mud brick» / Izd. of the USSR Academy of Architecture, -Moscow, (1944), -**64**.
3. V.A. Anistratov, V.S. Starodubtsev, «How to build a seismic-resistant house» / Frunze, «Kyrgyzstan», (1984), -**72**.
4. A.T. Shapanov, M.N. Tolegenov, Zh. Y. Mamatov, «Design and construction of buildings made of clay in seismic regions» / CGAP Newsletter 3 (21), Bishkek, (2008), **23-28**.
5. Zh.Y. Mamatov, A. U. Chymyrov, «The construction of earthquake-resistant houses with local materials in Kyrgyzstan». Proceedings of the International Forum "Natural disasters and the security of the construction of buildings and structures" / UNECF Committee on Housing and Land Management. - Baku, Azerbaijan, on 16-17 November (2010).
6. Zh.Y. Mamatov, Zh.Sh. Kozhobaev, B.S. Matozimov, B.S. Ordobaev, «Analysis of the results of a series of experiments of low-rise buildings carried out on the seismic platform of the KSUCTA n.a. N. Isanov» / Bulletin of KSUCTA №3, (2013), **219-225**.
7. D.R. Ruziev, «Clay as construction material» / -Dushanbe, (2007), -**75**.
8. D. R. Ruziev, «Use of clay as building material» /UNDP, (2009).

9. S.A. Hakimov, «Technological techniques of antisemitic reinforcement of school buildings» / Manual for builders, -Tashkent, «Extremumpress» (2009), -**65**.
10. T.R. Rashidov, Zh.Y. Mamatov, «Results of the assessment of the degree of seismic damage to private residential developments» / Eurasian Union of Scientists (ЕСУ), №6, (63)/(2019), part 1, -. **33-37**.
11. Zh. Y. Mamatov, Zh. S. Kozhobaev, and others. «About the influence of the directed explosion in construction of GES-2 «Kambar-Ata 2» on buildings and constructions located in its vicinity. / Scienced and new technologiesa/ - BIshkek, № 3 (2010), - **28-34**
12. Zh. Y. Mamatov, «The report on the safety assessment of the visual target preschools in the Batken region» / UNICEF project. - Bishkek, (2011).
13. Zh Y. Mamatov, «To build safty houses with local materials» - Bishkek: Al Salam, "Habitat-Kyrgyzstan" Kayrymduuluk Koomduk Foundation, (2012) - **80**.
14. Zh. Y. Mamatov, «Ways to Build Safe Homes and Reinforce Homes» Textbook, - B., Polygraph album resource, (2017). -**164**.
15. Zh.Y. Mamatov, «Modelling and experimental analysis of residential buildings from local materials» / Science, technology and life-2015. Proceedings of materials the international scientific conference. Czech Republic, Karlovy Vary-Russia, Moscow, 24-25 December (2015), **131-143**.;
16. Zh. Y. Mamatov, «Modelling damage and destruction of low-rise buildings» annual report SRW-superviser. Bishkek, (2019), -**97**.
17. D. A. Pitluik, «Testing of building structures on models». Construction publishing house. Leningrad, (1971). –**160**.
18. B. S. Ordobaev, Zh. Y. Mamatov, K. I. Kenzhetaev, Zh. Sh. Kozhobaev, B. S. Matozimov, B. Orozaliev, «Guidelines for the calculation, design and strengthening of houses of adobe, adobe masonry in seismic regions KR» / Tutorial. - Bishkek, (2011). - **48**.
19. Zh. Y. Mamatov, Zh. S. Kozhobaev, B. S. Matozimov, Destruction of mud houses under seismic loads and identification of the most vulnerable nodes. / -Vestnik KRSU named after. B.N. Eltsin, Tom 17, № 8, -Bishkek, (2017), - **125-129**.
20. SN KR 20-02: 2018. Earthquake engineering. Design standards. - Bishkek: State Agency for Architecture and Construction of the Kyrgyz Republic, (2018). - **131**
21. S.T. Imanbekov, M.M. Deglina, G.V. Kosivzov, S.K. Uranova, Y.I. Khitipov, Guide for the construction of individual houses in earthquake zones./ - Bishkek, Kyrgyz NIINTI (1992), -**67**.
22. S.T. Imanbekov, G.V. Kosivzov, V.N. Troshkin, A.G. Gron, U.T. Begaliev, «Construction of individual dwellings with local materials in the Kyrgyz Republic» / - Bishkek, KNIPS, (2002), -**40**.
23. SN KR 22-01:2018. «Assessment of the earthquake resistance of existing buildings». State agency ASiHKH under the Government of the KR, Bishkek, (2018), **65**