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# LESSONS OF THE LUGOVSKY EARTHQUAKE IN THE REPUBLIC OF KAZAKHSTAN

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## *Abstract*

The introductory part of this work gives a brief description of the recent earthquakes that have occurred in recent years in the Republic of Kazakhstan. The following is more detailed information about the consequences of an earthquake: the scale of destruction, the procedure for dealing with the consequences of an earthquake, methods of strengthening buildings.

*Keywords: earthquake, magnitude of earthquake, intensity of earthquake manifestation, epicenter, ground vibrations, surveys, building reinforcement.*

## Introduction

The territory of the south and south-east of Kazakhstan is one of the most seismic of the Central Asian seismically active east of the Kazakhstan. Over the past three, 120 strong earthquakes have occurred here: Vernenskoye – 7.3 with a magnitude of 1887, Chilikskoye – with a magnitude of 8.3 since 1889, and Keminskoye – with a magnitude of 8.2 since 1911, and the weaker number (5-7 points) is estimated in dozens.

Seismic regions of Kazakhstan occupy about 43% of the total area of the territory of the republic. More than 6 million live here. a person or about 40% of the total Kazakh population of the city. At the same time, the population of the city, in 9 living-2.0 million, is a ball zone. a person (V. G.) in the core. Almaty – 1.85 million people); in the 8-ball zone-1.1 million people; in the 7-ball zone – 2.0 million and 6-ball zone – 1.2 million people.

The earthquake of May 12, 2003 at 01:23 a.m. occurred Destructive local time (on May 12 at 18: 22 GMT) Of the Republic of Kazakhstan in the part west of the territory of the southern (350 km) city of Almaty, east (100 km) of the city. Taraz, point coordinates VS: 42o 52' s.sh., 72o 53' v.d. at the epicenter station of Lugovoye village. According to the data of the engineering seismometric station "Almaty" to the Lugovsky magnet, the earthquakes are M = 5.4 on the Richter scale, the focal depth (different estimates) is from 4 to 8 kom. According to the intensity of the MSK scale of the earthquake at the epicenter of 7-8, the score is 64. For almost 3 to 3 repeated Aftershocks with a ball intensity every day for months.

## 1. Parameters of The Lugovsky earthquake shock

The Lugovsky earthquake occurred on May 23, 2003 at 01:12 local time (May 22 at 18:12 GMT) in the area named after T.Rysukulov, Zhambyl region, in the southern part of the territory of the Republic of Kazakhstan, west (350 km) of Almaty, east (100 km) of Taraz.

According to the Almaty Seismic Observatory, the earthquake was located at a depth of about 14 km near the Lugovaya railway station. The coordinates of the epicenter of the main shock are 42o 52□ north latitude, 72o 53□ east longitude, with a magnitude, M = 5.4 [1].

The epicenter of the earthquake is located on the territory of the Lugovaya station and does not coincide with the position of the epicenter determined by instrumental data. Approximately the epicenter, determined by instrumental data, is located at a distance of 7 km in the direction to the northwest from the center of Lugovaya station. In the epicenter zone, no seismic dislocations were detected on the ground surface during the survey.

According to the network of stations of the Institute of Seismology of the Ministry of Education and Science of the Republic of Kazakhstan, the magnitude of the earthquake was 5.4 with a depth of the hearth (according to various estimates) from 4 to 8 km.

Based on the studies, a preliminary scheme of the isoseist of the Lugovsky earthquake was compiled (see Fig. 1).

Fig. 1. Earthquake isoseist.

Instrumental data on ground fluctuations in the epicentral zone were not obtained, therefore, the intensity of the earthquake manifestation was estimated based on the descriptive part of the MSK-64 seismic scale.

The intensity of the earthquake manifestation in the macroseismic epicenter varies from 7 to 8 points (the assessment was made according to the macroseismic part of the MSK-64 scale) [1].

A preliminary analysis of digital recordings obtained at the station showed that in the first 7 hours after the earthquake, 75 aftershocks occurred in the intensity range of 2-4 points, three of which were noticeable.

The main results of the macroseismic survey are given in Table 1.

Table 1

| **№** | **Name of the locality** | **Earthquake intensity in points** |
|---|---|---|
| 1 | Lugovaya station | 7-8 |
| 2 | Enbekshi<br>village | 7 |
| 3 | village Kyzylsharva | 7 |
| 4 | villageillage Kulan | 6-7 |
| 5 | the village of Karakystak | 6-7 |
| 6 | village Akbulak | 6-7 |
| 7 | Zhalpak saz | 6-7 |
| 8 | village Kazakh village Tasholak | 6 |
| 9 | village | 6 |
| 10 | Military camp | 6 |

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| | | |
|---|---|---|
| 11 | village Zhaksylyk | 6 |
| 12 | the village of Kokdonen | 5-6 |
| 13 | the village of Koragaty | 5-6 |
| 14 | village Karakat | 5-6 |
| 15 | the village of Zhanaturmys | 5-6 |
| ***Note.*** *The table shows data on localities where the earthquake occurred with an intensity of at least 5 points.* | | |

By May 26, the number of aftershocks decreased to 27 per day. The strongest was recorded with an intensity of 4 points on May 26, 2003.

## 1.2. Comparative assessment of earthquake intensity

According to the results of research by the US Geological Survey, in the XX century, the annual purity of earthquakes with $M \geq 8$ (I= 11-12 points) averaged 1 case; $M \geq 7$-7.9 (I=9-10 points) about 20; $M \geq 6$-6.9 (I=7-9 points) – 120; $M \geq 5$-5.9 (I=6-7 points) - 800; $M \geq 3$-4.9 (I=4-6 points) – with more than 50 thousand cases.

Thus, the Lugovsky earthquake with M = 5.4 on a global scale does not belong to the category of rare events. On average, there are 2-3 such earthquakes on earth per day [2].

## 1.3. The number of dead and injured people

The population of the T.Ryskulov district as of January 1, 2003 was 61.5 thousand. Human. The affected area is dominated by a rural population with a low density of 6.8 inhabitants per 1 m2. The district center named after T.Ryskulov is the village of Kulan. On the territory of the district there was 1 settlement district, 13 rural districts, 44 settlements.

As a result of the Lugovsky earthquake, 29 people were injured, including 3 were killed, 10 were hospitalized with injuries of varying severity, 16 received medical assistance on the spot. 20,900 people were left homeless. 18 settlements with a population of 38 thousand people were in the zone of severe destruction [2].

Fig. 2. One of the families affected by the Lugovsky earthquake

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### 1.4. Direct and indirect material damage

The economic damage caused by the earthquake exceeded $ 120 million, of which $ 95 million (78%) - the cost of demolition and new construction and $ 27 million (22%) – the cost of strengthening buildings and repair and restoration work. The elimination of the consequences of the earthquake was carried out by the own forces of the Republic of Kazakhstan.

The demolition of such houses and the construction of earthquake-resistant ones will lead to large material costs. It is more expedient to strengthen the houses of this design, as can be seen from the example of the Lugovsky earthquake. Economic analysis shows that the construction of a new house that meets the requirements of the norms costs about $ 20,000, strengthening the affected house – $ 5,000. In addition, the reinforcement of houses significantly reduces the time of housing commissioning [2].

## 2. The causes of the devastating consequences of the Lugovsky earthquake

The territory of the south and south-east of Kazakhstan is one of the most seismically active areas in Central Asia. Three strong earthquakes have occurred here over the past 120 years: Vernenskoye – in 1887 with a magnitude of 7.3, Chilikskoye – in 1889 with a magnitude of 8.3, and Keminskoye – in 1911 with a magnitude of 8.2, and the number of weaker ones (5-7 points) is in the tens. Seismic regions of Kazakhstan occupy about 18% of the total area of the republic. More than 7 million people live here, or about 42% of the total population of Kazakhstan. At the same time, the population living in the 9-ball zone is 2.0 million people (including 1.85 million people in Almaty); in the 8–ball zone - 1.1 million people; in the 7–ball zone - 2.0 million people and the 6–ball zone - 1.2 million people [3].

The first information about strong and destructive earthquakes in this area dates back to ancient times. The collection and systematization of macroseismic data on tangible earthquakes in the Northern Tien Shan began only in the second half of the XIX century, and instrumental observations - since 1927. The depth of the foci of these earthquakes varies from 15 to 40 km. On the modern Map of the general seismic zoning of the territory of Kazakhstan, the 8-point zone extends in a wide band from the village of Merke in the west to the east and northeast. The presence of this zone is historically due to the pleistoseist zone of the Belovodsk earthquake of 1885 (the epicenter of this earthquake was located on the territory of the modern Kyrgyz Republic, east of the village of Kara-Balta). Zhambyl region of Kazakhstan is located in the earthquake hazard zone (Fig. 3). The zone of active seismic impact with an intensity of 7-8 points occupies 21.6% of the total area of the region, where 75% of settlements are located, including the regional center - the city of Taraz with a population of more than 300 thousand people (2003). Seismicity of the territory in the south of the district them. T.Ryskulova of the Zhambyl region, where the Lugovsky earthquake occurred, has been accepted as equal to 8 points on the MSK-64 scale since 1951. After the Zhambyl earthquake of May 10, 1971, which had a local character (M = 5.5), there was no information about noticeable damage to buildings and structures on the territory of the modern T. Ryskulov district [3]. After this earthquake, the seismicity for the territory of Taraz (Dzhambul) in 1971 was changed to 8 points. These changes practically did not affect the territory of the T. Ryskulov district. The southern part of the territory of the district named after T. Ryskulova experienced noticeable concussions in 1992 during the Suusamyr earthquake on the territory of the Kyrgyz Republic (M= 7.7). The intensity of the manifestation of this earthquake on the territory of the T. Ryskulov district did not exceed 8 points and corresponded to the seismicity of the area adopted according to the current Map of the general seismic zoning of the Republic of Kazakhstan [3].

Thus, one of the main reasons for the devastating consequences of the Lugovsky earthquake is the natural realization of the natural potential seismicity of the region into a random event within the maximum previously predicted levels of seismicity and probability.

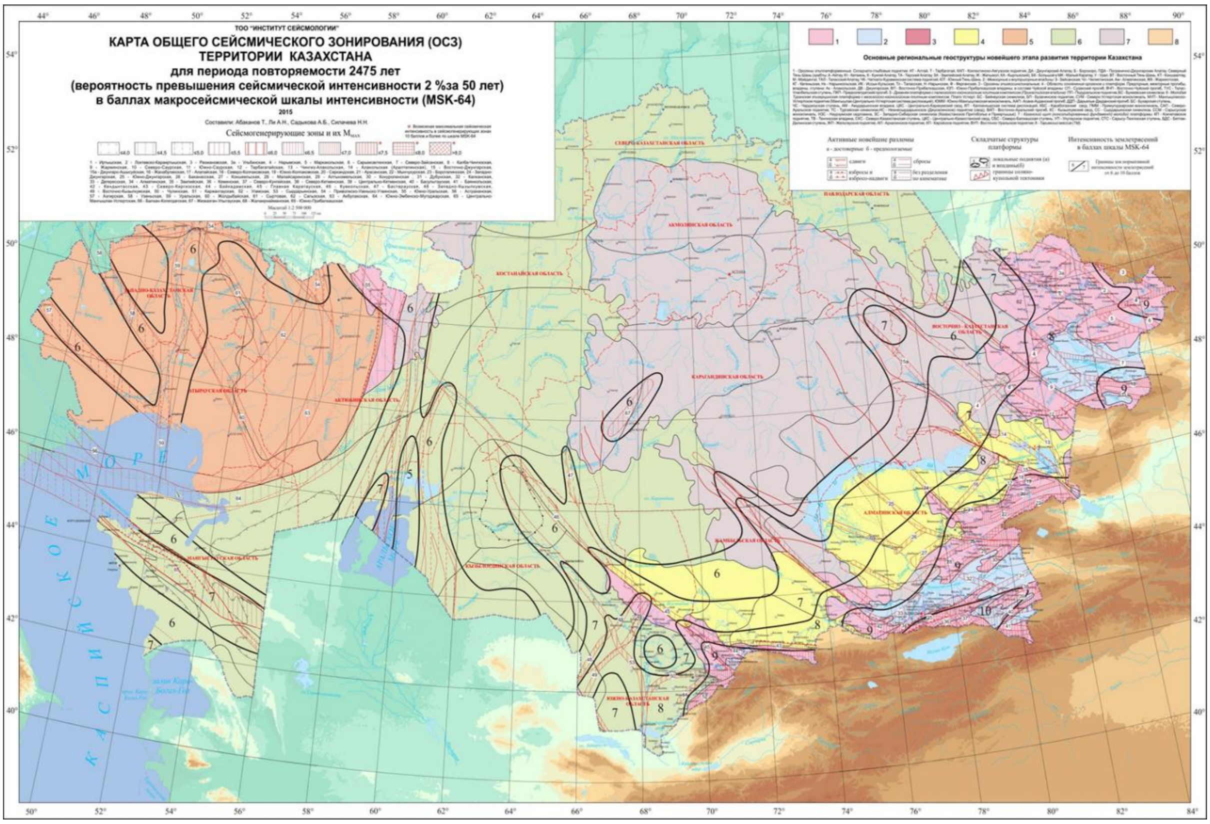

Fig. 3. Map of the general seismic zoning of the Republic of Kazakhstan

## 3. Residential buildings in the earthquake zone

Single-storey residential buildings with load-bearing walls made of adobe masonry predominate in the settlements, the total number of individual residential buildings in the earthquake zone is 8878 buildings, of which 62% are adobe; 26% are brick; 3% are wooden; 2% are made of reinforced concrete structures.

Residential buildings at the Lugovaya station had the greatest degree of damage, where the intensity of the earthquake manifestation on the international scale MSK-64 ranged from 7 to 8 points. On the territory with an earthquake intensity of 7 points (part of the Lugovaya station, the villages of Enbekshi, Kokaryk, Kzylsharua), residential buildings were damaged from 2 to 3 degrees. With an earthquake intensity of 6 to 7 points (the villages of Zhalpaksaz, Kulan, Karakystak, Akbulak), residential buildings were damaged from 2 to 3 degrees. With an earthquake intensity of 6 points (the villages of Kazakh, Tasholak, Zhaksylyk), residential buildings received mainly damage of 2 degrees. With an earthquake intensity of 5 to 6 points (the villages of Kokdonen, Karakat, Zhanaturmys), residential buildings received mainly damage from 1 to 2 degrees.

With an earthquake intensity of 5-6 points, there was serious damage. Almost all houses with adobe masonry walls were damaged at least 2 degrees during the earthquake. Approximately 50% of these houses were damaged from 2 to 3 degrees, and some - 4 and 5 degrees (complete collapse). Damage to adobe houses (see Fig. 4).

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Fig. 4. Destruction of adobe houses as a result of the earthquake on May 23, 2003

Such serious damage to residential buildings with an earthquake intensity of 5-7 points is explained by the low strength of adobe blocks used in construction. The average compressive strength of adobe samples was 3 kg/cm2.

A small group is represented by one, two and three-storey houses with load-bearing external and internal walls made of brickwork and wooden or precast reinforced concrete floors, as well as with walls made of wooden sleepers

The most severe damage was caused to low-rise buildings at Lugovaya station with the maximum intensity of the earthquake manifestation on the MSK-64 scale from 7 to 8 points. At the same time, in buildings with wooden floors, the degree of damage was higher than in buildings with reinforced concrete floors [4].

Houses with wooden floors located in an area with an earthquake intensity on the MSK-64 scale from 7 to 8 points were damaged from 2 to 3 degrees and recommended for strengthening with the transfer to complex structures.  These houses were recommended for demolition.

Large-panel houses are made with one, two and four floors. The structural scheme of the houses is adopted with load-bearing transverse and longitudinal walls made of reinforced concrete panels. The ceilings of four-storey houses are made of panels with a support along the contour.

As a result of the earthquake, all the supporting structures of buildings in this group received minor damage in the form of small cracks in the seams between the floor panels, crumbling in some areas of whitewash and plaster. In general, the load-bearing structures of large-panel buildings have satisfactorily endured earthquakes, and does not require reinforcement. The partitions were damaged up to 2 degrees on the MSK-64 scale and recommended for strengthening.

### 3.1 Recommendations for strengthening residential buildings

In the process of eliminating the consequences of the earthquake, the construction organizations of the Republic of Kazakhstan strengthened and repaired 4,756 residential buildings and built 2,563 new houses.

In a two-week period, the KazNIISA Institute developed ways to strengthen buildings. For the first time in our practice, a massive reinforcement of adobe houses was carried out [5].

To obtain complex structures, it was recommended to strengthen all bearing walls of buildings with double-sided vertical layers of high-strength reinforced plaster on a cement-sand mortar grade of at least 150 or shotcrete and a thickness of at least 40 mm along reinforcing wire mesh with a diameter of at least 5 mm of class Bp-I (see Fig. 5).

To prevent wall breaks in at the floor level, flat reinforcement frames were installed on both sides of the walls, replacing antiseismic belts.

The flat frames were made of two longitudinal reinforcing rods Ø12 mm of class A-III and transverse rods Æ6 mm of class AI with a step of 300 mm. For anchoring in the antiseismic belt, the floor beams were connected to flat frames with clamps made of reinforcement rods of A6 mm class AI.

Note: On the grid plan, the gains are shown by dotted lines.

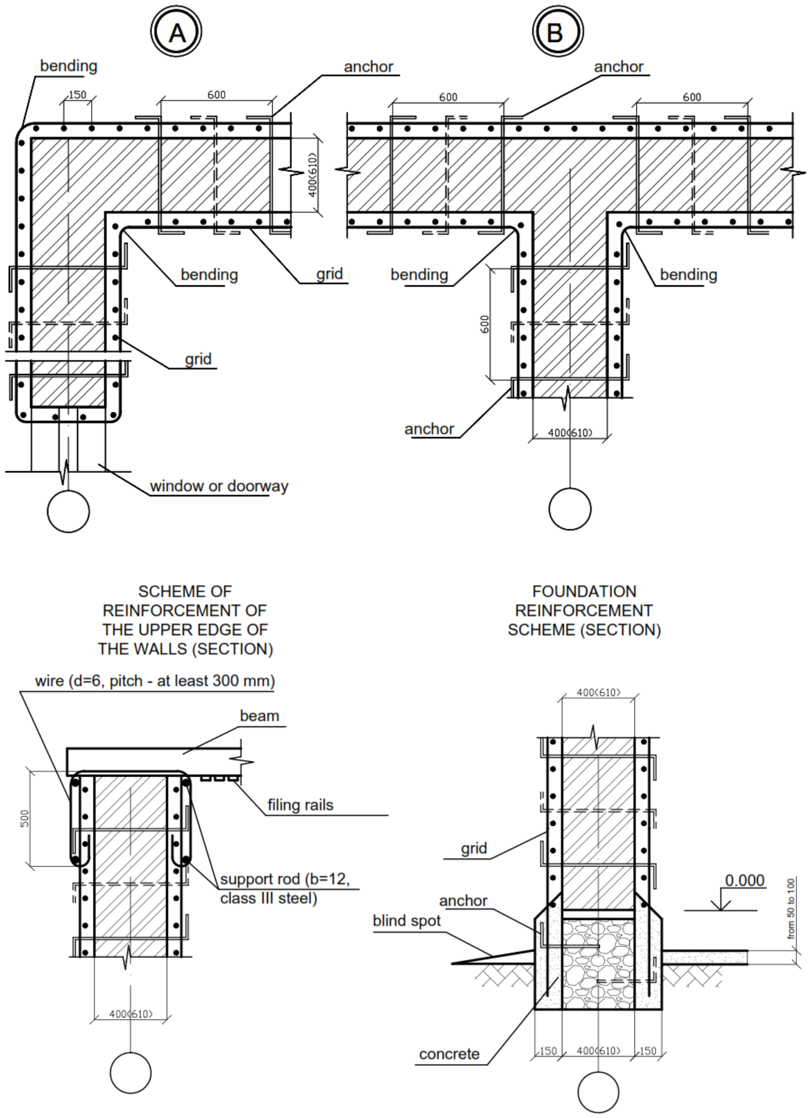

Fig. 5. Reinforcement of adobe walls and foundations with reinforcing grids in a layer of high-strength mortar.

The rubble stone foundations were also reinforced on both sides with reinforcing grids in a layer of fine-grained concrete of class at least B12.5 and with a thickness of at least 100 mm. The grids were made of reinforcement rods Ø8 mm of class A-III with cell sizes 200x200 mm [5].

With the proposed method of reinforcement, a rigid spatial system was obtained, consisting of reinforced external and internal walls reinforced with double-sided vertical layers of high-strength reinforced plaster. In order to evaluate the effectiveness of the proposed reinforcement method, instrumental studies of the dynamic characteristics (periods and forms of natural oscillations, logarithmic decrements) of houses with adobe walls, brickwork before and after reinforcement and the

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actual strength of cement-sand plaster reinforcement were carried out. Dynamic tests showed that the periods of natural oscillations of adobe houses with damage of 3 degrees before amplification were equal, about 0.16 seconds. The periods of natural oscillations of adobe houses after amplification were equal to 0.04 seconds. The rigidity of adobe houses after reinforcement increased by an average of 16 times compared to the rigidity of non-reinforced houses (Fig.6.).

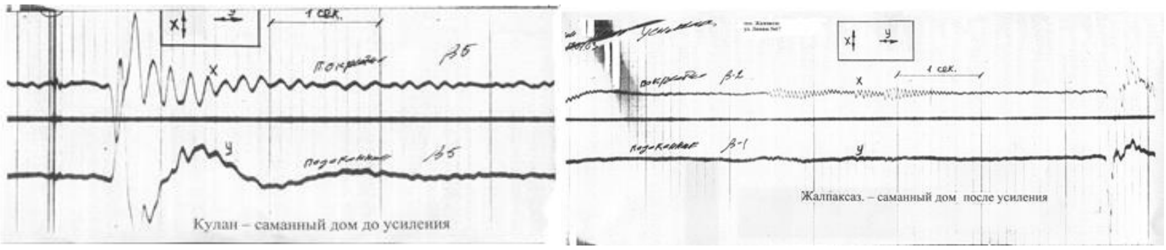

Fig.6. Periods of natural oscillations of adobe houses before and after strengthening

## 4. School buildings

There are 15 schools located on the territory of the earthquake-affected area.

Seven schools are made with load-bearing brick walls. The ceilings in five of them are made of precast reinforced concrete multi-hollow slabs. In two schools, the ceilings are made of wooden structures.

Five schools are made with load-bearing brick walls of complex construction (see Fig.7).

Fig. 7. General view of schools with load-bearing brick walls of complex construction

Three schools are made with a reinforced concrete frame.

One school is made with load-bearing wooden walls and one school is made with load-bearing walls of adobe masonry.

School buildings, which were subjected to seismic impacts of intensity 6-8 points, also received serious damage. Of the fifteen buildings of secondary schools:

Three that did not have antiseismic measures had to be demolished; 3 new schools were erected instead by the first of September.

Twelve, despite the presence of some antiseismic measures in them, had to be strengthened. All these schools were put into operation by the beginning of the school year.

The main causes of damage to school buildings were associated not so much with the intensity of the seismic impacts that took place, as with the poor quality of construction and deviations from design decisions.

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During the examination by the KazNIISSA Institute, the strength of the masonry adhesion was checked in all schools with load-bearing walls made of brickwork. In all academic buildings of schools, the values of the temporary resistance of brickwork Rr varies from 0.3 to 0.7 kg / cm2, which is significantly lower than those established in the norms (at least 1.2 cm2).

### 4.1 Hospital and polyclinic buildings

Hospitals and polyclinics - a total of 18, of which 1 is with load-bearing wooden walls; 1 is with load-bearing adobe walls masonry; 16-with load-bearing brick walls. As well as a large group of administrative buildings, social and cultural facilities, communication companies and hotels.

Within two weeks after the earthquake, the KazNIISSA Institute conducted a detailed survey and developed project documentation to strengthen 15 school buildings. The survey showed that buildings with load-bearing brick walls received severe damage during an earthquake with an intensity of 7 points (see Figure 8). Buildings damaged from 3 to 4 degrees are recommended for demolition. Buildings that have received damage from 2 to 3 degrees are recommended for strengthening.

Fig. 8. Damage to schools with load-bearing brick walls.

The school building in the village of Zhaksylyk with monolithic reinforced concrete frames with external brick walls. The structures of the monolithic reinforced concrete frame were severely damaged at an earthquake intensity of 6 points due to the extremely poor quality of construction (see Fig. 9.

Fig. 9. Damage to the reinforced concrete crossbar in the School building

### 4.2 Recommendations for strengthening public buildings

To ensure the seismic safety of school buildings, the following measures are recommended to strengthen:

- transfer load-bearing walls from non-reinforced brickwork to the category of complex structures. To do this, double-sided reinforcement of all walls with reinforcing grids should be carried out in a layer of high-strength plaster made of cement-sand mortar [5].

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- to reduce the distances between the transverse walls in the compartments of the building, it is necessary to introduce additional (replacing transverse walls) into the existing structural scheme steel reinforcement frames associated with ceilings and wall structures (see Fig.10).

In order to make the proposed reinforcement method effective, instrumental studies of the dynamic characteristics (periods and forms of natural oscillations, logarithmic decrements) of school buildings before and after reinforcement were carried out.

The periods of natural oscillations of buildings with brick walls before amplification were equal, about 0.45 seconds, after amplification decreased, to 0.24 seconds. Accordingly, the rigidity of buildings after reinforcement increased 3 times.

Fig. 10. Reinforcement of brick walls with reinforcement grids

Brick walls and partitions received serious damage, which absorbed the bulk of the seismic load, which saved the building from collapse. It is recommended to strengthen the buildings: a) strengthen the columns of the transverse frames of the frame with clips made of steel corners; b) strengthen the crossbars of the frames by increasing the compressed zones of the crossbar, with the device in the upper zone of additional reinforcing rods and grids (see Fig. 11).

Fig. 11. Reinforcement of columns and beams with steel clips

Dynamic tests showed that the periods of natural oscillations of frame buildings before amplification were about 0.34 seconds, and after amplification about 0.2 seconds. The rigidity of the building after reinforcement increased by an average of 3 times compared to the rigidity before reinforcement [5].

In the process of eliminating the consequences of the earthquake, 12 schools were strengthened and repaired by construction organizations. 1 district hospital was demolished, 1 new hospital was built, 17 hospitals were strengthened. And all administrative buildings were subject to strengthening.

All schools were completed by the first of September.

The general management of survey and design work was carried out by the head research Institute of the Republic of Kazakhstan in the field of earthquake-resistant construction "KazNIISSA".

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In the process of construction by the KazNIISSA Institute, in newly erected houses and in newly built 3 schools with load-bearing walls of brickwork, the strength of the clutch of the masonry was checked for separation along unbound seams in accordance with GOST 24992-81, sustained for at least 7 days.

The tests showed the following results of 0.1 kg/cm2 to 0.4 kg/cm2. The low adhesion strength of the masonry is explained by the violation of the technology of work. The brick was laid without soaking in water, was not cleaned of dust. After testing the masonry for separation, the quality of construction improved for the better. The clutch strength of the masonry for separation was 1.2 kg/cm2 to 2.4 kg/cm2.

The construction of new residential buildings and the reinforcement of existing residential buildings was completed by the end of 2003.

## Conclusion

In the process of eliminating the consequences of the earthquake, the technical and economic efficiency of the work on strengthening mass buildings in comparison with new construction has been proven.

In the studied area for a long time, the construction of residential buildings was carried out without any projects and without proper control of the architectural and construction inspection.

The damage from the Lugovsky earthquake could have been significantly less, provided that the basic requirements of the building regulations governing construction in seismic areas were met.

The effectiveness of work on strengthening buildings (especially with load-bearing walls made of adobe masonry) was confirmed experimentally by dynamic tests performed by KazNIISSA for a number of buildings before and after their reinforcement.

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