Relation of dynamic parameters of brick masonry fragment at fracture under static and dynamic loading

D G Kopanitsa[1] and E S Useinov[1]
[1]Tomsk State University of Architecture and Building, Department of Metal and Wooden Structures, Tomsk, 634003, Russia

E-mail: useinov_em@mail.ru

Abstract. The article shows the results of experimental analysis of brick masonry fragments under static and dynamic loading. The measurements of fractures and natural vibration frequencies of samples have been carried out in the course of tests. It has been shown that at appearance of inelastic deformations and cracks, there is a change in natural vibration frequencies, received from the analysis of the corresponding spectra. Comparison of results of experiments of brick masonry fragments, received under action of static and dynamic loads has been carried out.

1. Introduction

Evaluation of analytic models of structures, experiencing the action of seismic load is very complex issue and it is necessary to analyze the results of numerous experiments to find the solution. Study of brick buildings is complicated because of the complexity of building behavior modeling under seismic load. Along with tests using dynamic machines, experimental studies on static loads impacts created by powerful jacks shifting the building footing according to the set scheme are conducted. The dynamic effect is achieved by the load loss. The seed of loading of building structure is relatively low. Measurements show that earthquake and overloads arising in building structures do not exceed 2g [6]. Low loading speeds slightly influence material properties; therefore the results of static experimentation are quite acceptable for justification of analytic models.

Detailed study of the brick building behavior at destruction can be simplified by considering the operation of its models. Relatively full scope of information on the operation of brick structures can be obtained by studying fragments of the building or its models. It has been established by M. Dzhabarov that decrease in natural vibration frequency of a wall fragment to 62% indicates its fracture [1]. In order to study change of dynamic parameters of brick masonry in the process of fracture, experimental investigation of the brick masonry fragments, described below, has been conducted.

2. Experimental investigation

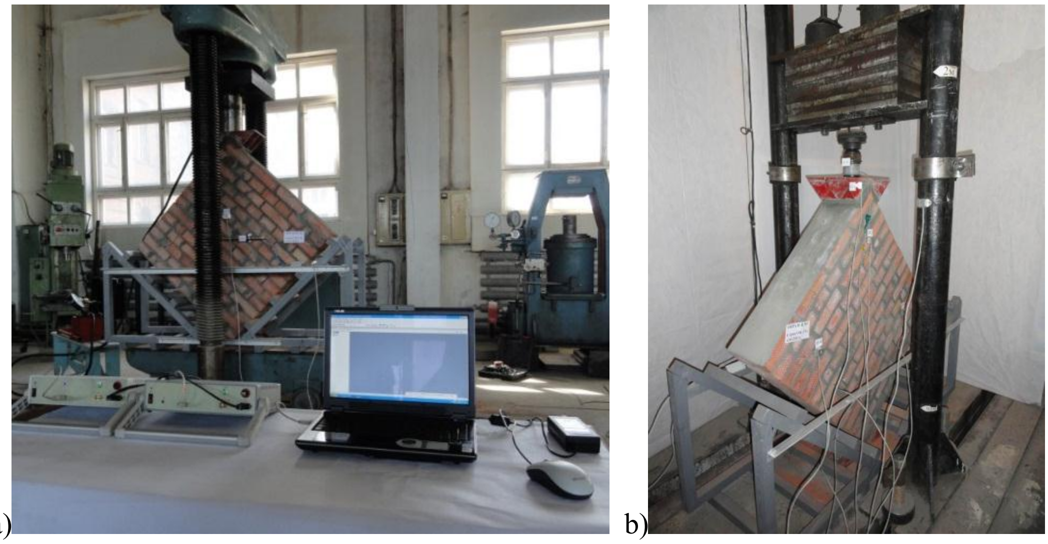
For carrying out experiments the scheme with cross loading has been chosen. Such loading corresponds to the third stage of deformation of wall partition under action of horizontal component from seismic load causing masonry fracture in its plane. Sample fracture accrues under action of the main tensile stress.

Samples were obtained in laboratory conditions with chain system of bonding by the bricklayer with secondary qualification from the solid ordinary clay brick of M100 type and masonry mortar of M75 type.

4 samples were tested. Two of them were tested for static loading, two - for impact. Comparison of the received results followed the tests.

When conducting experiments on static force the load was applied from top to down along diagonal of the sample, put in load frame section of hydraulic press. Overall observation of tests is shown in Figure 1a. Fractures were measured by dial indicators and linear position sensors. Test of each sample had been carried out for 10 stages. Measurements of natural vibration frequency of sample were carried out while the increase of load at each stage of tests. These measurements allowed showing the influence of damage rate of tested samples on the change of their dynamic parameters.

Dynamic tests of studied samples were carried out on pile driver. Load action was accepted according to the scheme of static tests along a diagonal of sample (Figure 1b). The load on sample was performed by energy of falling weight. The impact accrued to the dynamometer, which was on distributing strongback. The mass of dropped weight was 500 kg, and drop height was ranging from 0,5 to 1,5 m. Series of impacts carried the samples of brick masonry to a limit state. Ultimate failure of samples or crack formation and crack opening more than 5 mm in brick masonry was accepted to a limit state. Measurements of accelerations, speeds and movements were performed during the experiment.



a) b)

Figure 1. Overall view of testing bed: a) tests for action of static load; b) tests for action of dynamic load.

Tests showed that all samples had identical sequence of crack formation and fracture with the appearance of the first crack in the sample center along the pressed diagonal, with further crack opening up to ultimate failure. Similar nature of fracture of masonry and vibrated brickwork panels is established in works [2, 3, 4].

In order to receive information on the behavior of the sample under loading, accelerometer fixing dynamic parameters in two planes on surfaces of brick masonry in direction of sample diagonals was installed. By online measuring results, the chart of accelerations has been plotted (Figure 2). Referring to the chart, it is seen, that brick masonry fracture is accompanied by release of stored energy in the form of accelerations of various intensity [5].

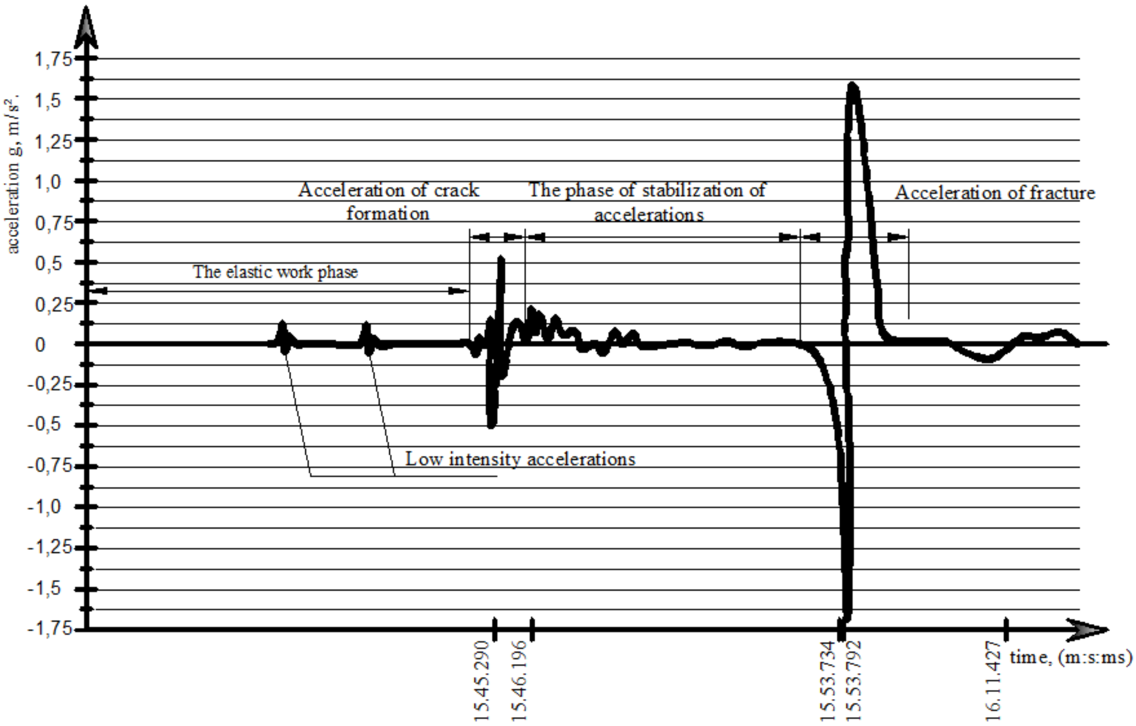


Figure 2. The chart of accelerations at masonry fracture under static load.

With load increase to 0,6 Pfr (Pfr - fracture load), chart shows low intensity accelerations, caused by embrittlement of material and sampling of interwelded pinhole. It didn't cause decrease in natural vibration frequencies of the fragment. The load increase to 0,95 Rfr caused the appearance of inelastic deformations and vertical crack to 2,4 mm with the corresponding rush in accelerations to 0,5 g. The phase of stabilization of accelerations in the process of which there was a redistribution of internal forces in the body of masonry is characterized by the insignificant growth of fractures. The further load increase (to Pfr = 280,0 kN) led to the fast growth of fractures and loss of bearing capacity of the sample. Opening of existing cracks and formation of new ones, at the time of sample fracture, (Figure 3) caused the appearance of accelerations to 1,6 g, with the corresponding decrease in natural frequencies.

Figure 3. Fracture of samples under action of static force.

The measurement of natural vibration frequencies was carried out in the process of load increase at each stage of tests. Oscillations were excited by impact load and fixed by computing and measuring complex by means of accelerometer, installed on a lateral area of sample. The general spectrogram of natural vibration frequencies power of masonry fragment (Figure 4) has been plotted by results of measurements. The first measurement was performed while preparing of test sample. Oscillations were excited by impact load and fixed by computing and measuring complex. The "zero" load step is characterized by the corresponding range of frequencies.

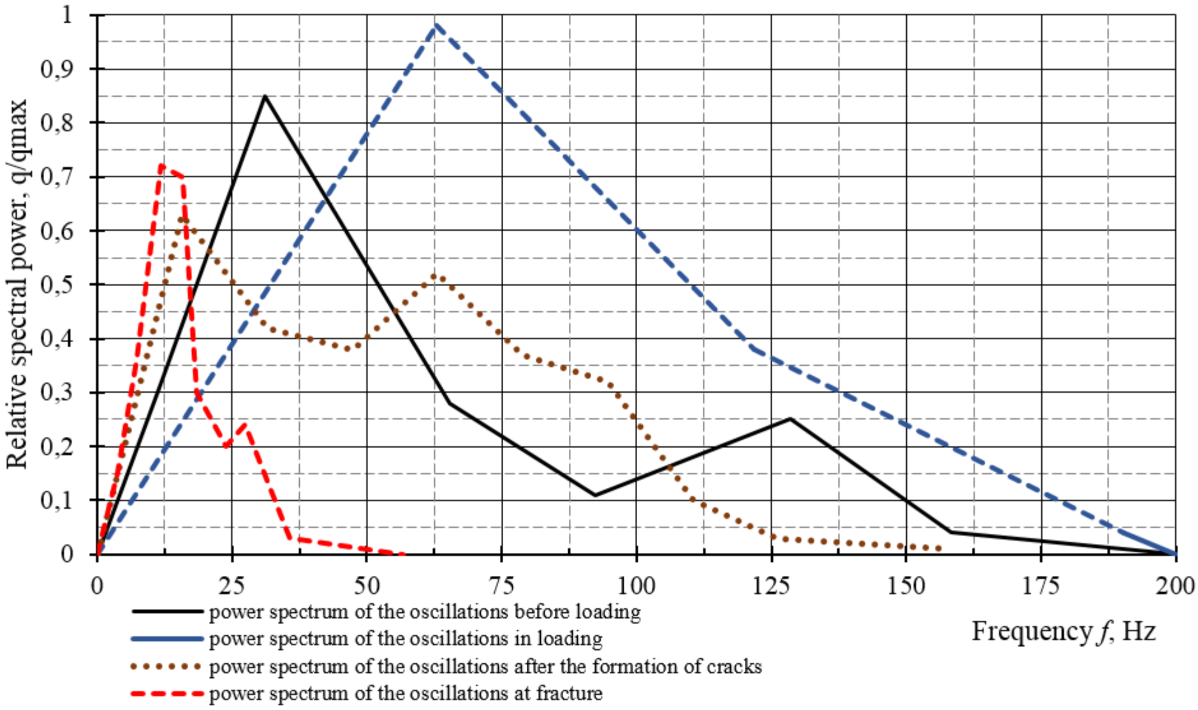


Figure 4. Ranges of vibration power of fragment at test for action of static force.

Natural vibration frequency on the eigentone of not loaded sample is equal to 31,1 Hz. The static load of 32,0 kN applied at the first stage caused double increase in frequency due to inclusion of lower and upper support in work (Figure 4). At load increase to 208,0 kN there were higher frequencies on the accelerogram at almost not changing ranges of natural frequencies.

The load increase to 272,0 kN caused the appearance of inelastic deformations and vertical crack to 2,4 mm with the corresponding range expansion and its shift to the area of low frequencies (Figure 4). At the same time the lower value of frequency decreased from 60 Hz to 15 Hz.

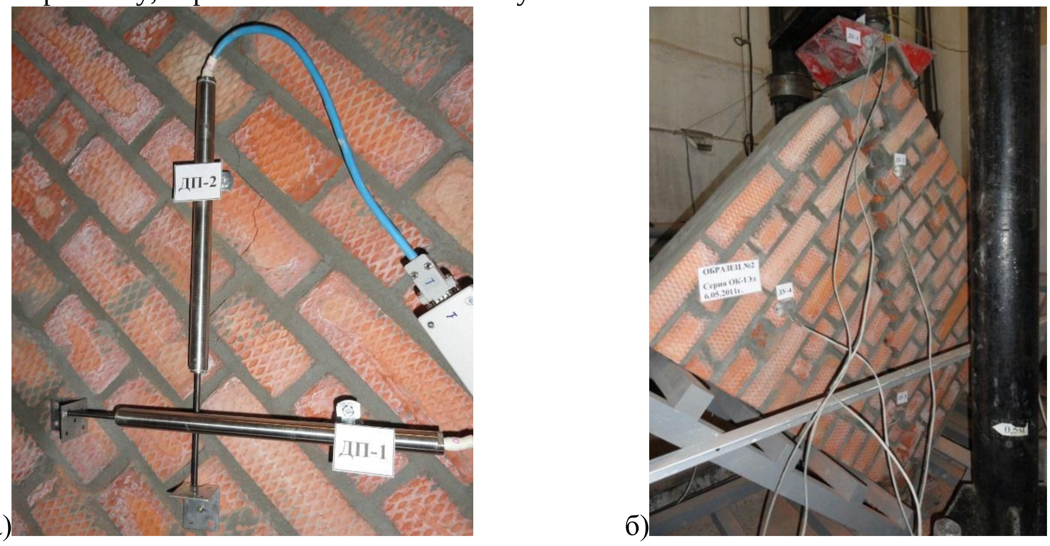
The load increase to 280,8 kN led to sample fracture with the corresponding natural frequency decrease of the sample to 11,1 Hz (Figure 4).

Experimental investigation showed that fracture of masonry fragment under the action of static force can conditionally be divided into 2 stages. The longitudinal crack along the pressed diagonal with 4-x fold decrease in natural vibration frequency on the eigentone was formed at the first stage. At the second stage with an insignificant load growth, there was development of cracks and sample fracture.

Dynamic tests were carried out in two stages for action of two consistently enclosed shock loadings. At the first stage, the impact was created by dropped weight of 500 kg from height of 0,75 m. Duration of load action was of 15 ms with the maximum value of 360,14 kN.

The first impact caused the crack appearance along the pressed diagonal the crack development was recorded by motion sensors installed in center portion of construction (Figure 6a). Crack opening width was of 1,7 mm.

The second impact was carried out on the sample with crack. Damping behavior of masonry promoted the change of the load chart. The load gradient decreased in relation to the first impact by 30%, respectively, exposure duration increased by 30% from 15 to 19 ms.



a) б)

Figure 6. a) crack along the pressed diagonal after the first impact, b) masonry fragment fracture after the second impact

Response of the sample to real load is reflected in charts of accelerations of AS-2 and AS-3 sensors, installed on the main diagonal in direction of real load (Figure 7). The specified sections of charts reflect sample variations at the action of impact load (section I) and after weight rebound (section II).

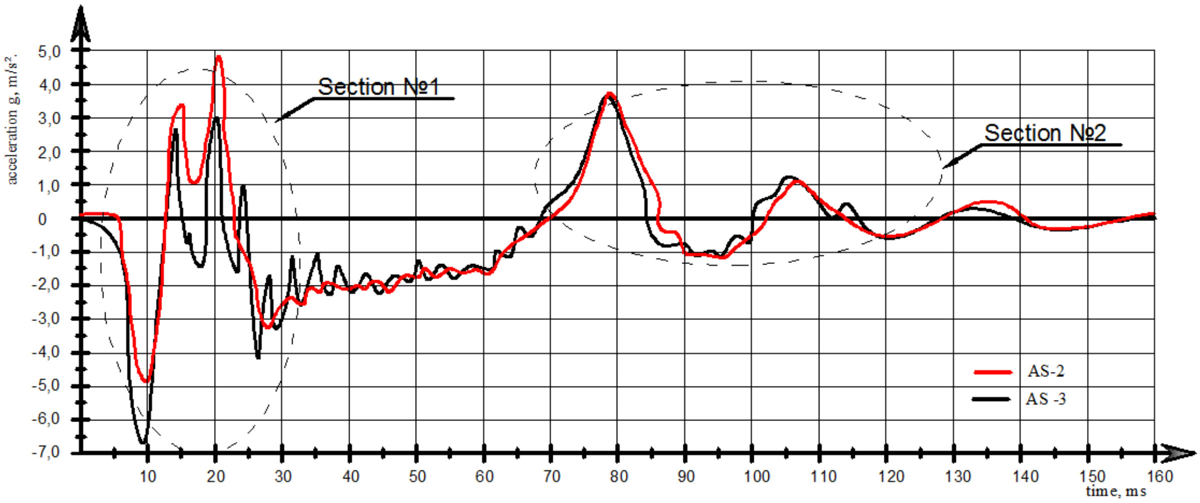


Figure 7. Vertical accelerations of sensor AS-2, AS-3 at the first impact.

Acceleration sensor-2 (AS-2) located closer to strongback showed smaller values of accelerations in comparison with the acceleration sensor-3 (AS-3) located in the zone of structural bearing. Amplitude of accelerations of the above-located sensor AS-2 is of 48,41 m/s^2. Impact action caused the acceleration of structural bearing to 67,4 m/s^2 (AS-3). The corresponding power spectrum of vibrations is shown in Figure 8.

The frequency of 62,34 Hz corresponds to the eigentone of vibrations. Amplitude of vibration spectrum of sensor AS-2 is 1,5 times lower in comparison with amplitude of vibration spectrum of the sensor AS-3. It corresponds to more intensive process of deformation of sample bearing.

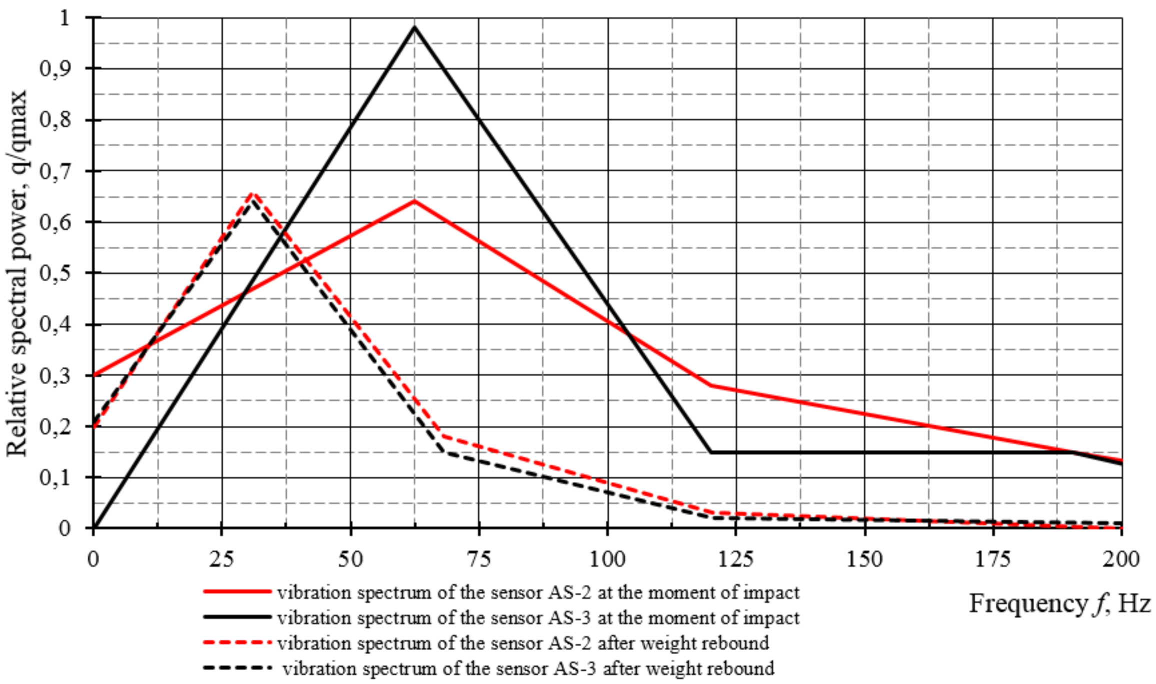


Figure 8. Power spectra of vibrations of sensors AS-2, AS-3 at the first impact.

There were vibrations of load-free construction after weight rebound the second section of the accelerations chart in Figure 7 corresponds to this process. According to power spectrum of vibrations in Figure 8, the frequency of 31,3 Hz corresponds to the eigentone. Decrease in vibration frequencies to 31,3 Hz reflects the cracking in construction body with aligning of power spectra of vibrations of sensors AS-2, AS-3.

Drop height of weight was reduced to 0,5 m at the second stage of tests, the mass of weight of 500 kg was not changed. Load time was of 19 ms with the maximum value of 210,8 kN. Load action on the second impact destroyed the sample in two approximately equal parts (Figure 6). Maximum value of accelerations of 49,3 m/s^2 was recorded in the first vibrations cycle. Action of the second impact was on the right part of fragment separated by crack. According to the power spectrum of vibrations, vibrations of the separated part generally happened on the first and third natural vibration frequency. Base frequency was of 31,11 Hz, and frequency in the third form of vibrations was of 92,7 Hz.

3. Conclusions

Experiments showed that the crack formation in brick masonry both under static and dynamic loading is accompanied by the change of dynamic parameters. Appearance of decompactions and cracks in masonry at load increase is characterized by shift of power spectrum of vibrations to the area of low frequencies.

Dynamic load action at speed up to 5 m/s has no essential influence on the nature of formation of cracks in comparison with crack formation under action of static load.

Sample fracture of brick masonry under action of static force is characterized by three stages. There were microcracks with weak impulses of accelerations to 0,125 m/s^2 at the first stage. The crack of limited length characterized by surge in accelerations to 0,5 m/s^2 appeared at the second stage. Final sample fracture happened when the main crack appeared, it divided the sample into two parts with the corresponding impulse of accelerations with the amplitude of 1,6 m/s^2.

The scheme of sample fracture of brick masonry under action of static force qualitatively coincided with the scheme of sample fracture under action of dynamic load.

Comparison of experimental results showed, that fracture of test samples both under and dynamic load began at the same natural vibration frequency with the bottom tone of 62,84 Hz.

Formation of cracks in brick masonry caused the change of dynamic parameters of samples and was characterized by the shift of power spectrum of vibrations to the area of low frequencies with corresponding decrease in vibration frequency.

Acknowledgement
The research performed with the financial support of the Ministry of Education and Science of the Russian Federation within Governmental Decree No.218 of "Measures of state support for cooperation of Russian higher education institutions and organizations, for implementation of complex projects of high-tech production", integrated project No. 02.G25.31.0022, "Production technologies of energy- and resource-efficient housing of economy class based on the universal framed prefabricated architectural and construction system".

References
[1] Джабаров М 1986 Методы усиления кирпичных зданий пневмобетоном и штукатурными слоями в сейсмических районах: *Диссертация на соискание ученой степени кандидата технических наук* (Душанбе: Академия наук Таджикской ССР Институт сейсмостойкого строительства и сейсмологии)
[2] Кожаринов С В 1980 Исследование деформаций кирпичной кладки при действии горизонтальных нагрузок *Динамика и сейсмостойкость зданий и сооружений* 127-134
[3] Коноводченко В И 1967 Усиление стен кирпичных зданий для повышения их сейсмостойкости *Сейсмостойкость крупнопанельных и каменных зданий* (Москва) 180-186
[4] Тонких Г П, Кабанцев О В и Кошаев В В 2007 Результаты статических испытаний каменной кладки, усиленной железобетонной аппликацией *Вопросы безопасности военной деятельности, создания и функционирования объектов военной инфраструктуры Сб. научных трудов под ред. Латушкина С. Н., Малофеева Ю. В.* (Москва: ЦНИИ) 105-116
[5] Усеинов Э С 24–27 апреля 2012 г. Образование трещин в кирпичной кладке при сжатии// *Труды IX Международной конференции студентов и молодых учёных Перспективы развития фундаментальных наук* (Россия, Томск: Национальный Исследовательский Томский политехнический университет*)* 800-802
[6] Фахриддинов У 2004 Сейсмозащита многоэтажных кирпичных зданий в районах высокой сейсмической опасности: *Диссертация на соискание ученой степени доктора технических наук* (Москва: Московский институт коммунального хозяйства и строительства)