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Experimental Studies of Brick Masonry on Climatic Action Impacts

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Annotation: An increase in the eccentricity of the force due to the deviation of the wall from the temperature difference (e = 2.78 cm) led to a decrease in the bearing capacity of the brickwork.

Key words: Brick, mortar, cement, concrete, weather, construction, deformation, eccentricity.

In the world, the highest average annual temperature is observed in countries located in the southern latitudes of the Earth - Africa, South America and Central Asia. In these countries, during the hottest days of the year, temperatures can rise to 63°C, and on cold days go down to -15°C.

The climate of the territory of the Republic of Uzbekistan, ocated in the Central Asian region is sharply continental with hot summers and cold winters. In the summer season, daytime temperatures rise to +45°C, and night falls to +25...28°C. The relative humidity of the environment, on the contrary, during the day it decreases to 12...17%, and at night it rises to 20...40% [1]. In the summer, on the brick walls of buildings, apart from the ambient temperature, the sun's rays work. From exposure to sunlight, the temperature on the surface of the brickwork reaches up to 50-60°C [2].

Brickwork under these conditions is in a complex stress-strain state. On the surface of the brickwork, oriented in the direction of the sun's rays, deformation from temperature and sunlight will be greater, than on the opposite surface of the masonry. In this case, the masonry is not deformed symmetrically. If the brickwork is free, then the masonry is deformed freely and temperature stresses do not appear in the masonry. When the free deformation of the masonry is limited (it occurs in the walls of multi-storey buildings), temperature stresses arise in the masonry.

Multi-storey brick residential buildings, erected according to a rigid constructive scheme in such difficult conditions, as uneven subsidence of soils and earthquakes, must be resistant to daily and year-round changes in temperature and humidity, as well as the influence of the sun's rays.

Limiting parameters of multi-storey brick buildings, erected in seismic areas according to a rigid design scheme, depending on the seismicity of the area are limited [3]. To increase the limiting parameters of buildings, the brick walls of the building are converted into complex structures by reinforcing them with reinforced concrete elements.

Thus, multi-storey residential brick building is a complex system, under the influence of the environment and force factors. As a result, in the complex structures of a brick building, internal stresses arise in the masonry and reinforcement elements due to the difference in temperature and force deformations.

The influence of climatic impact in the conditions of Samarkand was carried out in the scientific laboratory of the Samarkand State architectural and Civil-Engineering University. Four series of brick samples were made in accordance with the requirements of GOST [4]. Some series of samples were stored in laboratory conditions, and others in open areas exposed to direct sunlight.

According to the results of experimental studies, it was found that direct exposure to sunlight adversely affects the strength of brickwork. The strength of samples exposed to direct sunlight, decreased by 14% compared with the strength of the samples, performed in laboratory conditions.

Direct exposure to sunlight also adversely affects the deformation of the brickwork. As a result of uneven deformation of the brickwork from the ambient temperature and sunlight, the top of the masonry moves, which results in additional eccentricity.

When calculating brick walls exposed to direct sunlight, due to the difference between external and internal temperatures, one should take into account the deviation of the wall towards a lower temperature and, as a result, an increase in the initial eccentricity of the external force.

The displacement of the top of the masonry due to the difference between the external and internal temperatures of the free masonry can be determined by the following formula [5]:

$$\Delta_{kt} = \sum \alpha t_0 \Omega_{\bar{N}} + \sum \frac{\alpha \Delta t}{h} \Omega_{\bar{M}}$$

Here: α - coefficient of linear thermal expansion of brickwork;

$$t_0 = \frac{t_1 + t_2}{2};\text{-}\ \Delta t = t_2 + t_1;\ \ t_2 > t_1;$$

h- wall thickness, mm;

$\Omega_{\bar{N}}$ - longitudinal stress surface N per unit of force;

$\Omega_{\bar{M}}$ - surface of the bending moment M from a unit force

The design eccentricity for calculating the bearing capacity of a brick wall, taking into account the influence of temperature, is determined by the following formula:

$$e = e_0 + \Delta_{kt},$$

Here: $e_0 = M/N$- eccentricity from external load; N – longitudinal force; M- the bending moment.

Below is an example of calculating the bearing capacity of brickwork with and without taking into account the influence of temperatures.

Example: brand of brick M100; brand of solution M25; cross-sectional dimensions of brickwork 380x1160 mm; total longitudinal force acting on brickwork N=3000 kN; long-acting part – Ng=2000 kN; total bending moment M=30.0 kNm; moment from long-acting load Mg=25.0 kNm; temperature: outdoor t1=50 oC; t2=30 oC (figure).

Eccentricities due to external loads: $e_0 = \frac{M}{N} = \frac{30}{3000} = 0,01\ м;$

$$e_{0g} = \frac{M_g}{N_g} = \frac{25}{2000} = 0,0125\ м.$$

Movement of the top of the wall due to temperature differences

$$\Delta_{kt} = 5\times10^{-5}\times40\times3+5\times10^{-5}\times\frac{20}{0,38}4,5 = 0,0178\ м\cdot$$

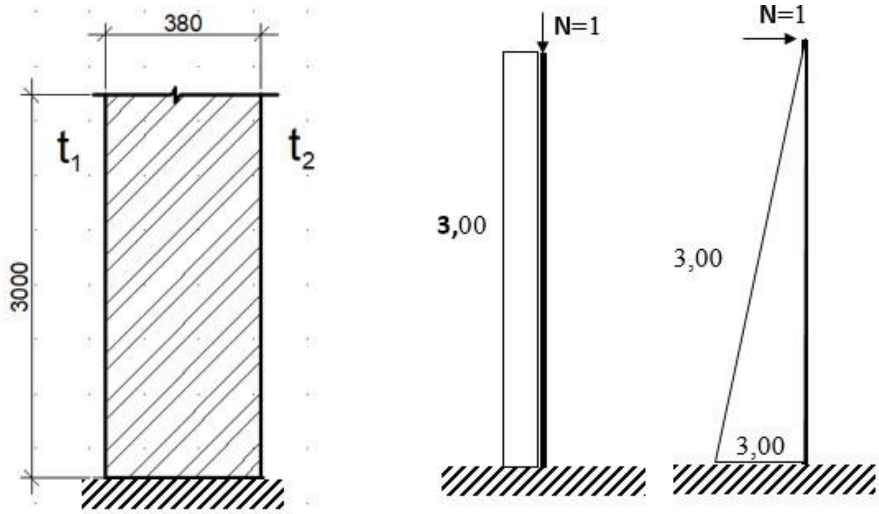

Fig. 1. Brick wall

Eccentricity taking into accounts the deviation of the top of the wall from the action of external load and temperature difference.

$$e = e_0 + \Delta_{kt} = 0,01+0,0178 = 0,0278\ м = 2,78\ см.$$

Given that $\eta = 0$

$$m_g = 1-\eta\frac{N_g}{N}\left(1+\frac{1,2e_g}{h}\right) = 1.$$

For rectangular section $\lambda_h = l_0/h = 300/38 = 7,9$ then $\varphi = 0,92$;

l_0 – estimated length; h - minimum size of a rectangular section.

Height of the compressed zone of the section:

$$h_c = h-2e_0 = 380-2\times27,8 = 352,2\ мм.$$

Flexibility: $\lambda_{hc} = l_0/h_c = 300/35,22 = 8,5$ then $\varphi = 0,91$.

$$\varphi_1 = \frac{\varphi+\varphi_c}{2} = \frac{0,92+0,91}{2} = 0,915.$$

Cross-sectional area of a brick wall:

$$A_c = A\left(1-\frac{2e_0}{h}\right) = 380\times1160\left(1-\frac{2\times2,78}{38}\right) = 376304\ мм^2.$$

The value of ω is determined according to table 19 of the regulatory document [6]. For rectangular section.

$$\omega = \left(1+\frac{e_0}{h}\right) = \left(1+\frac{2,78}{38}\right) = 1,07 < 1,45.$$

Bearing capacity of a brick wall

$N \le k_t m_g \cdot \varphi_1 \cdot R \cdot A_c \omega$ = 0,95·1·0,915·1,3·376304·1,07=

=454999,23 МПа×мм^2 ≈455 кН.

Here: k_t = 0,95 - coefficient taking into account the influence of temperature. If the influence of temperature is not taken into account:

$$e = e_0 = 0{,}01\ м;\ \eta = 0\ и\ m_g = 1.$$

For rectangular section

λ_h=l0/h=300/38=7,9 then φ=0,92.

Height of compressed zone:

$$h_c = h - 2e_0 = 380 - 2\times 10{,}0 = 360{,}0\ мм.$$

Flexibility: λ_{hc}=l_0/h_c=300/36=8,3 then φ=0,91.

$$\varphi_1 = \frac{\varphi + \varphi_c}{2} = \frac{0{,}92 + 0{,}91}{2} = 0{,}915.$$

Cross-sectional area of a brick wall:

$$A_c = A\left(1 - \frac{2e_0}{h}\right) = 380\times 1160\left(1 - \frac{2\times 1}{38}\right) = 417600\ мм^2.$$

$$\omega = \left(1 + \frac{e_0}{h}\right) = \left(1 + \frac{1}{38}\right) = 1{,}02 < 1{,}45.$$

Bearing capacity of a brick wall

$N_u(КМК) \le m_g \cdot \varphi_1 \cdot R \cdot A_c \omega$=1·0,915·1,3·417600·1,02=

=506669 МПа×мм^2 ≈506,7 кН.

Difference:

$$\frac{N_u(КМК) - N_u}{N_u(КМК)}\times 100 = \frac{506{,}7 - 455}{506{,}7}\times 100 = 10{,}2\ \%.$$

High temperatures can reduce the bearing capacity of masonry by up to 10.2%.

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