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Reinforcement of Small-Sized Stone Walls with Prefabric Concrete Cores with Its Preliminary Clutch of Masonry

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ABSTRACT: During Tashkent earthquakes on April 26, 1966, there were many cases of predominant damage to the lightly loaded walls of the upper floors in brick buildings. The same picture was observed in our studies. Lightly loaded piers collapsed at low loads, and piers compression to 3.5-4.0 kg/cm^2 stresses (surcharge 20 tons) increased the bearing capacity of an unreinforced pillar 4 times (from 1.8 to 7.2 tons). Based on these factors, we proposed to carry out an artificial preliminary compression of the walls masonry of the upper floors in buildings, which will increase their seismic resistance.

This compression is technically not a very difficult task. It can be carried out similarly to the known method of prestressing concrete by tensioning reinforcement onto concrete. To do this, you need to anchor the steel ropes in the lower belt and pass them through the pier and the upper seismic belt without sealing. After the masonry has set a given strength, the strands are tightened and anchored on the upper seismic belt, thereby transferring the compression force through the seismic belt to the masonry section located between the two seismic belts.

KEYWORDS: Piers, pre-compression, reinforced concrete cores, reinforcement tension, tie rods, prefabricated cores, strength, surcharge, anti-seismic belts.

1. INTRODUCTION

A multi-storey buildings survey during Tashkent earthquakes on April 26, 1966 showed that the main damage was in the walls of the upper floors of brick buildings. This phenomenon could be explained by the insufficient resistance of the wall masonry to the shear stress during bending (shear). In this case, the initial ones from the established regularities.

$$Q \leq [Q] = R_{cp}\frac{ab}{\mu} \quad \text{и} \quad R_{cp} = \sqrt{R_p\left(R_p + \sigma_o\right)};$$ where:

R_{cp}- is a design resistance of masonry when shearing;

R_p- is a design tensile strength of masonry;

σ_o – is a compressive normal stress;

Q – is a horizontal force.

The walls resistance in its plane can be increased due to R_{cp}, by increasing the values (σ_o), that is, preliminary compression of the masonry. The results of our research show that if the masonry is loaded with a vertical load ((σ_o), then under the action of horizontal loads, the shear resistance increases. Table 1 shows some test results.

Table 1

Sample designs	Surcharge (vertical load) in tons.	Average adhesion of mortar to stone (MPa)	Load in tons at	
			1st crack	destructions
Core walls	3,5	0,158	6,0	10,2
Core walls	20,0	0,158	9,6	15,6
Coreless walls	3,5	0,158	1,2	2,8
Coreless walls	20,0	0,158	5,2	7,2

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Note: *Surcharge (vertical load in tons) 3.5 tons - emitting load of the covering and roof weight of a brick building.*

II. MAIN PART

The positive influence of pre-reduction on the strength of the complex structure is also subject to work [1]. Since the reinforcement of brick walls with reinforced concrete cores for buildings in seismic areas was introduced [2], studies were carried out to create a preliminary compression of masonry together with precast reinforced concrete cores and anti-seismic belts. With insignificant additional costs (placement of the tie through the channels of the cores and their tension on the belts), the shear strength of the masonry can be increased. It remains unknown to determine the prestressing loss in the weight (reinforcement) from shrinkage and creep of masonry.

An experiment was set up to study the possibility and efficiency of creating artificial loading of a complex structure with prefabricated cores similar to the prestressing of reinforced concrete structures with tension of reinforcement on hardened concrete [3].

Compression can be done in several ways. The most acceptable of them are two: steel strands are fixed in the lower seismic belt and passed through the pier into the upper seismic belt. After the masonry has set a given strength, the strands are tensioned and anchored on the upper seismic belt, transferring the compression forces of the complex structure with prefabricated cores through the seismic belt, the strands are passed through specially left holes in the core (Fig. 1).

The issues of stress loss in masonry due to shrinkage and creep have been investigated [4]. The technique used in this work is as follows.

The stress losses in the masonry and the tension straps were determined by examining samples of two types of posts. The first type - the main one - was used to directly measure the masonry and the strands deformations that strain it over time. Since the force in the ties with the shrinkage and creep deformations development in the masonry was applied and the samples were under alternating stress. The series and the number of samples tested are shown in table. 2.

Pre-compression masonry.

Table 2.

Masonry category	Sample group	Number of samples	Tensile strength of masonry at the 28 days, MPa	Loading level, MPa	Tie forces in kN	Strain tension, MPa	Stress in masonry, MPa	Fittings diameter (A-IV)
I	A	3	2,9	0,012	35,6	230	0,375	F-10
	B	3		0,024	71,2	460	0,75	F-14
	A	3	2,1	0,016	35,6	230	0,375	F-10
	B	2		0,030	71,2	460	0,75	F-14
II	V	3		0,040	88,0	440	0,93	F-16
	G	3		0,060	132,0	500	1,39	F-18

The second type of samples was used as a control. One part of these samples was under constant stress - 6 pieces, and the other remained unloaded to reveal the shrinkage of the masonry - 6 pieces. In total, there were 12 samples of I and II masonry categories. The samples were brick pillars bounded above and below by concrete distribution elements. The brickwork height is 104 cm (14 rows of bricks), and the concrete elements are 22 cm, as a normal seismic belt. Samples section is 25x38 (1.0x1.5 bricks). Manufactured in an unheated room.

Testing the samples with a long-term load was carried out by a lever device. The loading was carried out at 28 days of age at the physical center. Deformations measurements in the masonry samples were carried out with portable meshes with a base of 450 mm. The storage duration under load is 10 months. The temperature during the period of the experiments ranged from 0 to+36ºC, and the relative air humidity 30-80%.

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It was found that the shrinkage of brickwork is intensively developing in the initial period. After 100 days, attenuation occurs. Shrinkage of I masonry category samples for 100 days is 10% less than shrinkage of II category samples.

The creep strain is obtained by subtracting the shrinkage strain from the total strains obtained by direct measurement on loaded samples. Shrinkage deformations are much less than creep deformations; creep increases with an increase in the reduction level.

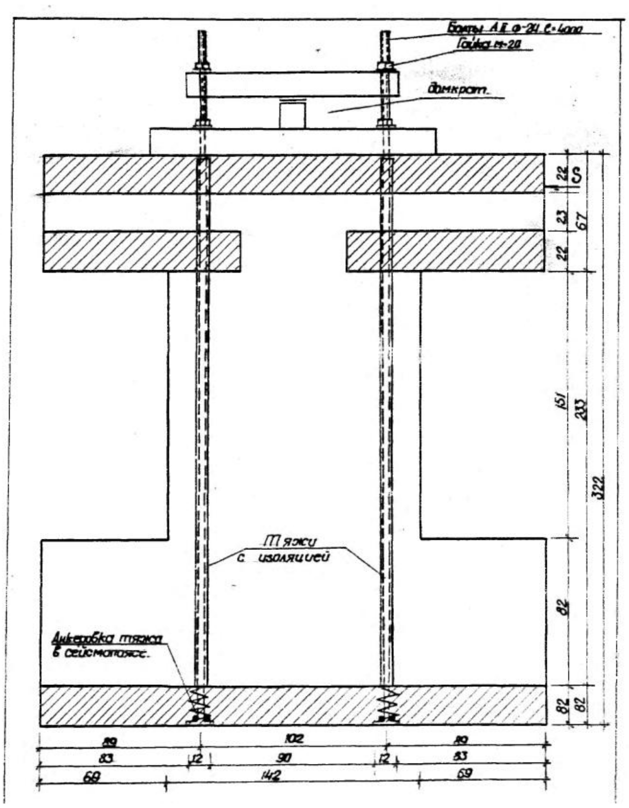

Fig.1 Designs of samples with strands without cores.

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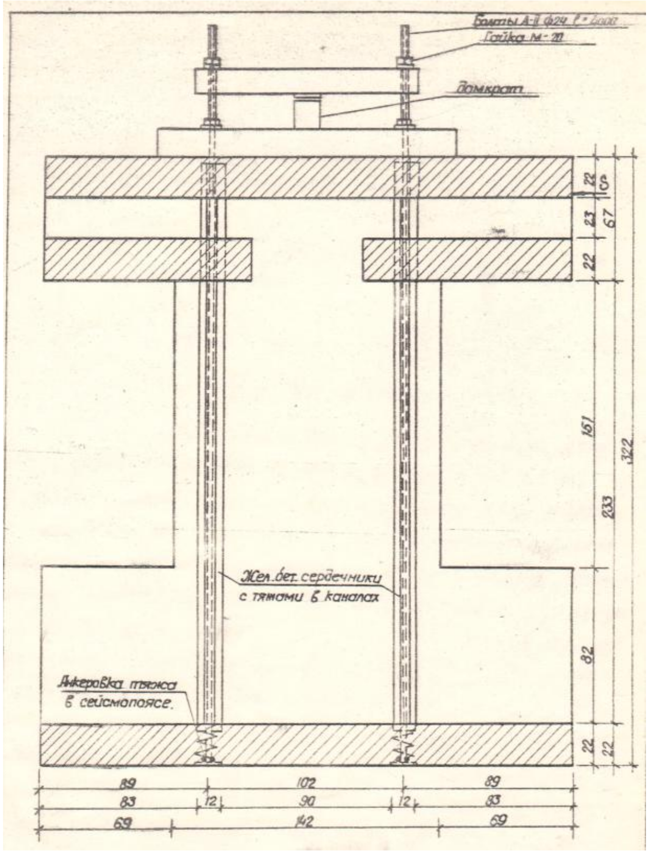

Fig. 2. Designs of samples with strands and cores.

An increase in creep curves for samples of series II G., in which the loading level $\sigma/_R = 0{,}06$is observed after 250-300 days of age. A similar thing was found when loading concrete samples at 50% stresses of the ultimate strength in O. Ya. Berg experiments [5]. The obtained data on the creep of masonry can be described by a linear relationship between $\varepsilon_{\text{пл}}$ и $\sigma/_R$ [4]

$$\varepsilon_{\text{пл}} = \mathrm{A}\frac{\sigma}{R} \quad (1)$$

At moderate stresses after 100 days age, an increase in creep deformation is practically not observed, i.e. can be taken equal to zero.

The "A" coefficient value regardless of the masonry category is assumed to be

$$\mathrm{A} = 1{,}9 - \frac{\sigma}{R}$$

The change in the masonry creep value depending on the compression level is shown in Fig. 2 (a). Experienced losses of reinforcement prestress due to shrinkage and masonry creep were determined in accordance with the methodology proposed [6] for concrete:

$$\sigma_{\text{п}} = \mathrm{E}_{\text{н}}\varepsilon_{\text{кл}(t)} - \sigma_{\text{кл}(t)} \cdot n_t \qquad (2)$$

where:

$\mathrm{E}_{\text{н}}$ – is an elasticity modulus of prestressing reinforcement;

$\varepsilon_{\text{кл}(t)}$ – the values of the total deformations of the masonry measured in the experiment at the time - *t*;

$n_t = \frac{\mathrm{E}_{\text{н}}}{\mathrm{E}_{\text{кл}} \cdot t}$ –is the value of the elasticity modulus ratio of the reinforcement and masonry corresponding to the same moment in time - *t*;

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$\sigma_{\text{кл}(t)}$ - is a residual stress in the masonry at the time - *t*.

Experimental data were analyzed according to the methodology adopted by КМК 2.03.01-96. Based on the experimental data, the dependence of the creep stress loss of the masonry and the magnitude of the masonry compression after 100 days was constructed. The analysis showed that the obtained regularity can be approximated by the expression.

$$\sigma_{\text{п}} = \frac{\sigma}{R}150 + 30 \quad (4)$$

The recommended formulas are used to determine the prestress loss in reinforcement from shrinkage and masonry creep after compression after 100 days. The prestress loss in the reinforcement depending on the compression level is shown in Fig. 2 (b) in practical calculations; the question often arises of calculating the loss from shrinkage and creep at any moment.

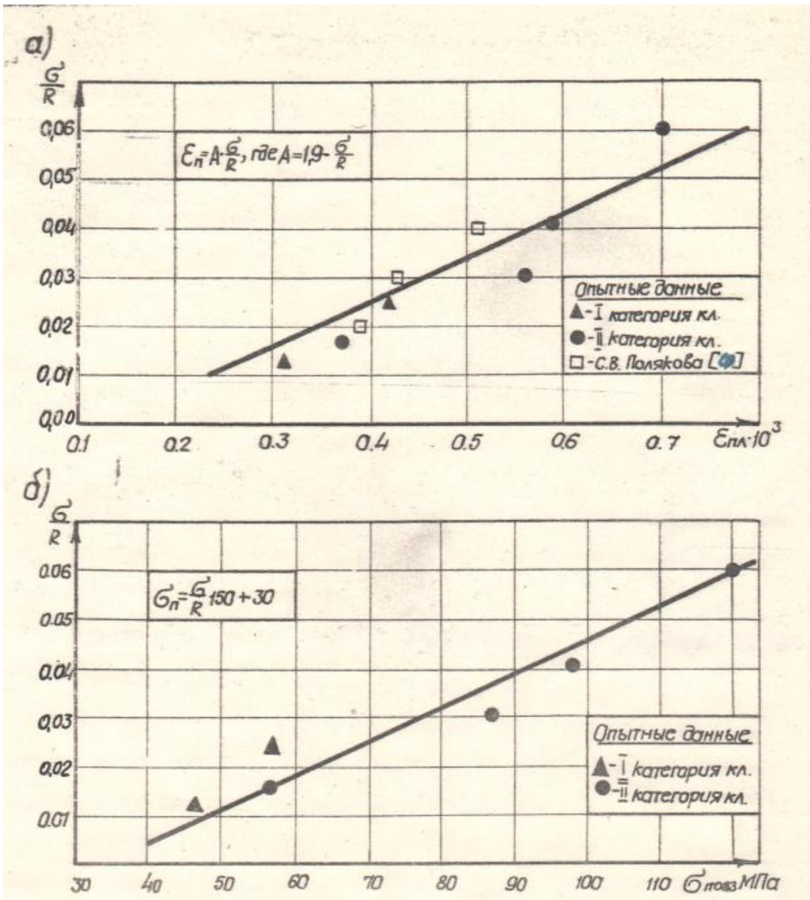

Fig. 3. Change in the masonry creep value (a) and the prestress loss in the reinforcement (b), depending on the compression level.

The analysis of the experimental data shows that if the actual loading time of the structures is known in advance, then the amount of loss from shrinkage and creep determined according to the above recommendations must be multiplied by β coefficient, similar to the same coefficient for concrete [3].

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$$\beta = \frac{9t}{100+8t} \quad (5)$$

where: t –is time in days from the day of preliminary compression of the structure.

III. CONCLUSIONS

1. Experiments confirm that the masonry resistance can be immediately increased by pre-compression of the buildings walls.It is practically possible to create a preliminary compressive stress in the masonry.
2. The magnitude of the prestressing loss from the masonry creep after 100 days, depending on the compression level, is satisfactorily described by expression (1). You can calculate the voltage loss at any age using the formula (4) taking into account the β function. Comparison of the experimental losses values with the calculated ones (formulas 4 and 5) showed a discrepancy of no more than 8-10%.
3. Prestressing losses in reinforcement - weight from shrinkage and a complex section creep for practical calculations can be recommended - 150 MPa.
4. By finalizing design solutions with a change in the work production method, it is possible to achieve equal strength of the brick walls of the first floor with the upper floor from seismic forces.

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