INDUSTRIAL ASEISMIC NORMAL AND MULTISTORIED BUILDINGS

Yu.V.Ismailov[I)], A.A.Chuprina[2)]

Stone-house-building is well-developed in many seismic regions of the USSR.

It is a matter of general experience that the behaviour of standard stone multistoried buildings is far from being adequate under severe earthquakes. For this reason intensive investigations directed towards increasing the seismic stability of the stone buildings has been carried out for last IO-I5 years. The tendency to enlarge the number of storeys originated in modern town-building complicates this problem.

The study of different methods for constructive strengthening of stone walls of a building has resulted in conclusions that high seismic stability of stone buildings can be achieved by incorporating the elements of a concrete frame into the wall composition.

Posts of such a frame are placed, as a rule, at conjunctions of main walls, and collar beams are placed at levels of all intermediate floors and coverings. The posts are made of cast-in-situ reinforced concrete using wall masonry as a falsework, and the collar beams are made of precast and cast-in-situ reinforced concrete.

In such buildings referred to as frame-and-stone buildings the wall masonry plays a role of a frame bearing filling. The frame itself is reinforced significantly weaker than in standard frame buildings. Therefore the buildings of such a type are characterized by high production-economics indices.

The high seismic stability of the frame-and-stone buildings has been proved by numerous horizontal load tests of fragments of their walls, by tests of the buildings using powerful vibration machines and at last by their behaviour during the Carpathians earthquake in I977.

Starting from the results of these tests the method for frame-and-stone buildings behaviour analysis under the seismic action has been developed. This method involves two parts: the determination of seismic forces and checking of the strength of wall bearing elements.

Dynamic characteristics of the building required for the seismic forces analysis may be found using the method of finite elements. But computation possibilities of the available computer programs realizing the method of finite elements do not always satisfy complex constructive solutions of modern frame-and-stone buildings. In this connection the method has been developed to substitute in analysed wall models the panels with openings in the filling by solid panels equivalent to the former ones by shear stiffness. The realization of this method allows to expand program computation possibili-

I) Master of Technical Sciences, Chief of the Kishinev Antiseismic Laboratory of the Central Scientific Research Institute for Building Constructions.

2) Senior Scientific Worker of the Same Laboratory.

ties and to reduce computer time consumption.

The strength of the frame-and-stone walls filling is checked by two hypotheses of failure using the method of finite elements. For each i -th finite element are computed two values of shearing force - $Q_{T1(i)}$ and $Q_{T2(i)}$, the first of which denotes the force taken by a wall tier comprising the i -th element as the first crack is being formed in it as a result of masonry shear along an unbonded section. By $Q_{T2(i)}$ is meant shearing force taken by the same wall tier as a crack is being formed in the i -th element of the filling as a result of overcoming of the masonry associated resistance along bonded section by main tensile stresses.

The values of $Q_{T1(i)}$ and $Q_{T2(i)}$ are determined from the formulas taking into account the fact that the horizontal load is of variable sign.

$$Q_{T1(i)} = \frac{R_{cu} + f\sigma^{p}_{y(i)} \mp \tau^{p}_{xy(i)}}{\pm \tau^{1}_{xy(i)} - f\sigma^{1}_{y(i)}}; \qquad (1)$$

$$Q_{T2(i)} = \frac{\pm\sqrt{A_i^2 - 4B_i\left[R_{r\Lambda}^2 + R_{r\Lambda}\left(\sigma^{p}_{x(i)} + \sigma^{p}_{y(i)}\right) + \sigma^{p}_{x(i)}\sigma^{p}_{y(i)} - \left(\tau^{p}_{xy(i)}\right)^2\right]} - A_i}{2B_i}, \qquad (2)$$

$$A_i = R_{r\Lambda}\left(\sigma^{1}_{x(i)} + \sigma^{1}_{y(i)}\right) + \sigma^{p}_{x(i)}\sigma^{p}_{y(i)} + \sigma^{p}_{y(i)}\sigma^{1}_{x(i)} - 2\tau^{p}_{xy(i)}\tau^{1}_{xy(i)}; \qquad (a)$$

$$B_i = \sigma^{1}_{x(i)}\sigma^{1}_{y(i)} - \left(\tau^{1}_{xy(i)}\right)^2, \qquad (i = 1, 2, \ldots, n), \qquad (b)$$

where $R_{r\Lambda}$ is the design resistance of the masonry to the main tensile stresses;

R_{cu} is the design resistance of the masonry along the unbonded section (tangential coupling). It is determined from the masonry test results in a given region of the construction carried on according to the "Instructions for determining the bond strength in masonry";

$\sigma^{1}_{x(i)}, \sigma^{1}_{y(i)}, \tau^{1}_{xy(i)}$ - are normal and tangential stresses in the i -th element of the filling caused by isolated shearing force taken by the j -th tier of the wall which the i -th element belongs to.

$$\left.\begin{aligned} \sigma'_{x(i)} &= \frac{\sigma^{Q}_{x(i)}}{Q_j}\,; \\ \sigma'_{y(i)} &= \frac{\sigma^{Q}_{y(i)}}{Q_j}\,; \\ \tau'_{xy(i)} &= \frac{\tau^{Q}_{xy(i)}}{Q_j}\,; \end{aligned}\right\} \qquad (3)$$

$$(i=1,2,\ldots,n); \qquad (j=1,2,\ldots,m),$$

where Q_j is the shearing force taken by the j -th tier of a m -storeyed wall according to its design diagram.

Among all the values of $Q_{T1(i)}$ and $Q_{T2(i)}$ a minimum value - $Q_{Tj(min)}$ is selected for the filling of each tier of the wall.

In recent years some designing institutes of the USSR have developed a wide variety of projects of frame-and-stone buildings up to 9 storeys high. These buildings advantageously differ from large-panel and cast-in-situ concrete-steel ones by economics indices. But when the filling of the frame-and-stone buildings is made of brick or small blocks the erection of such buildings is characterized by rather high labour consumption and large extent of wet processes. It can be avoided by industrializing the production of stone constructions for buildings walls. The filling should not be manually made of small-piece elements, it should be mounted from large monolithic or composite blocks.

The monolithic blocks are made of lightweight concrete or cut out of high-strength limestone. But large blocks more often have to be made of small-piece building materials(brick, small blocks of natural stone and the like).

The developed constructional-and-technological solution of large composite blocks is based upon the usage of squeezing of green masonry by vertical reinforce ment being strained. Depending on the analyses results masonry horizontal reinforcement may be lacking on the whole or may be performed by oblique bars or by horizontal fabrics.

The frame-and-stone buildings with the filling made of large composite blocks of the described structure is characterized by high strength indices including the seismic stability as well.

But it is not always necessary that the bearing capacity of these buildings should be so high especially as its attainment involves reinforcing steel expenditure.

That is why the structure of composite blocks being strained provided with removable vertical reinforcement has been developed. Such blocks are made and mounted as standard prestressed composite blocks but after they have been mounted into the wall of a building the strained reinforcement is removed and sent back to the block manufacturer to be reused. When the filling of the frame-and-stone buildings is made of such blocks the metal expenditure on buildings walls is substantially reduced.