PRESENT-DAY SOLUTIONS OF ANTISEISMIC STONE BUILDINGS

by

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SYNOPSIS

Low solidity and brittle nature of failure of masonry under seismic action gave rise to the development of constructive techniques for its reinforcement.

At present in civil engineering practice there is a wide use of vertical and horizontal reinforcing of masonry by means of usual and prestressed reinforcement, reinforcing it with armoured monolithic concrete. Today a growing number of developments are being found for the so called frame and stone buildings, main walls of which comprise a combination of masonry and prefab-monolithic or monolithic reinforced concrete frame. While constructing such buildings the wall masonry is utilized as a form for reinforced concrete elements of the frame.

In this case the reinforcement of these elements is minimum. Such buildings can be built up to I2 storeys and sometimes higher.

The experience of designing and constructing of stone buildings with walls of different constructions, experimental and theoretical examination of these buildings behavior during earthquakes showed that up-to-date solutions of stone buildings design exhibit high seismic stability while meeting a number of conditions.

This report presents the main results gained over last years and the requirements imposed upon designing and constructing the antiseismic stone buildings.

In many seismic regions stone is being continued to be a basic material for wall construction.

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In the last few years a general trend to growth of storeys number of urban buildings has extended to stone buildings. This condition in conjunction with generally low seismic stability disclosed by such buildings during many heavy earthquakes has resulted in the development of a number of methods for constructive reinforcement of masonry.

Complex wall structures are widely used. For reasons of economy cross-section dimensions of monolithic ferro-concrete reinforcement elements are set as small as possible. And this adversely affects the quality of their concreting. As a result, an increase in seismic stability of a stone building due to the reinforcement of wall masonry by monoli-

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thic ferro-concrete insertions is often found to be rather low.

Testing of the complex structures has revealed that the structure does not always behave as a single whole at high levels of load when the reinforcement elements are placed along the side planes of masonry piers.

To unanimous thinking of specialists one of main causes of low seismic stability of structures made of natural or man-made stones lies in low strength of their bonding to mortar. Squeezing the masonry by prestressed reinforcement is an efficient constructive method for solving this problem. This statement has been proved by the results of testing the horizontal force of stone wall fragments 270 cm in length, 160 cm in height and 20 cm in thickness fabricated of limestone and light-weight concrete blocks.

These experiments have revealed that the change of the intensity of the masonry squeezing from 0 to 10kg/cm^2 increases the bearing capacity of the wall fragments almost fourfold.

In practice, different systems of reinforcing building walls by vertically-arranged prestressed reinforcement are possible: along the full vertical extent of the building, only along the walls of the upper storeyes. But the interstitial variant is also possible at which self-bearing walls are reinforced along their full vertical extent and the bearing ones only in the upper part. The selection of reinforcing system and parameters depends on the results of a building design with due regard to possible seismic action.

It is advantageous to position the prestressed reinforcement bars in the enclosed masonry channels or in the open slots which are then worked in by cement mortar.

Reinforcing the walls of stone buildings using the prestressed reinforcement is one of a promising method for increasing the seismic stability of these buildings. Jet this method requires rather high construction efficiency.

Opposed to spreading this constructional solution in the practice of antiseismic construction is the fact that the behaviour of the buildings with prestressed walls under dynamic conditions has been poorly studied. Rather extended and labour-consuming research in this trend should be performed.

Stone-frame buildings have gained wide acceptance in many countries due to their adequante behaviour when subjected to a number of strong earthquakes.

The walls of such buildings represent a frame (usually reinforced concrete), the cells of which are filled with masonry. Some cells of the frame are provided with a blind filling, but the majority of them are panels with openings.

Scientists of many countries studied the behaviour of the wall fragments of stone-frame buildings under the action of the horizontal load or under the simultaneous action of the horizontal and vertical loads. Unfortunately in these investigations the importance was not attached to the fact that there were two types of such buildings distinguishing for the character of their behaviour under the load.

In the buildings of the I^{st} type the frame is initially erected, following which its cells are filled with masonry. When such succesion of the wall erection process is followed the contact closeness and bond strength between the filling and the frame elements are usually characterized by rather low values.

In virtue of known difficulties the most difficult task is to carry out a close contact between the masonry and the lower planes of the cross-bars. In practice, there are rather wide gaps at these points which are sealed only on the outside.

When constructing the buildings of the 2nd type at first the masonry is erected within the limits of each storey. And then the monolithic elements of the frame are erected with the masonry used as a form when laying concrete. Owing to this fact close and reliable contact is achieved between the filling and the frame. The menshined features of erecting the walls of the buildings of the Ist and the 2nd types specify the following essential differences in their behaviour under load:

In the buildings of the Ist type the filling does not exhibit the resistance to the vertical load and only some part of the filling is subjected directly to the horizontal load.

In the buildings of the 2nd type the main fraction of both the vertical and the horizontal loads is taken by the filling. As a result, the frame reinforcement requires a minimum of steel. In such buildings due to the reliable bond to the frame the filling features greater stability due to the type of its operation than in the buildings of the Ist type.

Thus it may be stated that the buildings of the 2nd type have essential advantages over the buildings of the Ist type.

High bearing capacity of the buildings of the 2nd type allows them to withstand comparatively weak earthquakes without any damages.

According to the up-to-date approach to providing the reliability of the buildings at strong earthquakes the damage of some structures not leading to their failure may be tolerated.

As is obvious from the experimental investigations of the frame wall fragments with the filling of the 2nd type, the masonry damage results in a distinct drop of the wall stiffness, but it does not mean that the walls bearing capacity is exhausted.

This suggests the main principle of designing such buildings, the essence of which is in the following: If the walls failure during an earthquake is bound to, it should start with the filling. Such approach taking into account the drop of the seismic forces acting on the building allows to keep the frame elements from being damaged and the building itself from failure.

It is evident that the damage of the filling at various sections of the walls changes the building stiffness in different ways.

It is possible to determine such sections of the filling, the damage of which is best preferred during a strong earthquake as the general stability of the building is provided. Such sections may be in the filling of the ground floors, staircases, etc.

This advances the principle of planning the damages of the building walls at their designing.

The results of the experimental and theoretical investigations of the author have manifested themselves as the "Instructions for designing the stone-frame buildings for seismic regions" which is worked out for design institutes.

The procedure recommended by the Instructions for designing the buildings of the 2nd type is based on using the finite elements method and computers.

Designing of the walls consists of two main parts, the first of which amounts to determining the loads acting on the building and to making its design scheme.

The second part of the design consists of examining the filling strength against two hypotheses and selecting the cross-section area of longitudinal and transverse reinforcement for cross-bars and frame supports.

The designing procedure takes into account the above menshined main principles of providing the reliability of stone-frame buildings during earthquakes.

At present are made the designs of stone-frame buildings having of up to 9 storeys to be used in various seismic regions of this country. The majority of these designs has been already completed in antiseismic construction.

In some cases the masonry squeezing by vertical prestressed reinforcement may be used for stone-frame buildings. The seismic stability of such buildings will be the highest.

Partially this technique is used when erecting frame buildings with the filling in the form of big compound blocks made of natural stone and reinforced by prestressed reinforcement. Such blocks are in commercial production in Kishinev.