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PROVISION OF EARTHQUAKE SAFETY FOR BUILDINGS FROM WEAK LOCAL MATERIALS

Shamil Khakimov[1]

SUMMARY

Problem of earthquake safety of residential buildings, schools, hospitals in earthquake prone regions of Uzbekistan, constructed using weak local materials arise after Kamashi earthquake with M=5.4 occurred April 20, 2000. In this zone were situated 1-3 storey buildings from adobe(pahsa), adobe bricks, burned bricks, silica bricks, natural stone. Within all constructive types were revealed damages between grade 1 and 4 by MSK scale. For the each type of buildings were developed methods of reinforcement, taking into account material properties, expected service time, acceptable seismic risk and repetition period of earthquakes of different intensity. Based on results of our complex investigations the recommendations for design of buildings from weak local materials and reinforcement of existing houses were developed with purpose to implement it in other earthquake prone regions with intensity 7-9 units (EMS-98).

INTRODUCTION

In rural areas of Uzbekistan and Central Asia as a whole, more than 40% of population are living in buildings, constructed using traditional adobe and stone materials without antiseismic measures. In many sites using local materials constructed also public buildings : schools and hospitals. As materials for construction of buildings from local materials were used: adobe bricks, rammed earth called “pahsa”, air dried clay rolled out of spherical shape “gualyak”, clay blocks, reinforced by saman (straw), natural sledged stones, limestone, silicate bricks etc. As the mortar are used usually clay, sometimes clay with lime. For foundation used sledged stone or sometimes no foundation at all. The buildings were constructed one-storey without special

[1] Doctor, Head of Dept. of construction , Uzbek scientific-research institute of typical and experimental design of residential and public construction, Tashkent 700095, 17 Niyazova , Uzbekistan; fax:(99871)2 676603, e-mail: khakimov_sh@yahoo.com

design. For construction the population was guided mainly by services of the national masters, using their expertise and traditions. Lifetime of such houses was nearly –10-15 years. At earthquake impact with intensity 7 and more units (MSK-scale) majority of houses of local materials have gained severe damages, up to total collapse. The facilities constructed using of indicated materials are dangerous for dwelling in conditions of strong earthquakes.

At the same time construction from local weak materials are continuing and widely used not only in Central Asia, but in Afghanistan, Iran, Turkey, India, etc.

The earthquakes, occurred in Kashkadarya region (Uzbekistan) and Lugovaya station (Kazahstan) evidently showed that adobe buildings constructed from local materials without special measures have obtained heavy damage, some houses were completely collapsed.

In paper are presented some implemented on practice methods of reinforcement of buildings from such materials. In building codes of Uzbekistan not explained detailed recommendations for such construction. Besides new methods of reinforcement are presented traditional effective methods of reinforcement of adobe construction using wooden frame.

Materials and strength properties

Local materials traditionally used for construction of buildings and it's properties are presented in table 1.

Type of material	Compressional strength kgs/cm^2
1.rammed earth"pahsa",	5-25
2. adobe bricks	10-25
3. air dried clay rolled out of spherical shape "gualyak	5-15
4. clay blocks, reinforced by saman	5-20
5. natural sledged stones, limestone	50-200
6. silicate bricks	50-100

Silicate brick – artificial stone, fabricated by autoclave processing of mixture of lime and sand and practically has not cohesion with cement –sand mortar.

As a mortar for masonry it is necessary to use cement-sand mortar with compression strength 25-100 kgs/cm^2. For foundation it is necessary to use concrete or rubble concrete with compression strength 100 kgs/cm^2.

Design system with wood frame, filled by adobe brick (synch)

The settled population of many regions of Central Asia traditionally used reliable enough type of construction applying wood frame with infill by rammed earth, called "synch". For construction of house from a wood frame synch it is required: the wood bolsters with cross-section not less 15x15 cm, wood pole with cross-section not less 8x8 cm, brick - adobe or gualyak. For the foundation construction - concrete M100 or rubble concrete, metal bars with diameter not less 10mm for reinforcement of the foundation, creation of discharges for fixing frame to the foundation, small amount of metallic cramps with diameter 16mm sharpened at ends.

Besides it is required clay saman mortar, elements of window, doors, floors, plaster, roof. List of these materials may be miscellaneous.

The seismic loads were accepted by all frame at the expense of its dimensional operation. The stability and geometrical invariance is provided with acclinal braces or braces, included in each edge of wall, and also fixing of parts among themselves in "thorn" and with metal cramps. The pieces of frame, fragment of joint are presented in fig. 1. Filled by adobe brick the frame is plastered from both sides by saman mortar with thickness from 30 up to 50 cm.

General view of wooden frame (synch) house of construction under construction in Bukhara district, Uzbekistan is presented in fig.2. Shown frame is ordinary, but may be double by thickness. To withstand the earthquake with intensity 9 the walls in corners should be reinforced along 120cm from corner by cement-sand plastering by steel wire mesh with diameter 5mm and size of cells 15x15cm.

DESIGN SYSTEM FROM RAMMED EARTH (PAHSA), BRICK - ADOBE, SAMAN BRICK OR BLOCKS

Design systems from adobe materials includes the buildings with rammed earth walls from pressed clay called locally ‘pahsa” , load bearing walls from adobe bricks, saman blocks or bricks. Houses from indicated adobe materials at earthquakes 7 and more intensity units, as a rule, obtained severe damages up to complete collapse. Typical types of damage is:

- the breakoff of walls in an orthogonal direction,
- orthogonal cracks in walls,

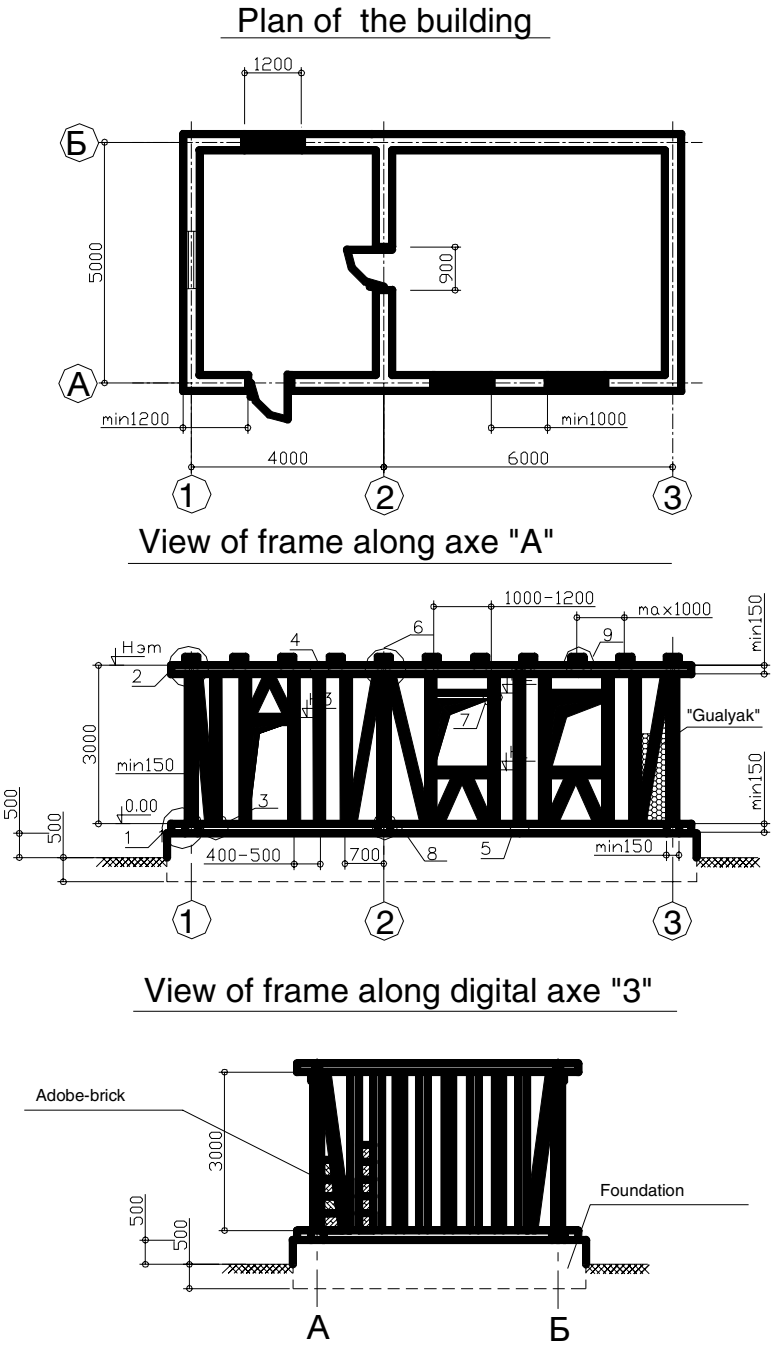

Fig. 1. View of wooden frame “synch”. Part of the walls.

- roof collapse,
- breakings of the foundations.

Such damages leads to severe economical losses, and sometimes are dangerous for life. In fig. 6.6 - 6.9 the representative views of damages of houses from adobe materials are shown.
The methods of antiseismic reinforcement of buildings from adobe materials are oriented on avoidance of the indicated types of damages and increases the safety of dwelling and exploitation of houses and other facilities.

Fig.2. General view of construction of wooden frame (synch) house in Bukhara district, Uzbekistan

For antiseismic strengthening of new construction from local weak materials to increase earthquake resistance up to intensity 7 and more units are recommended following materials:

- Concrete and rubble concrete grade M100 for foundation;
- Cement-sand mortar of grade M100;
- Wire mesh with diameter 3-5mm with cells 100x100, 150x150, 200x200;
- Steel rods with diameter 12-16mm for reinforcement of openings, cross-sections of orthogonal walls, foundations and antiseismic belts implementation.

Spatial rigidity of house was provided by frame from wire mesh in layer of high quality cement mortar with thickness 3-5cm.

Succession of operation should be as following:

- Implementation of foundation from concrete M100 of rubble concrete;
- Horizontal strengthening of walls by wire mesh in layer of high quality cement mortar;
- Vertical strengthening of walls from both sides in layer of high quality cement mortar;
- Connection of vertical mesh with free ends of horizontal mesh.
- Implementation of antiseismic belt at level of ceilings from reinforcement bars with diameter 12-16 mm from steel grade AIII.

Level of antiseismic reinforcement for different intensity is varied at the expense of steps of wire mesh, thickness of mortar layer (fig. 3).

Reinforcement of buildings from natural stones differs from above mentioned by additional vertical reinforcement of reinforced concrete inclusions, anchored in foundation and seismic belt in the top. Strength of cement sand mortar should not be less than M50.

Over every 50-70 cm by the height of masonry necessary to put horizontal reinforcement wire mesh in layer of mortar with width at least 25mm. Diametrical bars with step 300mm should have free ends over walls edge up to 8-10cm. Longitudinal reinforcement bars should cross cross-sections of vertical reinforcement of walls, openings and should be continuous along all walls. Masonry necessary to lead simultaneously by stages (height 50-70cm) along all perimeter of external and internal walls. Wooden beams of ceilings should be fastened to free ends off seismic belt, and at inner walls additionally fixed to each other by ends by construction cramps (fig.4 and fig.5).

Antiseismic strengthening of existing buildings from local materials.

Experience of world earthquakes showed that buildings constructed from weak local materials without special measures may have severe damage even after mediate earthquake equal to 7 intensity units. So such buildings should be necessarily strengthened and especially, if they experienced earthquakes and damaged in moderate degree less than grade 3 according to EMS-98 scale.

Moderate damage means: cracks up to 1-2 mm in joints of walls of orthogonal direction, in corners, in openings of windows and doors, diagonal cracks in internal walls.

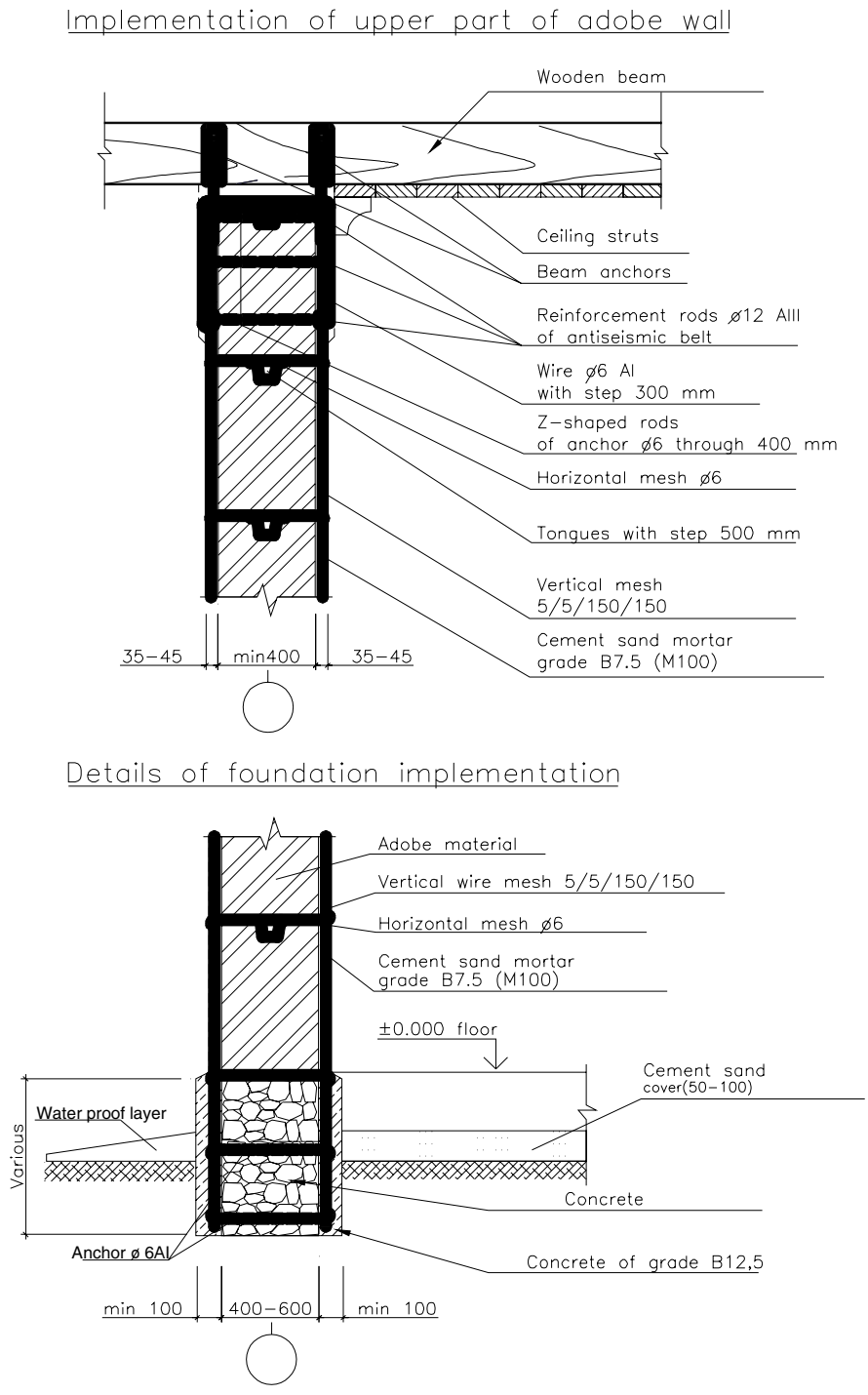

Fig.3. Reinforcement of buildings from adobe materials.

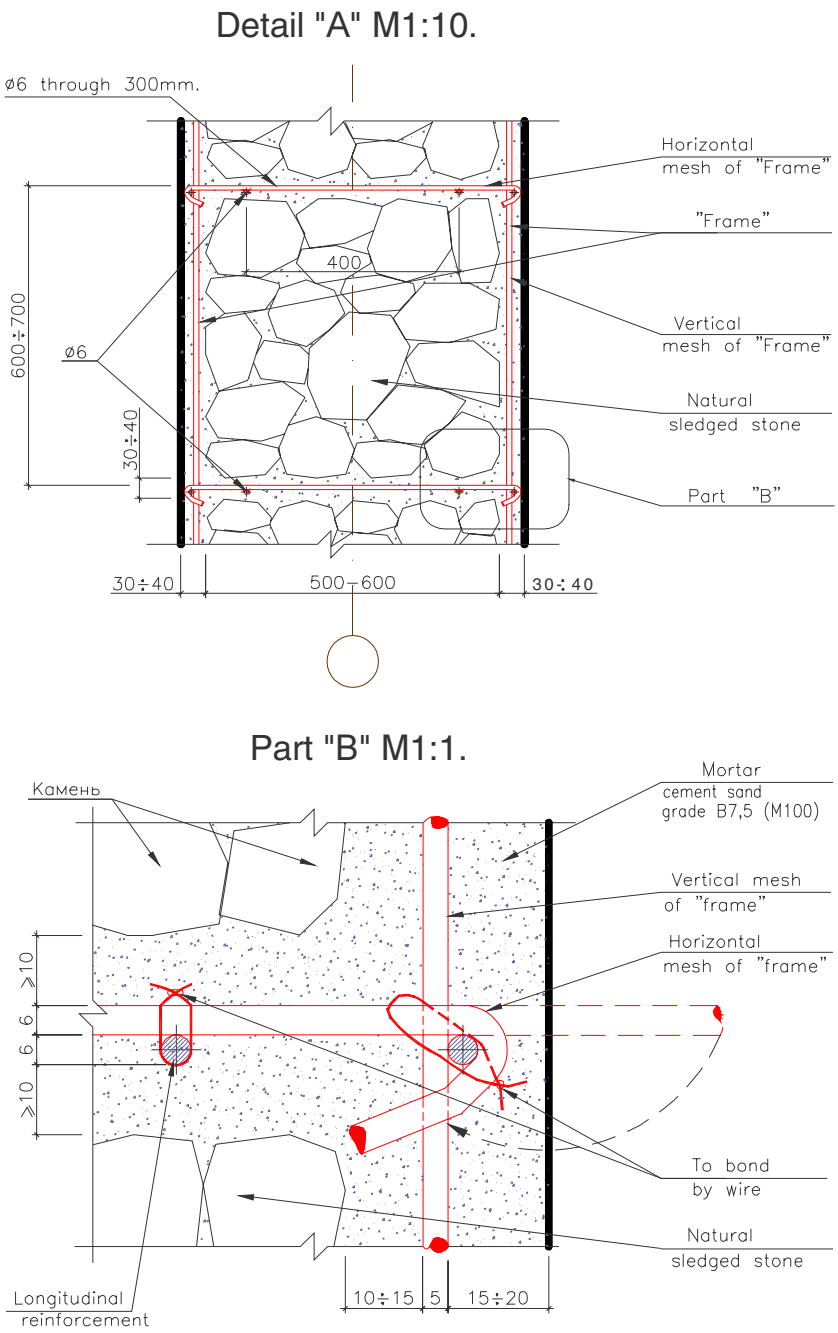

Fig.4. Reinforcement of wall from sledged stone.

Reinforcement of buildings from adobe materials recommended to provide based on creation of conditions for joint work of building elements unified as a whole, walls should accept shear loads, avoiding break of walls of orthogonal direction and breaks of foundation.

It is recommended to reinforce bearing walls from both sides by vertical grade Bp-1 steel wire mesh with cells 150x150 mm from wire with diameter not less than 4mm.

Vertical reinforcement mesh should have free ends below ground level by foundation at least 20 cm and blocked up by concrete M100.

In upper part mesh should be linked with antiseismic belt, consists of 2 steel rods with diameter 12mm, established continuously by all perimeter of bearing walls from both sides of the wall. Existing beams of ceilings at ends should be anchored in antiseismic belt.

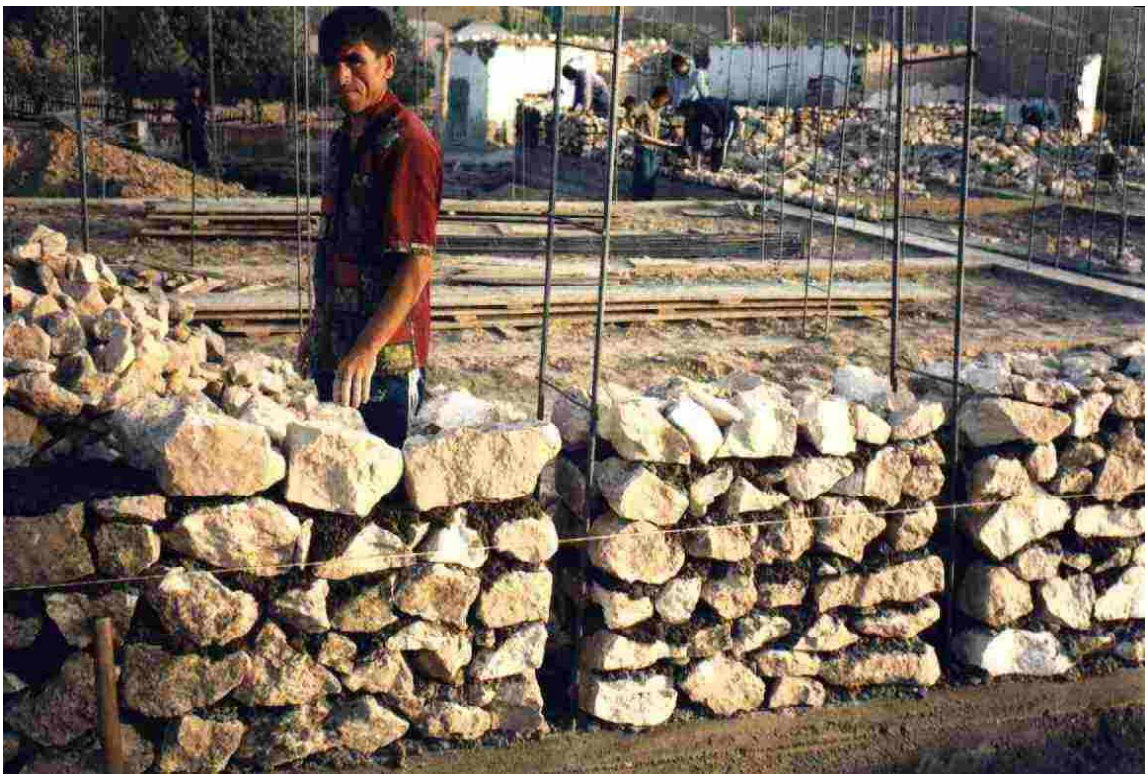

Fig.5. Process of construction of building with seismic reinforcement measures in Dekhkanabad district of Kashkadarya region in Uzbekistan

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Wire mesh from both sides should be connected by Z shape steel grade AI rods with diameter 6-8 mm. Before mesh implementation the plaster from both sides of walls should be removed. In staggered fashion with step 700mm should be putted tongues with size 100x150mm with depth not less 60mm. Simultaneously with mesh placing in staggered fashion with step 600mm in the wall drilled through holes with diameter 5mm for placing Z-shaped anchors from steel grade AI reinforcing bars with diameter 6mm. Wire mesh should be covered by cement-sand mortar with strength of compression not les than 100 kgf/ cm^2. Before putting mortar the wall surface should be moistened. Reinforcement of foundations carried out from concrete grade M150 by all walls perimeter from both sides. Recommended method of reinforcement of buildings from saman blocks was developed by Kazakhstan specialists (KazNIISA, Ashimbaev, Taubaev, Itskov and others) and implemented in liquidation of consequences of earthquake of 2003 in Lugovaya village, Djambul district of Kazakhstan.

Testing of reinforced buildings showed high efficiency of developed recommendations. Recommended measures were used as for reinforcement of damaged school buildings as for new construction of school buildings in hard to reach mountain regions of Kamashi and Dekhkanabad districts of Kaskadarya region.

Some reinforced buildings experienced the earthquake 18.01.2001 with the same intensity. Reinforced buildings were not damaged evidently showing efficiency of recommended technical solutions.

Cost of rehabilitation and antiseismic reinforcement in relation with damage grade of building is varied between 10 and 20 % of new construction cost. Cost of reinforcement of new construction, for example from sledged stone comprised 10-30 USD per 1 square meter of total space of building in relation with site intensity.

Developed methods of antiseismic reinforcement may be used also in other countries where widely used local weak materials, such as Afghanistan, Iran, Turkey, Indonesia and others.