ASEISMIC STRENGTHENING AND REHABILITATION OF SCHOOL BUILDINGS

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ABSTRACT:

Questions of earthquake safety of school buildings in many countries of the world are paramount because it is connected to safety of life of children. Classification of school buildings by constructive type in cities and settlements of Uzbekistan has been developed. A prevailing material of walls are: adobe; adobe brick, natural stone, wooden frame with adobe fill, burnt brick, brick walls strengthened with RC inclusions; silicate brick and RC frame - panel buildings. Economically and technically expedient there was restoration and strengthening of the school buildings with damages level not exceeding 3 degrees by MSK scale. In the paper experience of strengthening of school buildings in Uzbekistan is presented.

KEYWORDS: school building safety, earthquake resistance, vulnerability, reinforcement

In Republic Uzbekistan the National Program of Development of School Education for years 2004-2009 has been accepted. One of objectives of the program was provision of earthquake safety of school buildings. For more than 10000 school buildings were evaluated their seismic risk. As a result of such estimation it is established, that more than 25 % of buildings of schools at earthquake of various intensity will have damage exceeding 3 degree, and about 10 % may be collapsed. Depending on level of seismic safety of buildings about 10 % should be demolished, part should be reinforced. Instead of demolished buildings new construction should be provided. New schools buildings should be built with a protection level that guarantees that they remain functional after maximum probable earthquakes.

School buildings in cities and villages of Uzbekistan have various age and are constructed with application of different materials. Seismic hazard of territories of school building sites is characterized by intensity of earthquakes from 5 up to 9 and more units with various repeatability and various prevailing spectra of movement.

Classification of school buildings by constructive type in cities and settlements of Uzbekistan has been developed. A prevailing material of walls are: adobe brick and natural stone – 10%, burnt brick and brick walls strengthened with RC inclusions – 50%; RC frame - panel buildings – 35%. Others (silicate brick, adobe, wooden frame with adobe filling, etc) – 5% .

For implementation of the program were developed:

- Building codes for school building construction
- Typical designs of new school buildings with different capacity
- Typical design for reconstruction of objects
- Album of typical constructions and technical decisions for antiseismic reinforcement

11 Design Institutes participated

Frame-Panel Typology of school buildings

The structure consists of a pre-cast frame with generally continuous columns and beams connected to at the joints by means of in-place-sealing. The walls, both for the facades and the inner partitions are pre-cast and connected to the frames by means of cast-in-place sealing. The slabs are generally pre-cast pre-stressed lightened elements, connected to each-other on the support zone through some steel bars crossing the upper section of the beam.

The case of frames composed of a three-dimensional skeleton is not, however, universal; sometimes the beams are placed only on parallel planes. In these latter cases, the seismic resistance through the perpendicular direction is devoted to the slabs themselves. The sealing between the pre-cast elements is assured by the welding of the reinforcement bars along length of about 12-18 cm, and the pouring of cement mortar. It is only the joints to constitute the weak point of the overall structure. In fact, the reduced workmanship in realizing this kind of joint leads to a very bad performance of the structure, mostly under dynamic loads.

The imperfect welded connection between the bars and the not-well-cared pouring of the mortar leaves a high amount of void, with consequent corrosion. It normally produces fragility of the joint where the concentration of stress is higher compared to other elements. The undesired brittle behavior of the joint, where a ductile performance under dynamic and cyclic loads is strongly wished, reduces the possibility of dissipating mechanical energy within the hysteretic cycles. One can observe this feature in typical stress-deformation relation curves. Ultimately, this brings the structure in the most seismic-vulnerable state. A need is identified to fix this problem in existing structures and also to ensure that new construction avoid this type of structure from the constructive practice of school-buildings, or, as a alternative, in guaranteeing the correct execution of the joint by means of a stringent control procedure.

School №116 with capacity of 1716 children in Uchtepa district of Tashkent city has been constructed in 1973-1974 (blocks A - J) and modified in 1983-1984 after Nazarbek earthquake December 11, 1980 (blocks I-K-L-M). Construction site design intensity - 9 units by MSK scale. Blocks A-J were constructed according to standard design 222-1-162SP, developed by Tashkent Zonal Institute of experimental design of construction. In construction of blocks I - M were used a reinforced-concrete frame of series IIS-04.

The school buildings (blocks A-J) consist of the seven blocks subdivided by antiseismic joint on isolated blocks. The height of blocks A has three floors, B,D, J - two floors. The block C - sports hall - one-storeyed. For blocks A, B, J are used products of series 1-220 SA, hinged precast single-layered claydite concrete panels with thickness 30 sm.

As ceilings used precast reinforced-concrete prestressed multihollow panels. Staircases with combined landings from precast reinforced-concrete with Z-shaped form. The foundation - single precast reinforced-concrete of glass type.

According to results of inspection the following is established:

- deviation of columns from vertical (the maximal relative deflection) equal to 0,022 or 6,6 cm;
- cracks in joint of columns and crossbars;
- settling of basement (monthly maximal rate of the basement settling) equal to 16 mm;
- violation of maintenance regulations and absence of irrigational system resulted in wetting of foundation.

Detailed inspection established diagonal cracks in brick walls as result not only of basement settling, but also as a result of Nazarbek earthquake of 11.12.1980 year.

After the mentioned above earthquake with intensity 7 units in the building of school №116 the following damages have been revealed:

- diagonal crack in brick filling of staircases;
- cracks in places of support of ceilings on crossbars;
- hair cracks in separate zones of the central part of unit of a frame;
- horizontal and vertical cracks in joints between hinged panels;
- individual hair cracks in joint between plates of ceilings on the first floor and a little bit big on the top floors;
- separate hair cracks in bearing crossbars;
- diagonal cracks in partition walls.

It is necessary to note, that the building of school №116 much better withstand the earthquake, than the building of school №123 constructed with use of frame of series USK.

In bearing elements of frame 1-220SA (school №116) in junctions of the console with crossbar the width of cracks did not exceed 0,5 mm. Joining of releases of armature, as against frame USK, was carried out by welding an overlay from cores of armature 016AIII to releases from cross - bar and consoles of column. Such kind of welding was approved as more reliable.

It is necessary to note, that frame of system 1-220 SA as flat crosses, consist of the integrated columns on 1-2-3 floors with the consoles, connected by monolithic site with crossbars - inserts in a zone, the so-called zero moment and bracing crossbars.

By reliability at seismic influences the frame of series 1-120SA surpasses designs of frame IIS-04 known for mass destructions of buildings from this frame at Spitak earthquake of 1988.

The similar school has been erected in 1982-1983 in Gazli by standard design 222-1-162SP, developed by Tashkent Zonal Institute of experimental design of construction in 1971 in reinforced-concrete a frame from flat crosses of series 1-220SA with external walls from claydite concrete hinged panels. Site seismic intensity - 8 units. The building of school has experienced Gazli earthquake of March 19, 1984 with magnitude 7,2, that correspond approximately to 9 units by MSK scale. The building of school in Gazli has obtained serious damages: collapse of parts of hinged panels because of wrong their fastening to columns; collapse of partition walls because of poor-quality of their installation; damage of joint of zone of crossbar - insert with the console of column because of use of low mark of monolithic concrete and poor-quality welding of releases of armature. Nevertheless, collapse of the frame has not taken place, though intensity of earthquake surpassed design seismicity of site. Seismic influence was aggravated with that under the bases was observed ground liquefaction that has resulted to non-uniform a settling of the bases of columns. It has caused additional effort in elements of a frame of a building.

The analysis of consequences Gazli earthquake has shown high survivability of a frame of a series 1-220SA. A building of school in Gazli was recommended to restoration. For this purpose technical decisions on restoration of designs of a building of school have been developed. Thus it was provided:

- strengthening of the columns which have obtained heavy damage with metal holders and polymer mortar;
- joints of crossbars - inserts and consoles of columns should be taken apart and assembled anew with stacking of qualitative concrete;
- cracks in columns and crossbars injected by epoxy glue;
- fallen external reinforced-concrete panels were replaced by light three-layer asbestos cement sheets;
- for partitions walls is recommended to use asbestos cement sheets on frame.

The considered building of school №116 has considerably smaller damage to bearing elements and quality of joints of consoles of columns with crossbars inserts are much higher than in Gazli schools. Serious lack - bearing elements of school №116 have inflection and settlings of the basement, arisen because of non proper maintenance of building within more than 30 years.

At absence of the specified deformations of frame in view of the engineering analysis of consequences of Gazli earthquake the bearing frame of school №116 would not demand some essential expenses for strengthening. In this case it would be possible to be limited to restoration of the damaged sites of elements.

Actions on antiseismic strengthening of bearing elements of a building of school №116 should be directed into preservation of stability of a building at earthquake, stabilization of settling processes at exploitation.

In connection with stated, recommendations on maintenance of seismic and operational reliability include the following basic measures:

- to transform the frame system of building into bracing one with introduction in separate flights of longitudinal and cross directions cross shaped metal connections or strengthened brick diaphragms with strengthening of joints of columns by holder;
- to unit the basement under columns with the help of monolithic basement beams in longitudinal and transversal directions;
- to strengthen basic part of columns of ground floors by metal or reinforced-concrete holder;
- to strengthen the columns having serious damages with metal or reinforced-concrete holders;
- to unload cement floors in passageway parts by decrease of thickness (existing floors thickness is 20 cm);
- joints between plate ceilings to fill with cement-sandy mortar;
- at presence of resources, with purpose of frame unloading as variant, expediently to replace external wall panels into more light one;
- to provide non bearing partition walls with reinforcing and stability in a plane;
- to provide reliable organized drainage system of thawed and sewer waters from building. All engineering communications, as warm and tape water systems should be accessible to audit and control of their serviceability over operation down to sewer and water wells;
- at preservation of external wall panels it is expedient to limit access of children to zone of their falling (3 meters) by the implementation of decorative protections on perimeter of walls of school building.

Brick- wall Typology of school buildings

The structure generally consists of brick walls, parallel to the main dimension of the building, that support the different slabs, three or four, depending on the type of school. The brickwork is composed of industrial brick joined usually with cement mortar. The slabs are usually of the pre-cast type reinforced concrete, which are sometimes pre-stressed too. At the floor level, a reinforced concrete belt is provided, however, not always.
According to the data base collected, the school brickwork building stock can be classified in the following groups:

1. Non-seismic-resistant buildings (about 10%);
2. SNIP code (old code) compliant buildings (about 60%);
3. Uzbek building code 1996 compliant buildings (5%);
4. Complex structures with various reinforcements (25%)

Although there is no quantitative evidence derived by specific seismic analysis, there is general observation that the latter buildings with complex structures with various reinforcements about 25 % in brick building stock have some seismic resistant features. The bonding strength between brick surface and mortar bedding is about 0.05-0.08 MPA , which is well below the required strength level -0.12 MPA as per the new building code. The lack of a belt at the floor level, moreover, compromises the overall structural behavior of the building, increasing the stress level in the brickwork and contributing to the higher damage level. The other concerns are related to the fact that most of the 2nd category buildings (60% in prevalence) do not comply with the new code prescriptions, neither for the number of levels nor for the impact of seismic actions. In particular, the new code (KMK 1996), has increased the amount of seismic forces on brickwork structures unlike that in the old SNIP code.
To increase the bearing capacity of the basements the following variants of strengthening are recommended:

- reinforced-concrete "shirts" executed by torcrete method, grouting or stacking of concrete in timber with the subsequent waterproofing of surface of concrete;
- escalating with welding additional armature to exposed armature of the basement or with the help of reinforced-concrete (metal) beams, passing through the punched apertures and basing on reinforced-concrete plates of strengthening;
- piles placed outside contour of the existing basement;
- placing under the existing basement new reinforced-concrete elements;
- strengthening of the basement by chemical or thermal fastening of the ground, allowing to increase category of ground by seismic properties and, accordingly, to lower design seismicity of site.

In case of substantial growth of loading on tape basement and impossibility of placing new elements due to high level of ground water or presence of underground technological pipelines it is necessary to unite it in plate by escalating.
In development of projects of reinforcement of brick and stone buildings necessity of strengthening of the following bearing elements and units should be revealed:

- Partitions and walls, including parts of walls between door and window openings;
- Interfaces of longitudinal and cross walls;
- Connections between walls and ceilings;
- Pediments and other acting sites of walls;
- Interfaces of antiseismic belts and ceilings

It is necessary to apply the following ways to strengthening of stone and brick buildings;
- device of "shirt" from one or two sides;
- device of metal or reinforced-concrete holders:
. application of strained vertical and horizontal metal belts rigid or flexible;
- introduction additional rigidity cores as diaphragm, frames etc.;
- device of special connections as anchors, etc.
Gunit covering by wire mesh allows to increase bearing ability and rigidity up to design level of constructions as a whole.

Wire mesh reinforcement established on both sides of wall, incorporate with each other through apertures drilled in walls. Before strengthening brickwork should be cleared from plaster. Metal holders are carried out from strip, angular and round steel. Vertical rods in corners of apertures are established on mortar and welded by strip elements. The step of cross armature of reinforced-concrete holders is recommended to be accepted by calculation, but no more than 150 mm. Thickness of a holder also is established on the basis of calculation within the limits of 50-100 mm. Thickness of mortar on reinforced "shirts" is accepted no more 40 mm.

In case of excess of the distance established by norms, between cross bearing walls, it is necessary to reduce it up to normative sizes by installation of additional internal walls or frames replacing them.

For provision of reliability of connection of walls of various directions use of horizontal metal connections is recommended. Connections are carried out from rod armature, passed through the apertures drilled in laying. The ends of connections placed along surfaces of internal walls, are welded on the horizontal strips placed on both sides of internal wall and connected with each other by means of metal cores or bolts. In case of absence of antiseismic belts in a building their device from the metal channels connected among themselves, with walls and plates of ceilings is necessary.

Connection of ceilings with walls is provided with installation of bracings from the metal cores passed through horizontal apertures in walls in a level of top of ceiling. On perimeter of building in a level of top of ceiling the antiseismic belt from channels is arranged. A channel fasten to walls by means of metal anchors.

Rigidity of disks of ceilings, their teamwork with elements of building can be provided with the device of strained horizontal and vertical belts.

Adobe and stone materials buildings

Reinforcement of buildings from adobe materials recommended to provide based on creation of conditions for joint work of building elements unified as a whole, the 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.

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. 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.

The new provisions were placed taking into account the general bad behavior of this kind of building observed in the recent earthquakes.

Special training programs for children about living more safely with the natural hazards around them, as part of their basic lifeskills education, including their behaviour before an earthquake, during and after it, and their understanding of seismic hazard and mitigation of risk have been undertaken.

For most typical school building types – RC frame panel and masonry were developed planes with pointed out safety places in case of earthquake

Thus depending on constructive type of school building, its technical condition, the volume of retrofit may be varied over wide range. For buildings from various constructive systems, degree of damageability 3 may be accepted as a limiting condition, as at this level of damage after earthquake building keep the maintainability, and not lead to life loss for children.

The recommended concept and implementation of strengthening of existing school buildings allow to increase essentially the level of earthquake safety of school buildings and children.

Experience of Uzbekistan on restoration and strengthening of existing school buildings of various constructive systems, including low strength materials, reinforcement of buildings damaged by earthquakes, can be useful to the countries with similar seismic and natural conditions of their territories.