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SEISMIC STRENGTHENING OF NON-ENGINEERED SCHOOL BUILDING IN STONE MASONRY IN THE STATE OF GUJARAT

Chandrark Bhavsar[1], Ms.Megha Bhatt [2]

[1]PG Student, M.E.(Civil) Infrastructure Engineering, L.D.R.P. Institute of Technology & Research, Gandhinagar
[2] Faculty, Dept. of Civil Engineering, L.D.R.P. Institute of Technology & Research , Gandhinagar, Gujarat

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Abstract - *Non-engineered buildings are commonly adopted practice in the state of Gujarat and also across the country. This is happened because of lack of information and scarcely available trained and skilled artisans and civil engineers. Majority of the dwelling units, schools, PHC are constructed with locally available materials like random rubbles stones or course rubbles and burnt clay bricks manufactured locally, with the help of local masons and carpenters without deploying engineer Walling units being constructed from random rubble in cement or lime mortar are very heavy and unstable and not good in bending hence tendency to fall or collapse of the wall and roofing structure or slab. Under the seismic forces the wooden understructure with earthen Tiled roof exerts the seismic forces to the top of the walling section. The walls inner and outer faces delaminate and collapse and become highly vulnerable for human life living inside. Seismic strengthening techniques like, Welded wire mesh belts in horizontal and vertical direction, gable bend, corner reinforcement steel, diagonal anchor wire bracing fixing are used to imparts proper interconnectivity of the building elements and thus provide flexibility of the entire building to transmit forces and to withstand in even future earthquake.*

The purpose of this project is mainly to illustrate how effectively execution can be implemented for buildings constructed with locally available random rubble stone masonry in cement sand mortar or cement lime mortar or even with mud mortar. The method also gives idea regarding the use of minimum of materials and simplicity of execution by local artisans with minimum of training.

***Key Words*: Non Engineered, Random Rubble, Concrete Header, Seismic belt , Gable bend, welded wire mesh, Wire Bracing**

1. INTRODUCTION

Non engineered building:

When any non engineered building which is primarily a load bearing structure, constructed with locally available materials and by artisans with poor technical information and without proper supervision by engineer is consider highly vulnerable building during earthquake of little higher magnitude. This was being observed by the state of Gujarat during Bhuj earth quake,26th January,2001. Most of the non engineered building collapsed in the event happened and reportedly highest order of building collapsed and human life loss in the state of the Gujarat. During the 12th World Conference on Earthquake Engineering New Zealand, A.S. Arya presented the often quoted definition for non-engineered buildings as “those which are spontaneously and informally constructed in various countries in the traditional manner, without any or little intervention by qualified architects and engineers in their design” (Arya, 2000).

The school buildings constructed with non engineered way, proved highly vulnerable. The loss of life of school children due to collapse of the non engineered building in the event of earthquake is an engineering challenge needs to be addressed at all levels. Variety of damages observed in the school buildings constructed with stone in cement mortar or stone in lime mortar can be explained in the following manner.

1.1 Damage To Specific Wall Types

(a) Bulging of UCR masonry:

When header or through stones are not provided in sufficient numbers and due to poorly interlocked two adjacent walls making a corner of the building is poor, the heavy stone walls tend to separate. The beginning of this process significantly visible through a bulge in the wall.

(b) Delamination of UCR masonry

This is observed subsequently to bulging in which a portion of any adjacent walls separates from the other wall and collapses. This is clearly due to the absence of through/ header stones.

(c) Delamination of Thick Brick Masonry

The brick walls with higher thickness and courses are constructed with poor workmanship and interlocking through the use of a proper bonding pattern using headers and stretchers is not followed the thick walls tend to separate in brick walls also just like in UCR

(UCR: Un coursed Rubble masonry)

1.2 Damage To Specific Roof Types

The damage to the roof depends on the type of roof and materials used.

(a) Clay Tiled pitched roof

The clay tile pitched roof experienced maximum damage. Since the roof elements starting from the tiles to purlins, rafters and beams are simply put in position with no or weak connection with the element under it. Those resting on the walls are not anchored to the walls, the roof as well as the walls supporting them fell apart. The connection between the rafters and the beams also are marginal. The movement in the roof, in-plane and out of plane, simply pulls apart the elements from each other. Under the impact of an earthquake, such items simply collapse.

(b) Joist and Plank Roof

In the traditional joist and plank system the joists are simply placed on the walls without any anchoring to the walls. The wooden or stone planks are placed on joists with connection that is inadequate to hold the elements together. As a result in the event of an earthquake the joists simply separate from the main structure. This leads to the separation between the joists and the panels supporting them. All this amounts to the absence of lack of diaphragm action. As a result the lateral shear creates cracks in the walls, especially when the band is absent.

(c) RCC Slab Roof

The RCC slab has very high rigidity in its own plane. It also has much higher mass when compared to a tiled roof. As a result the roof imparts high lateral shear on to the walls. If the walls are weak they could easily develop racking shear cracks that are diagonal.

A portion of the slab roof collapses in the event of the collapse of the wall supporting it.

The RCC Slabs built in the rural areas are not built scientifically. The details find no place in their execution. Typically in the country a large number builders in the rural areas simply have little or no knowledge of the cranking of the slab reinforcement. As a result the slabs crack in the top surface when there is any upward movement due to an earthquake.

1.3 Weaknesses and causes in Load Bearing Construction

Table-1

No	Bldg. Element	Weakness	Cause
1	Masonry Walls	Vertical cracks	Bending Due to lateral shear
2		Diagonal cracks	Pulling due to racking or in-plane shear
3		Cracked Corner	Poor wall to wall connection
4		Horizontal cracks	Lateral Bending
5		Gable wall Collapse	Unrestrained free standing wall
6		Bearing Failure	Absence of bearing blocks
7	UCR masonry walls	De lamination or Bulging	Absence or shortage of through stones
8	Thick BBMM walls	De lamination or Bulging	Absence of Headers
9	Tiled Pitched Roof	Roof distortion	Absence of in-plane stiffness
10		Roof member separation	Inadequate connections
11		Tiles falling off at eave	No anchoring for tiles
12	RCC Slab	Sliding	Absence of connection with walls
13	Stone on joist floor	Separation of elements	No connection between elements and absence of diagonal ties
14	Stone on Joists roof	Separation of elements	No connection between elements and absence of diagonal ties.

2. SEISMIC STRENGTHENING TECHNIQUES

(a) For Walls

(1) Header stone :URM or in stone masonry walls ,stone Stitching the outer and inner wythes (stone layers) of the stone walls by the installation of reinforced concrete *headers* or ‘bond’ elements to serve as `through’ stones, so as to prevent de lamination.

Figure-1. Wall with Header Stone

Fig-1: Wall with Header stone

(2) Horizontal and Vertical seismic Belts

It is provided to ensure the action of the walls together to resist the lateral seismic forces effect on the entire building preventing the separation of the walls at the corners of the building, and installing cross ties across rooms connecting the seismic belts on the opposite walls. These ties acting in conjunction with the belt will hold the opposite walls together to improve the integrating action of the bands further. Similarly Vertical belts also provided connecting and stretching up to all all levels of horizontal belts to the foundation of the wall footing.

Welded wire mesh belts is provided for the same along with 6 mm steel wires fixed to the wall with masons nails and washers. This will allow the belts in their proper horizontal and vertical position.

Fig-2: Horizontal and Vertical Seismic Belts

(3) Gable Bends:

For wall height above lintel levels , where double pitched heavy joist and purlin truss is rested on the lintels and walls and gable ends being heavy stone masonry construction, Gable shaped welded wire mesh belt is also provided in the same manner as that of the horizontal and vertical seismic belts and also they are to be fixed with each other. This arrangement provide maximum integrity to the high walls constructed in stone and with heavy roofing system.

Fig-3: Gable Bends

(4) Corner Belt with Reinforcement

To prevent separation of two adjoining wall , corner belt along with vertical reinforcement of 6mm diameter is to be fixed with masons nail and washer

Fig-4: Corner belt with vertical reinforcement

(b) For Roof

(1) Wooden in-plane Bracings and wire Tie

For Pitched roof with wooden joist , purlin and rafter type of roof with clay tiles or Manglore pattern tiles , cross wooden bracing is to be provided to fix all the members from the bottom and ties with galvanized wire.

Fig-5: Wooden in-plane Bracing

3. CONCLUSIONS

In the state of Gujarat before Bhuj earthquake 2001, were built in stone masonry with lime mortar or with cement mortar. Major government schools are fall in the same category and with locally available stone and pitched roof with wooden understructure and clay tile as roofing material. Seismic strengthening or retrofitting can proved to be a viable solution as the techniques are very simple , easily replicable and local artisan can perform better with very limited training. As the techniques involved minimum use of locally available materials like , welded wire mesh, steel bars, masons nail, cement sand mortar. Gujarat state have implemented a program for repairs and retrofitting and seismic strengthening of school buildings in stone masonry and successfully completed many schools in the remotely located area heavily affected during earthquake of 2001 in kutchch and Saurastra.

It is also evident that as demonstrative model, the other non engineered buildings like PHC, Creche buildings and Post offices were also strengthen against future earthquake safe building for public use.

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