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DAMAGE TO BUILDINGS DURING DECEMBER 31, 1984 CACHAR EARTHQUAKE, NORTHEAST INDIA

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ABSTRACT

The paper reports in detail the damage to buildings during the December 31, 1984 Cachar earthquake in Northeast India. The mud houses were damaged badly and their collapse caused 13 deaths. The Assam type construction using brick masonry has mainly suffered damage to masonry portions. The light timber construction has generally been tilted due to absence of diagonal bracings and not burying the timber posts into the ground. A detailed discussion and the possible inferences which will be helpful in future construction are given.

KEY WORDS : Earthquake Damage Survey, Building Damage, Cachar Earthquake.

INTRODUCTION

The media reported extensive loss of life and property due to an earthquake in Bangladesh - India border region on December 31, 1984 and January 1, 1985. The Indian towns in the news were Silchar and Lakhipur. Map in figure 1 shows the area under reference and the epicentre of the December 31, 1984 Cachar earthquake of magnitude 5.6.

The total number of deaths due to this earthquake is reported to be thirteen. Both the Silchar and LaKhipur towns are about 15 km away from the epicentre. There was not much construction in the epicentral region and therefore it had experienced damage mostly to the ground only. Sonaimukh was the nearest locality with several buildings which suffered considerable damage The area is economically not well developed. The epicentral area is very fertile and is under cultivation. Generally the top soil is unconsolidated, cohesive and coarse mixed with fine grains. There are thin layers of fine impervious and coarse porous and permeable soil at different depths and the water table is shallow. All these conditions make poor foundation conditions for most construction.

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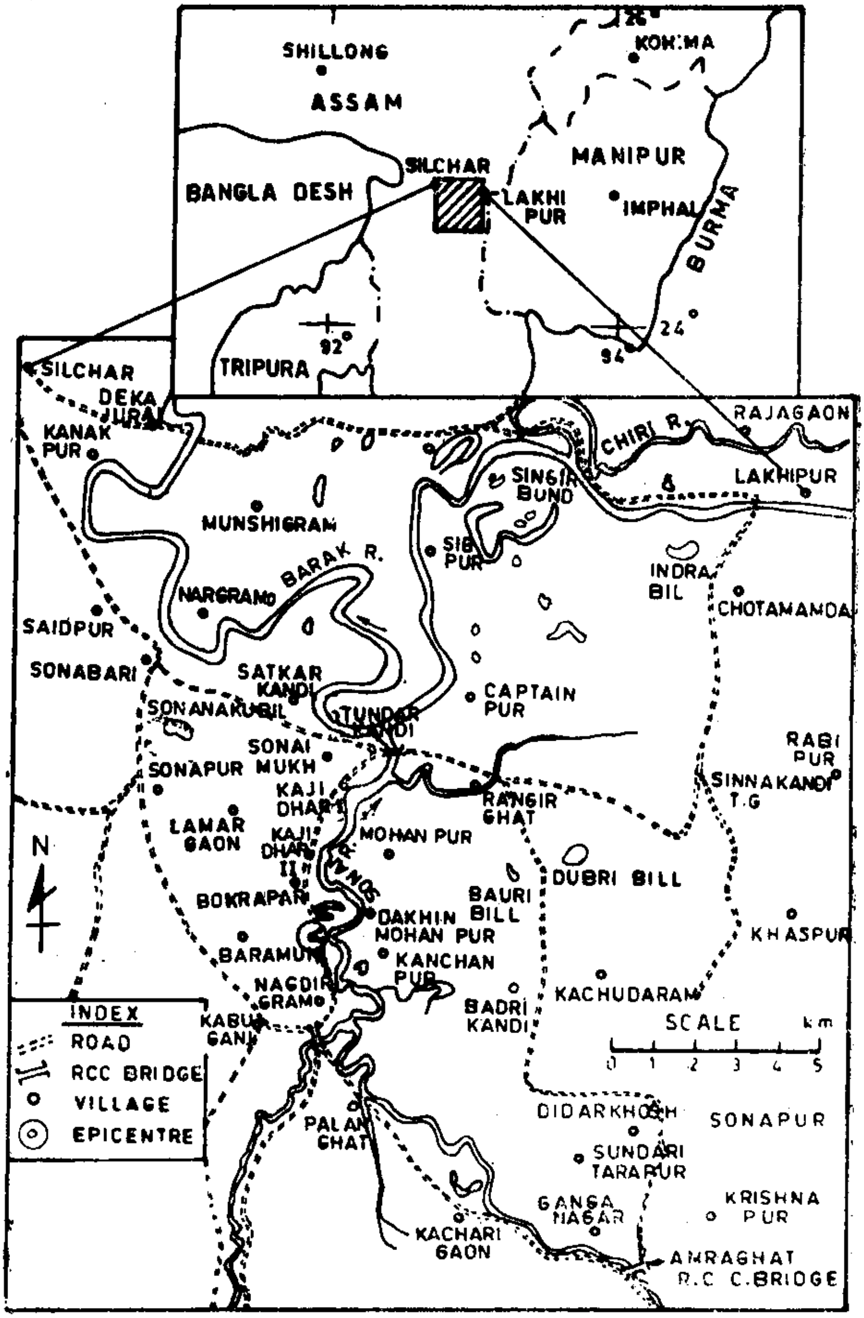

Fig. 1. A Map of area affected by December 31, 1984 earthquake and it epicentre.

People in the area are familiar to earthquake occurrence and their effects. The other natural hazard more frequently troubling them are the occurrence of cyclonic storms entering the area from the Bay of Bengal. Naturally, common people are more concerned about the safety, during these storms and are not so well prepared for the consequences of the less frequent earthquakes. The traditional Assam type construction used in the area has been modified to impove its performance in storms by use of brick-masonry and poor people have even adopted building mud houses.

A damage survey was conducted by the author from January 5 to 12, 1985. The ground failure, damage to two well designed and constructed RCC bridges, results of microearthquake recording and the isoseismal map are being compiled for publication separately (Agrawal, 1986). This paper includes details on the damage to buildings. The inferences which may provide improvement in the future construction are also discussed.

EXISTING BUILDING CONSTRUCTION

Most of the residential buildings were non engineered construction. The mud houses having simple plans consisting of one or two rooms with verandha and generally on raised plinth have suffered greater damage. The thached roof on well made timber cum bamboo frames are steeply slanting with maximum height at its central edge as much as 5 to 6 m and the side walls usually of 3 to 4 m height. The roofs are generally so designed in prismatic forms that the gable walls are not required. The sun dried lumps of approximate size 40 x 25 x 25 cm with mud morter and mud plaster have been used in the walls generally making them about 50 cm thick. The history of construction of such houses in the region is not more than half a century old and are introduced by the immigrants from Bihar to ensure impoved performance, due to their larger dead weight, in frequently occurring cyclonic stroms.

The traditional construction is using timber frames with walls n bamboo-ikra penels and mud plaster generally referred as Assam type construction. Such construction does not fair very well during the severe cyclonic stroms due to its light weight. Assam type construction mixed with brick masonary construction upto window level or upto lintel level and even totally replacing the bamboo-ikra walls has been lately prevalent perhaps to improve their performance during the cyclonic stroms. Generally the damage to such buildings is restricted to the brick masonry sections. Another common type of construction is the timber frames with walls in bamboo mats or timber. Such buildings have been generally tilted.

There were number of mosques constructed in brick-mud-masonry with lime-surkhi or cement plastering. The walls were thick and have high-flat ceilings supported on timber beams. The RCC frame coustruction is almost missing with the exception of few small size shops and two small partly incomplete buildings at Sonaimukh. One or two tubular steel sheds were existing. The hospital building at Sonaimukh was of relatively new Assam type with more careful construction.

DAMAGE OF BUILDINGS

The mud houses suffered very severe damage at various localities the farthest from the epicentre being Lakhipur and Chotamamda. It was impossible to find even one mud house which had escaped damage. Figure 2 shows a mud house at Kajidhar II whose walls have failed and fell inside killing five persons sleeping in the house. Generally the roofs of these mud houses were so well costructed that even with severe damage to walls the roofs mostly remained undamaged. Only after earthquake damage to walls the roof material is being removed for its reuse for new construction. Figure 3 shows that the damage is concentrated at opening in the walls from where vertical cracks have extended in the total height. Figure4 shows a mud house at Chotamamda where the wall collapse killed three people sleeping inside. This house is one of those few examples where the roof had also failed and collapsed. Another house in figure 5 also clearly show the development of mostly vertical cracks in the mud houses. The corner is damaged more due to the separation of the two walls. Generally the damage has been more or less uniformly distributed along the longer walls. For some houses the roof of the verandha on timber posts has been tilted and efforts to restore them to original condition were in progress.

There were several timber sheds with roofs of G.I. sheets at Sonaimukh. The one in figure 6 is a large one about 30×10 m for the daily market at Sonaimukh and had been tilted by about 30°. It has been partly restored to verticality with the help of inclined timber supports. Much more flexible and small shed with two diagonal braces in figure 7 did not get damaged At this location the adjoining mud houses were badly damaged. Figure 8 shows the damage to a house using walls in bamboo mating. A long row of shops seen in figure 9 with timber construction, G I roofs and bamboo matting wall has been tilted by as much as 45°. An individual store room at Sonaimukh rest house in figure 10 has been tilted. In figure 11 a shop with tiled roof has been tilted where as the adjoining similar one with roof of G.I. sheets has remained undamaged.

The damage to Assam type construction was generally limited to the brick masonry portions. Figure 12 shows the damage to brick masonry

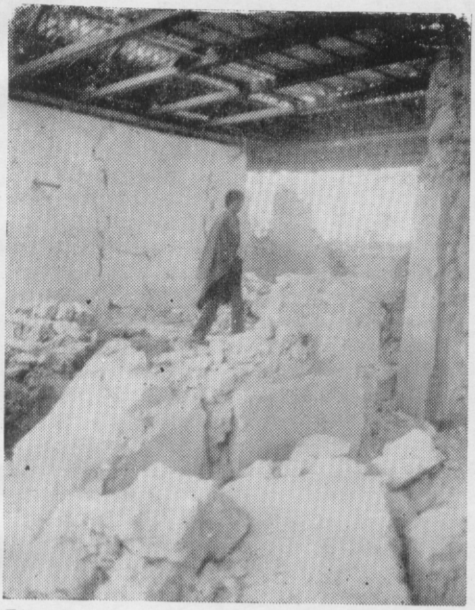

Fig. 2. Damage to mud house with thick walls and thached roof of very good timber cum bamboo frame at Kajdhar II-five people sleeping inside buried to death due to collapse of walls in this house.

Fig. 3 A mud house at Sonaimukh whose longer wall has been damaged-cracks have travelled from the openings more or less vertically perhaps top to bottom.

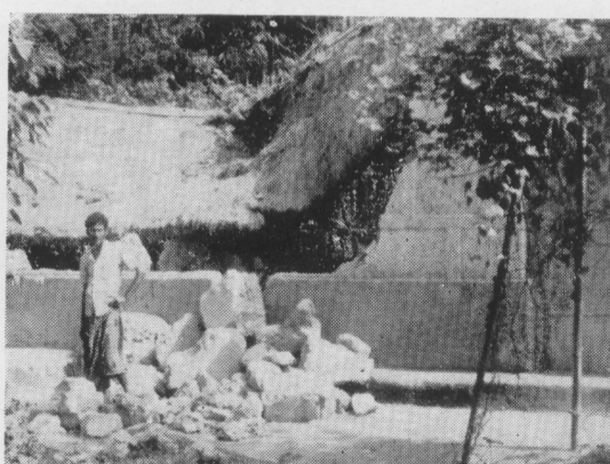

Fig. 4. Mud house at Chotamamda with thached roof whose collapse of a wall led to death of three persons inside-this is one of those few examples where the roof had also been broken.

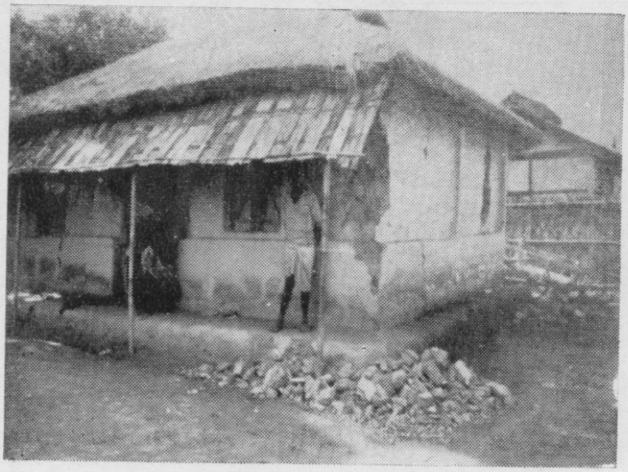

Fig. 5. More or less vertical cracks in the walls of mud houses and failure at the junction of the walls at Sonaimukh.

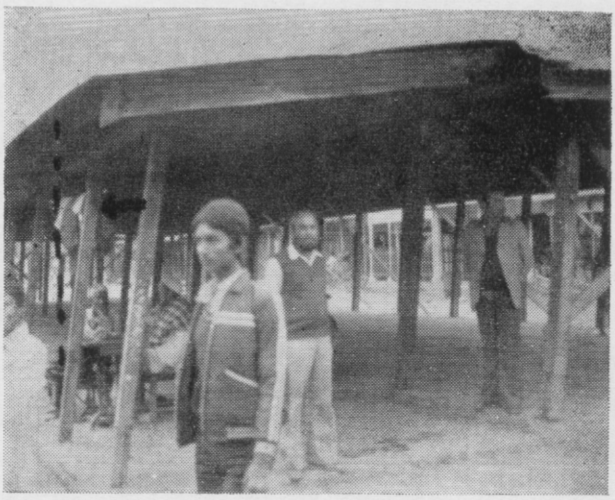

Fig. 6. 30 × 10m timber shed for daily market at Sonaimukh was tilted by about 30° market is being restored to verticality.

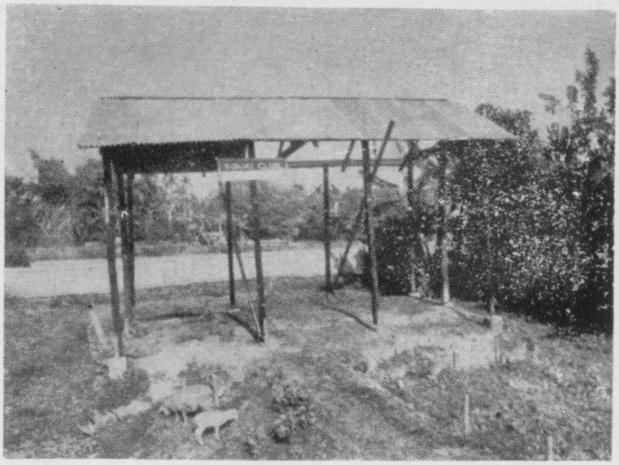

Fig. 7. 9×6 mm timber shed at Sonaimukh with only two cross diagonal braces in adjacent bays remained undamaged.

Fig. 8. A thached hut with walls in bamboo mat and mud plaster is tilted and mud plaster is partly peeled off.

Fig. 9. Tilting of a row of shops in the Sonaimukh market-efforts to restore them to vertical by giving supports as in photograph were already in progress.

Fig. 10. Tilting of a very light hut in timber and bamboo at the compound of Sonaimukh inspection house.

Fig. 11. Tilting of yet another individual shop with roof in tiles.

Fig. 12. Damage to the school building at Satakarkandi-the brick masonry below window level has failed at corner and at other places as indicated.

Fig. 13. Very extensive damage to a timber cum brick masonry building of school at Sonaimukh-the tilted door hangs with masonry due to lintel level reinforcement.

Fig 14. A view from left side of the building in figure 13-the broken masonry generally showed shearing of the bricks rather than spliting along the plaster.

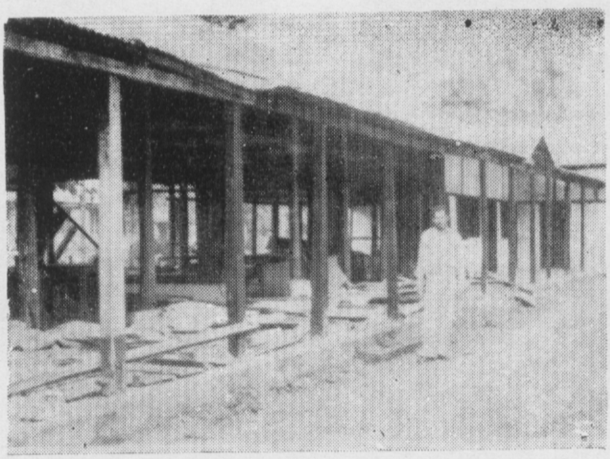

Fig. 15. Complete collapse of brick masonry walls (including partition walls) in a school building at Sonaimukh-some wooden window frames remained hanging on the rear face.

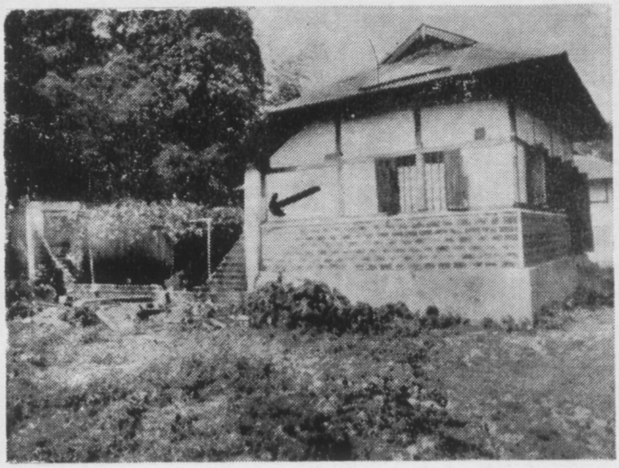

Fig. 16. Separation of column from the wall and collapse of the backyard wall in brick masonry.

Fig. 17. Closeup of the left end of the back yard in figure 16 and damage to the beam along the door.

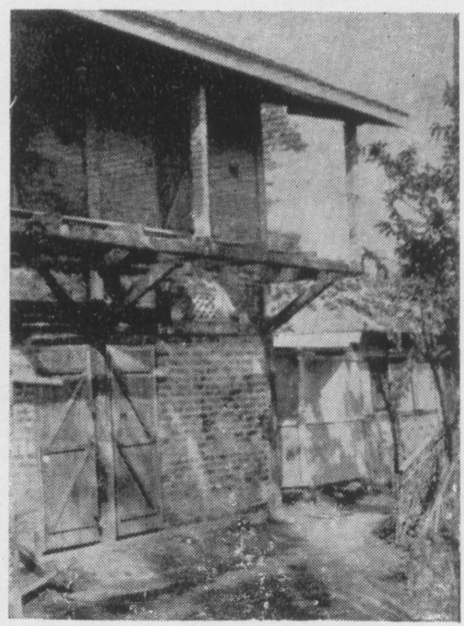

Fig. 19. An undamaged RCC frame building with brick masonry filler walls close to most extensive ground failure at Sonaimukh.

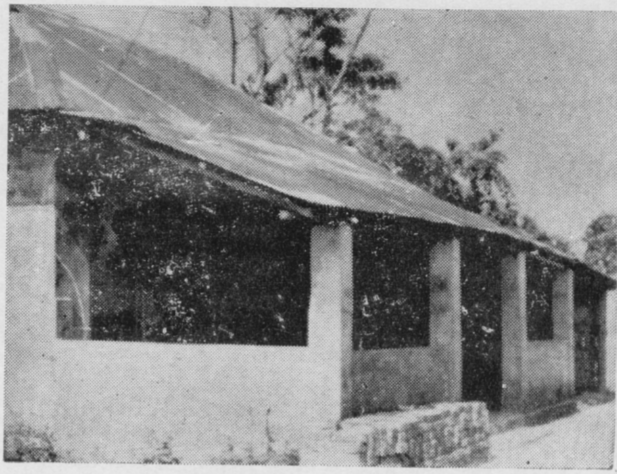

Fig. 18. Failure of the column at its mid height in a brick masonry building.

Fig. 21. Damage to a tubular steel frame shed with brick masonry filler walls-the steel-barties have served as hinges for the broken wall.

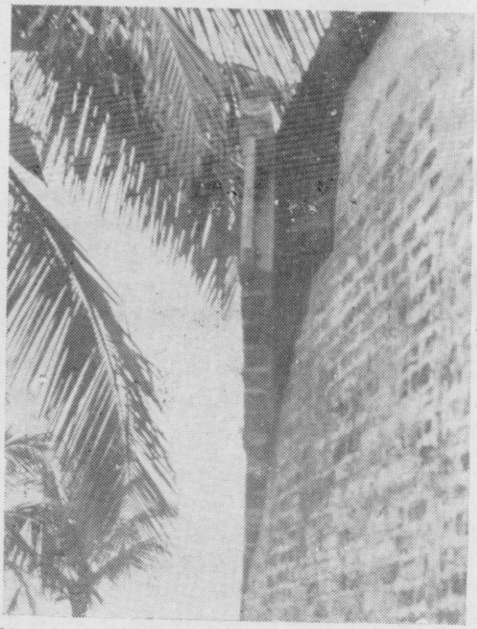

Fig 22. The same shed as in figure 21 but its face towards the hillock top-the two damaged corners are diagonally opposite.

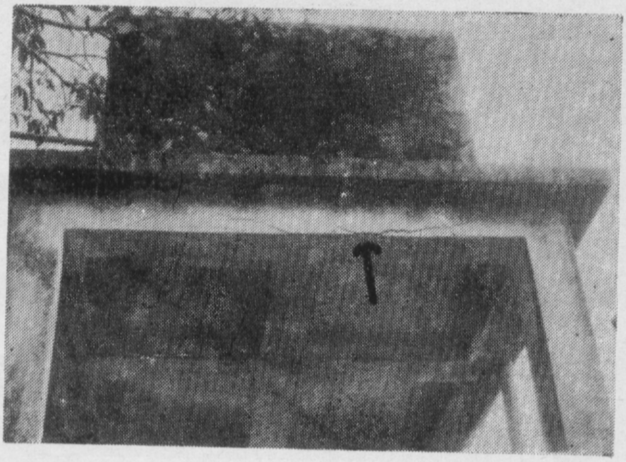

Fig. 20. Damage to RCC beam supporting a water tank at Sonaimukh.

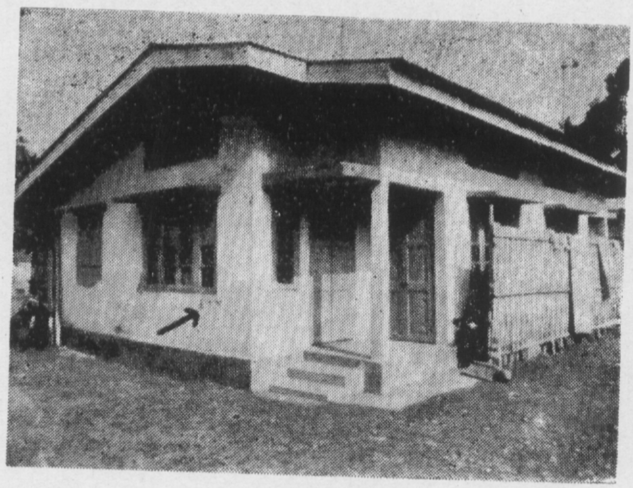

Fig. 23. Residential quarter at Sonaimukh Police station just adjacent to Barak river bank's major failure-only minor plaster crack below window level.

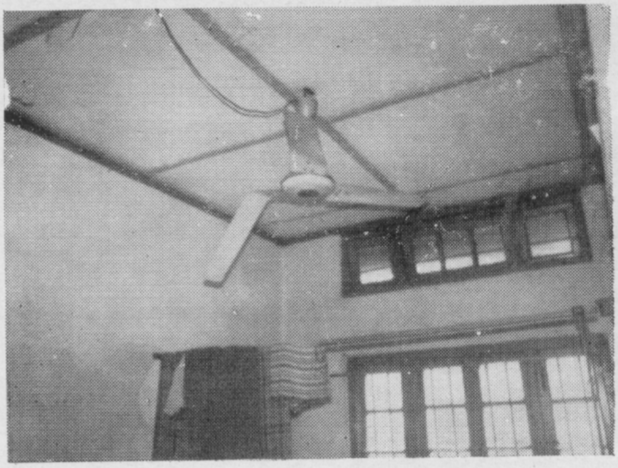

Fig. 24. Bending of fan blades in the buildi g in figure 23-some evidences of slipping of false ceiling attached to roof above the ventilator were seen.

Fig. 25. Close up of the slide surface between ceiling and walls of the building in figures 23 and 24.

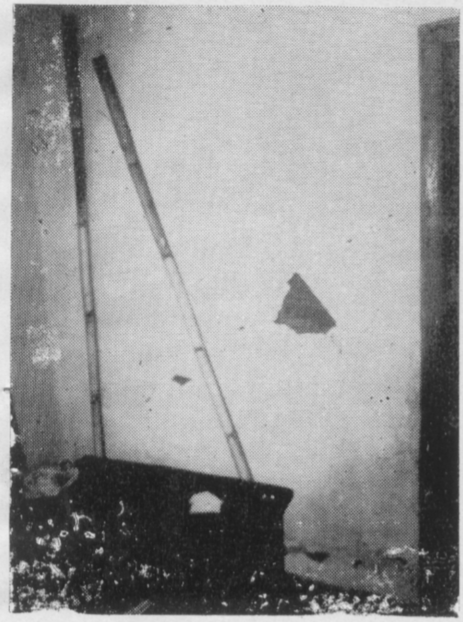

Fig. 26. Damage to plaster inside the building in figure 23.

Fig. 27. Damage to a very old Shiva temple in brick masonry.

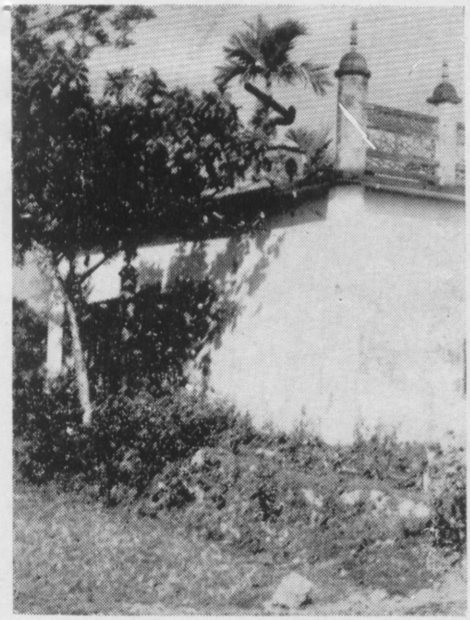

Fig. 28. Collapse of the rear parapet over the roof in a mosque at Kajidhar II.

Fig. 29. Failure of columns of a mosque building at Bokrapar.

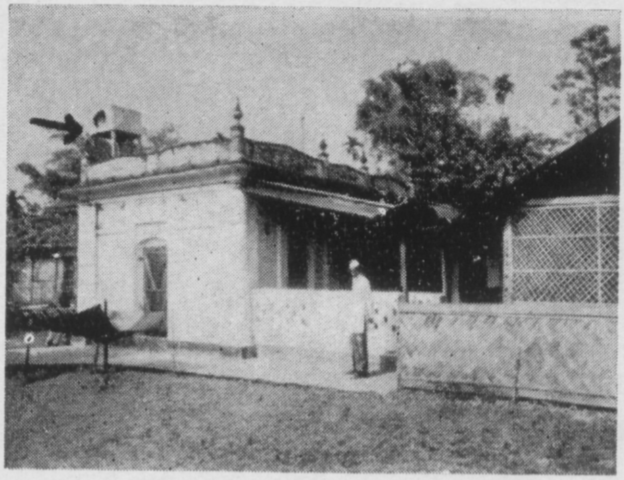

Fig. 30. The loudspeaker stand on the roof of a mosque at Sonaimukh was tilted.

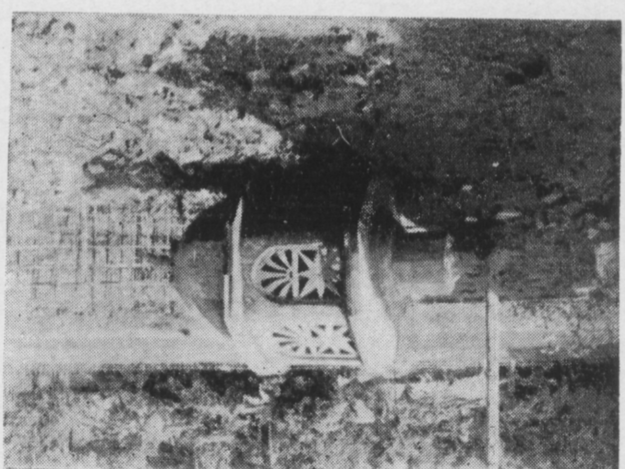

Fig. 31. Fall of one broken minar of a mosque.

below the window level in the school building at Satkarkandi. Figures 13 and 14 are for the school building at Sonaimukn in which masonry extended to ventilator height. The lintel level reinforcement has partly held back from falling the broken and tilted wall. It was interesting to note that the broken masonry wall did not show failure of the morter joints but mostly the shearing of the bricks. Figure 15 is another school block at Sonaimukh where both the longitudinal walls and most cross walls have been raised to ground whereas the timber shed stands vertically. Few windows on the rear wall were left hanging from the lintel level. Figure 16 shows a house at Sonaimukh where the damage is more to the backyard boundary wall and its junction with the building. A close up of the small cabin on left side is shown in figure 17 where even beam has been damaged. The columns of a brick masonry building with G.I. roof have failed at roughly their mid height but escaped falling as seen in figure 18.

An incomplete building with RCC frame seen in figure 19, and close to the major ground damage area along Barak river behind Sonaimukh Police station station, has remained undamaged. Two shops in some what similar RCC construction in Sonaimukh market had, however, some minor cracks in filler walls and in one of the beams at lintel level. A frame to support a water tank at Sonaimukh in figure 20 had also some what similar damage to RCC beams. A tubular steel frame construction with filler walls in brick masonry is seen in figures 21 and 22. This was located at a hillock near B.D.O's office at Sonaimukh. Damage to two diagonally opposite corners of this building is shown. The broken and separated walls have swung like hinged doors due to steel bar ties going around the corner steel pipes and embeded in the masonry. The walls have broken not along the plaster joints but through the bricks can also be noticed for this building.

A residential building in the Sonaimukh Police station compound as shown in figures 23 to 26 had minor damage. The outside plastering had cracked close to window frames and also the inside plaster on filler walls had diagcnal cracks. An interesting damage to the ceiling fan, i.e. bending of its blades in seen in figure 24. There were evidences of large relative displacements between the roof and the walls at the level above ventilator as seen is figure 25. Similar bending of fan blades was seen for atleast a dozen fans in the Sonaimukh school building.

Figure 27 shows damage to Shiva temple reported to be over 300 years old. An adjoining flexible shed, similar to one in figure 7 with diagonal braces, did not suffer any damage. Number of well constructed mosques had been damaged. Figure 28 shows the collapse of the rear portion of parapet on the roof of a mosque at Kajidhar II. Some minor plaster cracks inside and on columns at their junctions with arches could also be seen like for another mosque shown in figure 29. A very well constructed and maintained mosque again at Kajidhar II had been split into two all throughout perhaps as a result of 300 m long ground rupture below the mosque. Figure 30 shows the tilting of the loudspeaker stand at the roof top of mosque at Sonaimukh which had happened at number of distant localities also. Figure 31 shows the broken top of a minar on a mosque which has been thrown apart and is seen lying on the ground. Few mosques even in the localities of greater damage had escaped damage whereas a mouslim Peer at Phluretal near Lakhipur had also been badly damaged.

DISCUSSION ON BUILDING DAMAGE

The construction of mud houses by the Bihari immigrants to ensure safety against cyclonic stroms has not been found suitable for the earthquake shaking. Fortunately, the roofs have mostly remained undamaged otherwise it would have further, added to the fatalities. The poor people have found them more economical as mud being the main construction material is available free of cost making them cheaper to even bamboo huts. Another advantage is that ordinary peaple can do most construction by themselves. The current practice of mud construction is not at all suitable to the natural environment and needs substantial improvements. Prismatic roof design dispensing with the need of gable walls is a good feature. The use of braced timber frames with mud filler walls, use of bamboo matting as reinforcement in mud walls and reduction of free wall height by providing lintel level timber or bamboo bands are some of the simple possible improvements. The aseismic features of Dhajji-dewari mud construction of Kashmir Valley can be adopted with advantage in this region also. Unlike Kashmir where mud construction is preferred for thermal stability here it would be to provide greater safety during cyclonic storms. The relative suitability, practicability and economy of these and several such other alternatives will have to be worked out and the recommendations evolved will have to be popularised amongst residents.

Assam type construction seems most suited for the area. The use of brick masonry in walls to increase the dead weight of the building and improve its stability during cyclonic storms is a good idea but its use has to be improved with respect to the placement of masonry and its interconnections with timber members. The horizontal continuity in masonry walls created by placing them outside the timber columns/frames, most conspicous example of which was seen in Sonaimukh school building has proved to be very hazardous. Placing of masonry walls inside the timber panels with suitable interconnections would have substantially reduced the damage during the earthquake under study.

Use of diagonal braces in timber construction is essential. Even the good Assam type construction requires effective use of the diagonal bracings. The tilting of several shops, houses and sheds could have been avoided. It is also seen that the timber columns in such construction are made just to rest on ground or connected to a short masonry or RCC base with the help of steel flats. The burying of columns to one third or half the height of the building is recommended to increase its lateral stability and to eliminate the possibility of tilting. Such practice is common in coastal areas where the huts have greater flexibility due to higher floors to take care of high tide conditions. The heavier roof on one shop in figure 11 made it to tilt whereas the other adjoining one with lighter roof remained vertical. This kind of damage could be avoided if the suggestions made here are adopted.

Generally the ceilings in the buildings in the area are much higher. This is because of higher rainfall demanding greater roof slopes. In such buildings the free wall heights must be reduced by use of suitably placed horizontal ties. The damage to tubular steel construction in figures 21 and 22 could be avoided if suitably placed horizontal steel or timber members were used in the walls.

The free placement of roofs on the walls, even to allow its sliding, as in seen is the building in figure 25 is not a good practice, Suitably placed connections between the roof and walls would improve the overall strength of the building as a whole. Even in the mud construction the vertical bending cracks in the walls could be considerably reduced if the roofs were fixed to walls along their lengths at few points. A reference to the Manual of Earthquake Resistant Non-Engineered Construction would be found useful for these aspects discussed here.

The bricks used in the area are found not to possess the desired strength. The mortar used has been generally of good quality not allowing the mortar joints to be opened up. Improvements are required in the shear strength of the bricks which may be possible by their better burning, may be adding some other soil to take care of possible chemical deficiencies, etc. This in itself is an important aspect of the construction in the area and suitable test and studies are required.

CONCLUSION

On the basis of the foregoing account the following conclusions are made and their adoption will prove to be of advantage;

1. The mud houses being constructed in the region are not satisfactory and need careful consideration to allow selection of their suitable and improved designs.

2. Assam type construction with brick masonry suitably placed and connected to timber panels/frames seems most suited for the region.

3. Use of diagonal braces and burying of timber/bamboo columns into the ground would improve the lateral stability and the observed tilting of buildings could be avoided.

4. It is recommended that the roofs be connected to walls at number of places rather than to make them freely rest on them. This would increase the overall strength of the buildings.

5. The shear strength of the bricks in use in the region needs to be tested and improved.

6. A false sense of security allowing the residents to use damaged buildings and making inadequate repairs could be hazardous even in case of recurrence of a similar event.

ACKNOWLEDGEMENTS

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