

Behaviour of old historical buildings during August 21, 1988, Bihar-Nepal earthquake

S.K.Thakkar & D.K.Paul
University of Roorkee, India

ABSTRACT: A moderate size earthquake with $M_B=6.4$ rocked Bihar-Nepal border at 4.40 hrs. on Aug. 21, 1988 causing wide spread devastation leading to loss of lives and property. This paper describes the damages occurred in several old historical buildings in the area. The deficiency of construction, causes of damage and observations from the performance of these structures are highlighted. The reconstruction of new structures and strengthening measures must take into consideration the experience of failure of structures.

INTRODUCTION

In early hours on August 21, 1988 an earthquake with $M_B=6.4$ occurred in Bihar-Nepal border region. This earthquake had shaken Northern Bihar and several towns of Nepal and caused wide spread devastation, loss of life and property. The earthquake was also reported felt at distant places like Assam, Tripura, West Bengal, Delhi and Roorkee. The Northern Bihar lies in seismic zone IV of India. The maximum Modified Mercalli Intensity in the epicentral track was estimated to be VII to VIII. Those people who witnessed the earthquake of 1934 and 1988 are of the view that the intensity of 1988 earthquake was no less than the 1934 one but lasted for much shorter duration which was one of the reasons of relatively less damage. The main shock was followed by number of after shocks.

There are many old structures particularly buildings in the area which have an important architectural, cultural, historical and monumental value. There were damages ranging from partial to total. Most of the buildings had also suffered 1934 earthquake of Bihar. This paper describes the damages occurred in old historical buildings. The deficiency of traditional construction, causes of damage and observations from performance of these structures are highlighted.

DAMAGE SURVEY

The damage survey of various historical structures with respect to

structural/nonstructural damage, materials of construction, type and quality of construction was made. The objective of survey was (i) to study performance of different types of construction, (ii) to identify causes of damage, and (iii) to highlight significant observations from the damage that are relevant for future protection and construction. In the earthquake of August 21, 1988, there has been varying degrees of damage from minor cracks to heavy damage in buildings, in some cases total collapse also occurred. The example of massive old buildings surveyed after earthquake were : Governor's residence, High court building, Old secretariat building, School buildings, Medical college hostel building, Nalanda archaeological remain, Mosques and Temples. The detailed report on the damage survey by Thakkar et. al (1988) gives detailed account of damages to various types of buildings and structures affected in the region. Herein, the highlights of damage in some selected old buildings are described.

TYPES OF CONSTRUCTION

The old masonry buildings are constructed in burnt brick in lime-surkhi mortar. The roofs consist of inclined tile roof on rafter. The arch construction in door and window openings and verandah openings are very common. The dome construction in brick masonry in historic buildings is also common. The building plans are rectangular and are not always symmetrical. The building heights range

from one to three storeys. Most buildings are massive and heavy weight structures. The foundation soil is of alluvial type.

EARTHQUAKE DAMAGE TO OLD BUILDINGS

The earthquake performance of old buildings in August 21, 1988 earthquake is described below :

Governor's residence, Patna (Photo 1): The massive three storeyed structure used for residence was constructed during 1916-1918. It is a load bearing wall construction with massive brick floors. The walls contain several load bearing arches of small to large span. This structure was subjected to 1934 earthquake which had caused only minor damages. The earthquake of 1988 did not produce any cracks in N-S direction in masonry arches. Nearly, all verandah arches, about 10m span on all floors oriented in approximately E-W direction developed cracks near the crown. The 15m span arch on the western side of building developed a large horizontal shear crack on one side just above the crown. The cracks are fine in general. The cracks also occurred in roof slab and false ceiling at several locations. The damages were mostly repairable.



Photo 1 Governor's residence, Patna (Horizontal crack over the arch in right half)

High court building, Patna (Photo 2): This is massive two storeyed structure constructed in 1917-18 having 50cm thick brick wall in lime mortar. The building has a large masonry dome on its top which developed cracks on its outer surface. The cracking also occurred on the outside walls. The damage was also observed in false roof all along the wall junction. The separation of walls at the corners and between the roof and the wall was observed. The cracks were observed on

several walls of the building. The building was also a heavy weight structure.

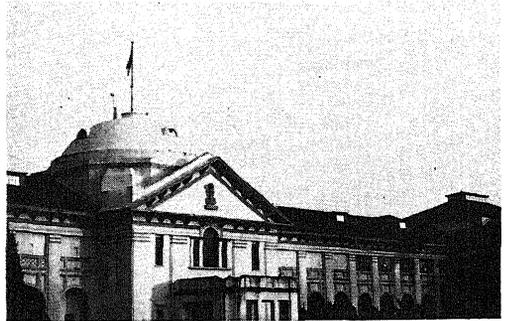


Photo 2 High court building, Patna. (Cracking of dome, walls, roof)

Old Secretariat, Patna (Photo 3): This is a massive two storeyed brick masonry structure in lime mortar constructed in 1916-18. The building consists of three main blocks connected with arch corridors. The building has a clock tower in the central block. The clock tower was damaged in 1934 earthquake, subsequently height of tower was reduced during reconstruction. The tie rods were used at the top in reconstruction. The clock tower did not show any damage as such during this earthquake but there was a slight crack in the wall where the girder was resting just above the clock at the top of the tower. The vertical cracks occurred near the crown of arches in both NS and EW direction.



Photo 3 Old secretariat, Patna (Walls and roof of left block cracked)

L.R. Girls High School, Darbhanga (Photo 4): This is a single storeyed

building in brick mortar approximately 70 to 80 years old. The school was damaged badly and was abandoned. The arches of the class room failed and there was extensive damage to the wall. The boundary wall was also badly damaged and collapsed at some portions.

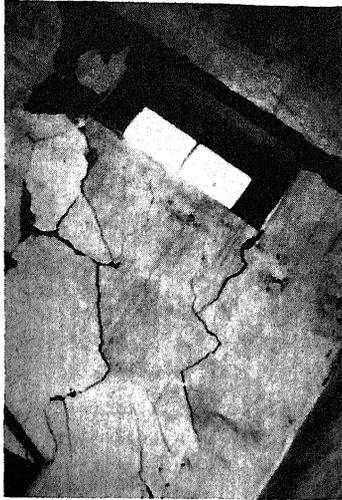


Photo 4 L.R.Girls High School, Darbhanga (Cracking of walls and roof)

Madarsa Hamedia, Qila Ghat, Darbhanga (Photo 5): This was an old single storey brick masonry building in L shape constructed in 1937. The building consists of fourteen class rooms (height 4.5m with 60cm thick brick wall) on either wing of 6.5 x 6.5m size. The building structure was a typical load bearing wall type of construction in lime mortar. The front portion of class room has a verandah corridor consisting of brick masonry arches resting on brick pillars. The roof of the class room consist of four small brick jack arches resting over steel girders. The arches of span 3.0m of the verandah got completely damaged in one wing and the class rooms were damaged beyond repair. The ties came out from the arches and the cross and longitudinal walls got separated at the corners. There were loss of lives in the collapse of this school building. The main reason of damage was due to the failure of verandah arch at one end due to lateral thrust and torsion of building which triggered a sequential failure of arches.

Medical College old hostel, Darbhanga (Photo 6): This is a two storeyed unsymmetrical brick masonry building built in 1927. There were 22 rooms on either side of staircase with jack arch roof. Front verandah consists of brick

masonry arches supported on brick pillars. The hostel was occupied by 180 students at the time of earthquake, only three students got injured. The first floor of the building was more severely damaged as compared to ground floor. One corner block of the building collapsed totally due to failure of corner arch. The damage to the other corner of building was also severe but did not collapse. The verandah arches had badly cracked near the crown.

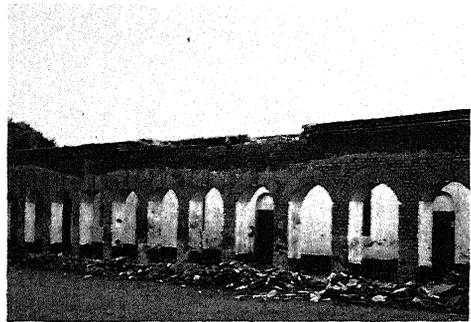


Photo 5 Madarsa Hamedia, Qila Ghat, Darbhanga (Cracking of walls and roof)



Photo 6 Medical College old hostel, Darbhanga (failure of arches, partial collapse)

Most of the walls along transverse direction of building showed diagonal cracks and in most cases the roof fell down. In other places, there was wide separation of walls at roof level. The roof consists of three small arches of

2m span and 30cm high resting on steel girders. The ties were used in some spans. The verandah showed severe damage all along, specially at the crown of arches. The arches on ground floor cracked badly in transverse direction whereas some arches in longitudinal direction were not damaged at all. The building was declared unsafe after the earthquake. The main reason of damage was due to failure of corner arches and torsion of building.

Nalanda Archaeological remain (Photo 7): The archaeological remain of Buddhist education centre, Nalanda University is in very bad shape which has developed cracks in the massive brick structure due to seepage of water. However, because of earthquake no damage was reported possibly due to its large distance from epicentre.

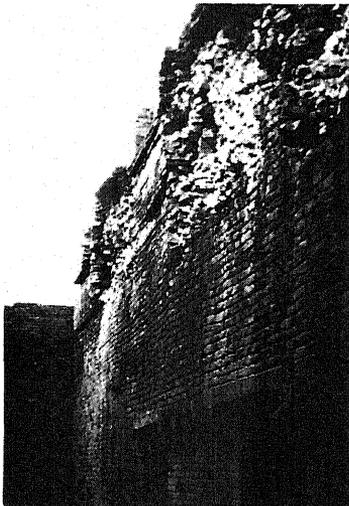


Photo 7 Nalanda Archaeological remain undamaged)

Jama Masjid, Darbhanga (Photo 8 & 9): This mosque was constructed in the year 1963. This was a brick masonry construction in cement mortar. The structure was severely damaged in this earthquake. One of the mehrab (domical portion) at the top was dislocated and hanging in a dangerous manner on eight 15cm size hexagonal columns. A horizontal shift of 7.5cm had taken place at the supporting level of dome on columns. The minarets of the structure were also badly damaged.

Shiva temple, Darbhanga (Photo 10): The arches of Shiva temple, a brick masonry structure (200 years old) developed cracks. The 20m diameter dome of the building was also cracked. The

separation was observed at the corner between verandah and temple walls. The vertical cracks at the corners were dominant. The temple was damaged in 1934 earthquake and subsequently repaired.

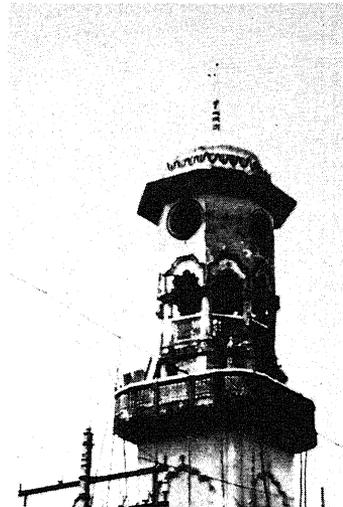


Photo 8 Jama Masjid, Darbhanga (top portion sheared, shifted to left)



Photo 9 Jama Masjid, Darbhanga (cracking at top of column/arch junction)

CAUSES OF DAMAGE OF OLD BRICK MASONRY BUILDINGS

The following causes of damage in brick masonry structures are identified:

(i) In old buildings, there was a deterioration of strength. Poor maintenance

has been the cause of failure in many cases.

(ii) The massive brick masonry buildings developed large inertia forces in earthquake. Such structures were brittle and had very low earthquake resistance.

(iii) No earthquake resistance measures were provided in old buildings.

(iv) The arch construction has been found to be weak and caused failure in most cases.

(v) The unsymmetrical buildings developed severe torsion and caused failure.



Photo 10 Shiva temple, Darbhanga (wide spread cracks in dome and arches)

LESSONS LEARNT FROM EARTHQUAKE DAMAGES

The following lessons are learnt from the observation of damages in Bihar-Nepal earthquake. These are relevant for future protection and construction.

(i) The old brick masonry buildings using traditional methods of construction are highly vulnerable to damage in earthquakes. The strengthening measures for future protection of these buildings in earthquake should be worked out.

(ii) The masonry arch and dome construction have been found to be weak under seismic conditions. Such construction should not be used to span bigger openings in new construction.

(iii) Poor quality of construction and poor maintenance has been the cause of failure in many cases. The rich mortar mix should be used in new construction.

(iv) The use of horizontal band at lintel level is most important in masonry buildings. The use of building

construction codes for incorporating earthquake resistance should be mandatory.

(v) Some damages of structures were associated with the liquefaction of soil. The proper design of foundation is very important to safeguard failures due to liquefaction.

CONCLUSIONS

The paper describes the salient features of damages in certain old brick masonry buildings in Bihar-Nepal earthquake of August 21, 1988. The possible reasons of damage are highlighted. The lessons learnt from this earthquake indicates the need to follow earthquake resistant measures more rigorously in planning and executing new construction. The use of masonry arch and dome construction should be avoided in new construction. Study of liquefiable soil of the region is necessary in order to bring improvements in foundation design.

REFERENCES

- Thakkar, S.K., Paul, D.K., Mukherjee, S., Bandyopadhyay, S., Kumar, A. & Lavania, B.V.K 1988, Damage Survey Report on Bihar-Nepal Earthquake of August 21, 1988, Department of Earthquake Engineering, University of Roorkee, Roorkee.

