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Record of Reinforced Brickwork in Indian Earthquake

Floors, ceilings and lintels were undamaged but in many cases were not tied in to connecting elements—Lack of reinforcement in vertical walls was a major cause of failure

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THE BIHAR EARTHQUAKE, felt over 3,000,000 sq.mi. of north India in January, 1934, was one of the notable seismic disturbances of recent times. Building destruction was general and loss of life reached the reported total of 7,200 persons. From an engineering viewpoint the earthquake was notable because the area affected included Patna, where the first successful construction with reinforced brickwork was carried out on a large scale. The authors visited Patna and also the city of Muzaffarpur after the earthquake, and the observations in this article are a result of that trip.

Throughout the area covered by the earthquake considerable numbers of structures have been built using various types of reinforced construction, both brick and concrete. Aside from the low mud-walled, thatched or tiled cottages of the peasants, construction falls into three classes. The largest number of buildings have brick walls laid up in mud mortar or lime mortar, with openings spanned by arches and the roof consisting either of jack arches or wood beams with stone slabs or tiles laid on them and surfaced with 4 in. of lime concrete. Quite a large number have the openings spanned by steel beams or heavy angle iron lintels; also there are roofs with steel beams and T-iron substituted for wood beams. A limited but still considerable number of buildings are made with reinforced floors and in some cases roofs, and with lintels of reinforced beams. Some of the larger government buildings are made with reinforced brick ceilings and tiled roofs. No walls have been reinforced in this area except occasionally a thin partition wall. None of these buildings was built for earthquake resistance, since the area had not been shaken in nearly a hundred years.



FIG. 1—TOWER on top of Assembly Building, Patna. Upper part is reinforced concrete, and lower part is unreinforced brick, which proved too weak under lateral motion of earthquake.

The legislative Assembly Building at Patna, built throughout of reinforced construction, was practically undamaged with the exception of four decorative towers on the corners, which were supported by unreinforced pillars.

The Secretariat, or government office building, in the same compound is a large building two stories high surmounted by a high clock tower in the center. The top of this tower broke off and crashed through the roof at its base. Veranda arches used for architectural effect in the ground story did not fail because the heavy pillars supporting them were tied together at the top by reinforced lintels. The upper floor was a solid slab of reinforced brick. The upper ceilings were of 3-in.-thick reinforced brick slabs supported by the lower chords of the steel roof trusses. Apparently the ceiling slabs were supported entirely on the trusses and not tied into the walls, with the result that in some cases the plaster was cracked loose along the edges of the slabs.

In the High Court Building, the second story was a reinforced slab extending over both the rooms and the veranda, the pillars supporting the latter being tied together by lintels over decorative arches. However, the roof and ceilings were unreinforced and gave the veranda pillars no effiective aid, so that every pillar right around the building was broken off at the floor line, and many were displaced horizontally or left out of plumb. Some of the breaks were horizontal and some downward at about 45 deg., presenting a difficult and dangerous repair problem.

Another place of interest in Patna was the Medical College, located on the bank of the Ganges River. Most of the buildings were damaged since the shaking near the river was especially severe. The most severely damaged building was the nurses' dormitory, a two-story building with rows of rooms



FIG. 2—REINFORCED BRICK roof, undamaged in spite of destruction of a portion of the unreinforced wall that supported it.

Editor's Note:

MASON VAUGH became interested in reinforced brick masonry during his work as Agricultural Engineer in India. He reported on a series of R. B. M. tests at the University of Missouri in an 84 page bulletin entitled "Reinforced Brick Masonry by Mason Vaugh, University of Missouri Bulletin, Volume 29, No. 27, October 1, 1928." One of the first controlled series of tests on this type of construction in the United States.

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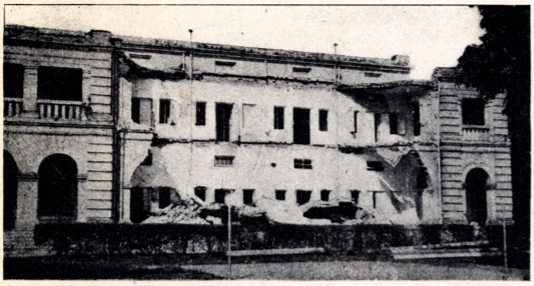


FIG. 3—DAMAGE TO NURSES' HOME, PATNA. Unreinforced walls of veranda arches collapsed, letting reinforced brick floor and roof fold down against walls. In the picture they have been cut loose and are piled on the veranda floor.



FIG. 4—STEEL-BEAM-REINFORCED lintel in Muzaffarpur, pulled away from its supporting pillar during the earthquake.

on both sides of a central hallway and a veranda along the front side. The walls were ordinary brickwork, but the upper floor and roof were reinforced slabs. The walls were badly shattered, with horizontal and diagonal as well as vertical cracks. No slab or lintel in the interior of the building was damaged. The front verandas, except the small end and center entrances, were destroyed (Fig. 3). As far as could be deduced, even here the failure was not in the slabs. Apparently the veranda pillars were thrown outward, leaving the slabs unsupported at their outer edge. The result was that the slabs simply folded down against the walls and hung there. They were later cut away to prevent possible accidents.

In Muzaffarpur the damage to the city as a whole was more severe than in Patna. Here most of the reinforcing was in the form of lintels made with structural shapes rather than with round rods embedded in cement mortar brickwork. Fig. 4 is a view of a new building which suffered severe local damage by serious subsidence and cracking of the ground. The front was heavily reinforced and stood up well, but the part immediately behind was severely shaken up.

Throughout the area buildings constructed with arch construction and using wood roofs were badly damaged. Typical of the damage was that done to the palace of the Maharaja of Darbhanga, shown in Fig. 5.

Ordinary brick buildings

The damage to ordinary brick buildings was observed to be generally traceable to one or more of four weaknesses:

1. The outstanding weakness lies in the use of arches especially to support the wall above doors and windows. Designed only for vertical loads, these elements fail when subjected to transverse forces. In other cases, the arches spread under excessive vertical loads until the supporting wall is ruptured.



FIG. 5—WOOD ROOF and unreinforced walls of a large building at Muzaffarpur.

2. Jack-arch floor and roof construction twists badly under the motion of the earthquake. Lime mortar materially strengthened such construction, but it still appears to be one of the weakest points in the buildings.

3. A third point of weakness exists in the type of construction used for vertical walls and pillars. Vertical walls varied in damage with the type of mortar used more than with any other observed factor.

4. The fourth major weakness in most reinforced buildings lies in not tying the different elements together. This applies particularly to ceilings and walls.

Reinforced masonry buildings

Two major weaknesses were observed in buildings of reinforced brick or concrete. In these buildings the reinforcement is limited to floors, ceilings and roofs and lintels over doors and windows.

1. The greatest weakness rests in the use of unreinforced vertical walls.

2. The second major weakness in such buildings is the lack of integral construction to prevent the separation of floor, wall and ceiling units. Even reinforced work was usually laid on top of walls rather than being built into them.

As this is the first time that reinforced brickwork has been field-tested on a large scale by natural forces, it is interesting to review its results. In general, the better the mortar the better the building withstood the shaking. Units made with mud mortar or with weak lime mortar were seriously damaged in all cases. Where originally good mortar had deteriorated, the same effect appeared. New buildings made with good materials stood better. Both arches and wood lintels were elements of weakness. The superintending engineer of the public works department of Bihar and his executive engineer agreed that the earthquake had made the arch obsolete.

There were no steel-frame buildings in the area, so that no comparison with this type of construction is possible. Reinforced concrete is definitely higher in cost, and there were only a few buildings utilizing this type of construction. Where it was possible to get comparisons, there seemed nothing to choose between reinforced concrete and reinforced brick as regards resistance to earthquake damage.