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PERFORMANCE OF BUILDINGS DURING THE JABALPUR EARTHQUAKE OF 22 MAY 1997

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Abstract

The Jabalpur earthquake of 22 May 1997, has a very special significance from the point of view of seismic preparedness and expertise in repair of seismically-damaged buildings in India. This is the first time that an earthquake has occurred close to a major city in India, and for the first time the seismic response of some of the typical modern constructions that are unique to India are observed. Even though tragic, this earthquake has provided an opportunity to learn about the earthquake response of some of the modern Indian constructions at a relatively low human cost. This paper presents a brief summary of the observations made by the authors in the meizoseismal area of the earthquake, with particular reference to damages in engineered and traditional buildings.

1. Introduction

The earthquake of magnitude 6.0 occurred on May 22, 1997 at 04:22 AM (local time) was centered about *8 km* south-east of Jabalpur near Kosamghat village (***Figure 1***). This moderate earthquake is considered to be different from the others in many aspects [*e.g.*, Gupta *et.al.*, 1997; Rajendran and Rajendran, 1997]: (a) it is one of the deepest intra-plate earthquakes, (b) the number of aftershocks is rather small, (c) it is associated with the Narmada-Son rift which has distinctive geological and geophysical expressions, and (d) it occurred in a region where moderate events have been recurring over intervals too short for stable continental regions. There were no instances of liquefaction of soil. No surface trace of rupture was noticed. However, longitudinal cracks in the ground were seen in some locations in the affected area including along the crests of the many earthen dams in the area.

The maximum intensity of shaking experienced during the earthquake was VIII on the MSK scale at villages Kosamghat and Kudaria. The shaking intensity varied from V to VII on the MKS scale in Jabalpur town as well as the entire affected area. During this event, a large number of houses were severely damaged and relatively smaller number of houses collapsed [Jain, *et.al.*, 1997]. The Indian seismic code [IS:1893-1984] locates the affected area in seismic zone III, implying that it is likely to sustain the maximum shaking intensity of VII on the MSK scale. This is generally consistent with the shaking intensity experienced in the area.

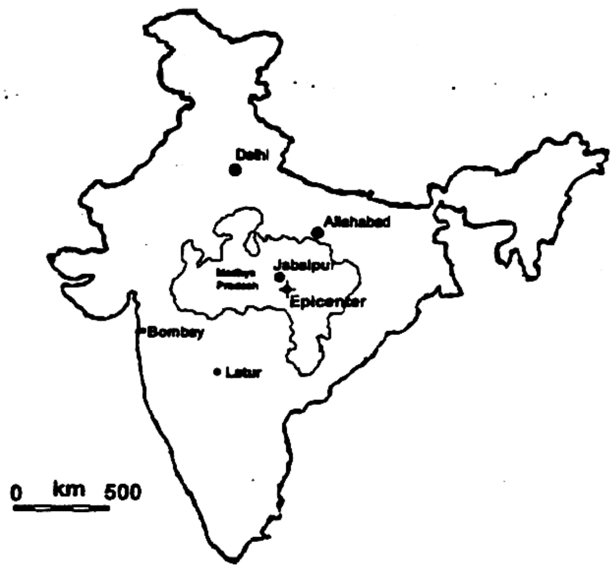

Figure 1: Map of India showing the epicenter of the earthquake

Figure 2: A mud house in Kosamghat village showing the separation of walls, which were built one at a time and without any positive connections between them.

2. Behavior of Buildings

The buildings affected during the earthquake include both rural and urban constructions. The rural constructions are predominantly of earthen type, while the urban constructions are mostly of load-bearing brick masonry type in mud or cement mortar. In Jabalpur town, there are a good number of reinforced concrete (RC) moment resisting frame multistorey buildings with unreinforced brick masonry infill walls.

The rural dwellings are usually single-storey type with earthen walls supporting pitched tile roof on wooden rafters and purlins. Only individual instances of good jointing between the rafters and purlins are noticed. In general, they are tied together only with coir rope, which often gave away resulting in collapse of roof. In these dwellings, the thick earthen walls are weakly connected to each other at the corners resulting in the out-of-plane collapse of walls as individual panels (*Figure 2*).

Most urban houses are built with burnt brick masonry in mud or cement mortar. These one or two storeyed load-bearing buildings sustained significant cracking in the walls. In the urban area, the maximum damage was experienced at the Jawaharlal Nehru Agricultural University campus in Adhartal. The extensive damage and partial collapse of the load-bearing brick masonry laboratory and residential buildings is attributed to very weak cement mortar and poor connection between the walls.

The Ammunition Factory and the Gun Carriage Factory in Jabalpur have housing colonies of about 400-600 houses each. These houses are typically two-storeyed load-bearing brick masonry structures with RC roof and floor slabs. These houses suffered extensive damages. The Department of Telecom housing colony also has load-bearing masonry buildings up to three storeys. These were also extensively damaged. A very distinctive feature of the performance of these houses consisted primarily of damage, or even collapse, of the stair-case tower (called *mumty*) portions (*Figures 3*), in addition to the usual cracking of walls. The *mumty* constructed with brick masonry walls and concrete slab, is a vertical projection of about 2 m above the roof slab. The walls in the *mumty* portion are usually connected to each other only through the slab above them. Such vertical projections in houses are known to be particularly prone to damage during earthquakes.

Fortunately, no lives were lost due to the shaking in numerous government owned houses, even though a large number of them were irreparably damaged. In none of these housing colonies, earthquake resistant features such as the "lintel band" were adopted. Interestingly, in seismic zone III, the Indian Standards [IS:4326-1993; IS:13828-1993] require no special provisions for ordinary masonry buildings up to three storeys or less. However, lintel bands are required in important masonry buildings, *e.g.*, schools and hospitals, and in ordinary buildings that have four storeys.

Jabalpur has a number of multistorey RC frame buildings with brick infill walls; most of these did not seem to comply with Indian seismic codes for earthquake forces [IS:1893-1984] or for seismic detailing [IS:13920-1993]. Despite this, most buildings with reasonably symmetric geometry and with no significant variation in stiffness and strength in plan and in elevation, performed well with only nominal cracking of brick infill walls.

Figure 3: Close-up view of the *mumty* collapse in the Department of Telecom housing colony.

A number of RC frame buildings with brick infills did sustain severe structural damage. However, these were irregular buildings having abrupt changes in the stiffness, *e.g.*, completely open ground storey with no infill walls, or ground storey open on one complete side and the other side with infill walls. The columns in the ground storey in the open area sustained extensive shear failure of columns (*Figure 4*), opening of transverse ties, and buckling of longitudinal reinforcement bars (*Figure 5*). The upper storeys experienced only nominal cracks in the filler walls. This earthquake has graphically illustrated the vulnerability of RC frame buildings with "soft first storey" due to the absence of brick masonry infills in the ground storey (for parking). All metropolitan towns in India have a very large inventory of multistorey housings with these very features; the experience of Jabalpur earthquake clearly illustrates the disaster potential in such towns.

The damage to industrial buildings was rather low or moderate. The smaller factory buildings usually consisted of single-storey *barrack-type* sheds in brick masonry built with pitched roof in corrugated asbestos sheets. These had traditional type of damage with diagonal cracks in the walls and damage to the gable end walls. The gable ends of a number of large industrial sheds (approximately *15m×100m* in plan) in the Gun Carriage Factory were damaged. Some of the more recent constructions of the regular industrial-type performed very well.

Figure 4: Damage to interior columns of the Youth Hostel building.

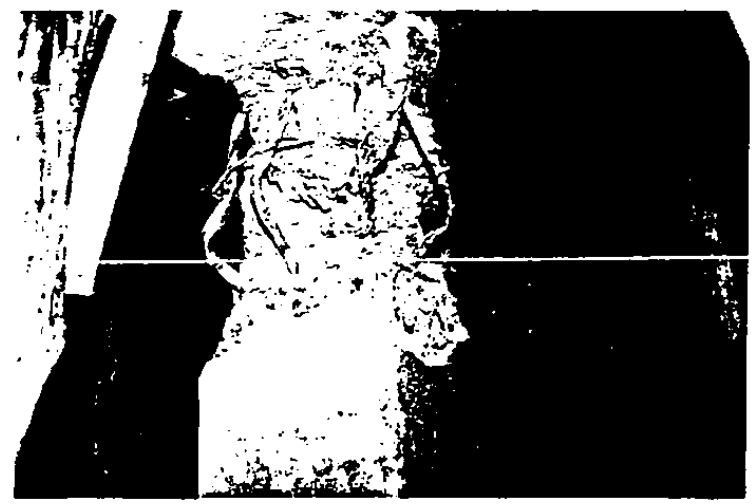

Figure 5: Damage to RC column in Himgiri Apartments.

3. Lessons Learnt

The earthquake caused moderate shaking of intensity up to VIII on MSK scale in the affected area, which lies in seismic zone III of India. This shaking intensity is in conformity with the expected level of shaking in such a seismic zone. For the first time, India had a damaging earthquake near a large town. Hence, the earthquake has emphasized some important and interesting issues from engineering view point. Some of these issues are:

a) The performance of RC frame buildings with brick infills having no abrupt changes in stiffness or mass, has been very satisfactory. This clearly shows the positive contribution that unreinforced masonry makes to the behavior of such RC moment resisting frame buildings. Current design practices treat the masonry infill as non-structural and ignore its contributions to strength and stiffness. There is need to develop design methodologies that can rationally incorporate the contributions of infill walls.

b) RC frame buildings with open ground storey (due to the absence of masonry infills for parking) have shown very poor performance as one would expect. This has serious implications for a very large stock of such buildings in modern India.

c) Indian Standard code has specific provisions regarding aseismic design, detailing and construction of buildings in seismic zone III. Despite this, hardly any concern existed in the area for seismic safety of the constructions and the seismic codes were simply not being followed in most of the constructions in that area. This includes construction of many multistorey RC frame buildings. It is expected that the situation is similar in most other towns in the country. The questions that arise are: Is this situation acceptable to the society? If not, how can it be tackled?

d) A huge inventory of government-owned housing was severely damaged in the earthquake. This became particularly acute since Jabalpur has large establishments of Railways, Ordnance Factories, Army Cantonment, and the Department of Telecom. The concerned engineers had no prior experience of handling post-earthquake situation. And, for most of them, it became very difficult to address issues such as: (i) To distinguish between houses which people can continue to occupy, perhaps with some temporary propping, and those from which residents should be evacuated immediately, (ii) To decide between those houses that can be economically repaired and those that need to be demolished, and (iii) Appropriate repairs and strengthening methodologies. A massive training program is needed to train the local engineers (as well as non-engineers such as administrators, politicians, opinion makers, and interested residents) on the issues of post-earthquake handling of buildings. Fortunately, considerable expertise on post-earthquake handling of buildings now exists in the neighboring state of Maharashtra after the massive rehabilitation project following the 1993 Latur (Maharashtra) earthquake.

e) After the earthquake, there was need for consulting engineers and contractors who have experience in post-earthquake handling of buildings. Unfortunately, the subject area of earthquake engineering is viewed in the country as a super-specialty to be handled by "professors" and not by the structural engineers. A time has come when we need to have a pool of structural engineers who are specialized in earthquake engineering.

f) For government engineering departments, it is very difficult to handle a huge emergency

project of seismic repair and strengthening of buildings with the existing work force in the concerned town. The team saw only in one government organization the concern regarding this; this department had arranged to bring some Junior Engineers from neighboring districts to Jabalpur on temporary duty for assisting with this work.

g) Many engineers and administrators were over-cautious in taking decisions regarding the safety of structures; this caused additional hardship to the affected people.

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