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TITLE:Seismically Retrofit Existing Important Buildings In Delhi

Prof. Y. R. Borkar[1], Amit D. Kamble[2], Akash A. Tayade[3], Akshay K. Shingane[4]

[1]*Asst. Prof., Department of Civil Engineering, J.D.I.E.T, Maharashtra, India,*
yogeshborkar471@gmail.com

[2]*Student , Department of Civil Engineering, J.D.I.E.T, Maharashtra, India,*
kambleamit999@gmail.com

[3]*Student , Department of Civil Engineering, J.D.I.E.T, Maharashtra, India,*
aktayade007@gmail.com

[4]*Student , Department of Civil Engineering, J.D.I.E.T, Maharashtra, India,*
akshayshingane10@gmail.com

Abstract

Delhi capital of India, home of average 14 million people, can face the earthquake problems from distant areas like large-magnitude earthquakes in the Himalayas and smaller local calamities. Delhi consist of large number of buildings as old and new constructed, high rise buildings, IGI Airport, important government buildings, Hauz khas fort, etc. If major earthquake strikes, many of these buildings are under the risk as these buildings are vulnerable to such seismic conditions. Delhi government with GeoHazard International conducted a project to built capacity of the Delhi Public Works Department (PWD) to seismically retrofit(such as changing a building's use or replacing it with a new earthquake resistant building) vulnerable existing structures. Thus improving the seismic capacity of these structures and protects the peoples and help them to respond more effectively to the earthquake conditions. GeoHazards International conducted a program in which researchers from India and United States guides Delhi PWD engineers as how to seismically retrofit buildings.

Project includes the buildings as the main government offices of Delhi, Police headquarters, educational buildings, old and historical structures, hospitals, disaster management authority offices. Structural systems included unreinforced masonry (URM) bearing wall, reinforced concrete shear wall, combination of concrete frame and URM bearing wall, reinforced concrete frame with URM infill. Delhi PWD engineers learned to increase the performance of buildings, detects the causes of falling hazards, how to retrofit buildings, aware homeowners to retrofit the houses. In this paper various technical challenges and lessons learned during the project are discussed, and recommends measures for the seismically vulnerable buildings, future projects to minimize risk developed by old and existing buildings.

Index Terms: *Retrofit, GHI, URM.*

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INTRODUCTION:

Delhi's earthquake hazard comes primarily from high-magnitude events occurring on the major thrust faults that underlie the Himalayas near about 200 km to the north, as well as from local sources. Various major sections of the Himalayan faults, called seismic gaps, have not experienced earthquakes for last 100 years, while strain has continuously increasing due to the continental collision of India and Tibet. Seismologists discovered that the next major earthquake to strike the Himalayas will occur in one of these seismic gaps. The gap located near to Delhi NCR(National Capital Rergion) is the central seismic gap. It is the main plate boundary that stretches approximately 600 km between the rupture zones of the Kangra(1905) and the Bihar-Nepal (1934) earthquakes.

Delhi is vulnerable to damage from Himalayan events and from local events. Though the history of earthquakes in Delhi is incomplete, and some information is available about events occure in last years. Records indicates that earthquake shock felt back at Delhi NCR which is originated 44km south-west of Muzaffarnagar in UP of capacity 4.0 Richter on 20th February 2019. The depth of earthquake was mapped at 10 km. Another recent earthquake of magnitude of capacity 4.0 richter has induced in Sonipat(Haryana) on 1 July 2018. Shocks of this earthquake felt back in some region of Delhi. Recently this month, a few back-to-back earthquake have been measured on January 31 in north and south India , mild tremors were felt in Delhi-NCR after a 6.1 magnitude earthquake in Hindu-Kush mountain range along Afghanistan-Pakistan border.

The IS building code placed Delhi in Seismic Zone IV, the second highest hazard zone. On 20 February 2019, a magnitude 4 earthquake struck 50 km north from the Delhi. A magnitude 4.0 richter earthquake is not large. If it occurs nearby, it can be felt, and may creat some damage, but it is almost never fatal. This earthquake was no exception: shaking has been reported to be weak to moderate. So, what is interesting about it? Actually, there is a lot to be learned from small, seemingly unimportant events like this. Let us use this earthquake as a means to explore the seismic risk in India. Recent study predicted that large magnitude earthquake may occure in the near future in the northwest Himalayas region.

Delhi's varied geotechnical conditions are expected to result in significant variations in ground vibration. The deep, soft alluvial sediments on the east side of the Yamuna River are expected to amplify seismic waves and to suffer liquefaction, causing increased hazards in East Delhi. Rock outcrops that wont tend to amplify shaking underlie a small area of Delhi proper, on the west side of the Yamuna, but a much larger area of alluvium underlies much of central Delhi, including smooth alluvium in the abandoned flood plains of the Yamuna.

Delhi has many buildings which are vulnerable to earthquake damage. Many of the buildings in the densely populated neighborhoods of Old Delhi and East Central and Northen part of Delhi are highly vulnerable, multi-story brick buildings with irregular configurations. Even mild shaking is expected to damage these buildings. The city also has many reinforced concrete buildings that were built with inadequate earthquake-resistant detailing. In addition, many buildings were built illegally, with no regulatory oversight or quality control. Delhi is taking steps to detect the problems caused by illegal buildings, but complex social and political issues make progress slow. Meanwhile, rapid growth continues to present a challenge, because builders sometimes overlook earthquake resistance, as they try to keep pace with the city's burgeoning population.

CAPACITY BUILDING FOR SEISMIC RETROFIT

Despite these challenges, the Government of the National Capital Territory of Delhi (hereafter Delhi Government) has begun to prioritize earthquake safety. This paper presents the results of a multi-year project to build seismic retrofit capacity in the Delhi Government's primary engineering agency, the Delhi PWD. Delhi PWD is responsible for the design, construction, and maintenance of most Delhi Government buildings, bridges, and lifeline infrastructure. The Delhi metropolitan area also includes other local governmental bodies, as well as the national government; all have one or more of their own engineering agencies. This project demonstrates seismic retrofits in a highly visible location, where the impact on other engineers can potentially be substantial.

PROJECT BUILDINGS:

The project covered three complexes of buildings that are representative of the range of occupancies, structural types, and ages of typical government building stock. The following sections describe the buildings, the results of the seismic assessment and retrofit processes, and technical challenges that the project teams faced.

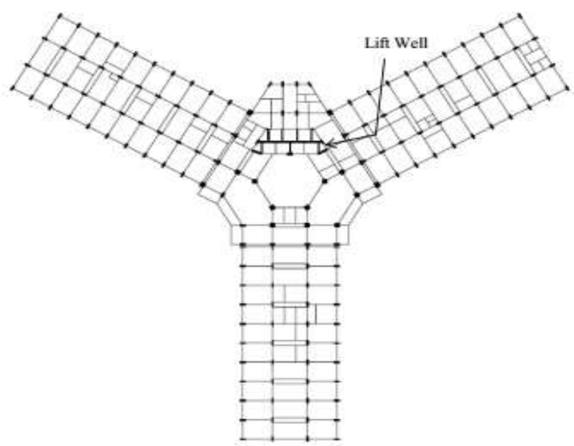
Delhi Divisional Commissioner's Office Complex:

Block A is a single story, British colonial, unreinforced brick bearing wall building, Block B is a three-story, unreinforced brick bearing wall building,Block C is a fourstory, reinforced concrete frame building, with masonry bearing walls in the ground story,Block D is a four-story, reinforced concrete frame building with brick infill walls.Blocks A and B were assessed using the Indian Standard for the seismic retrofit of unreinforced masonry buildings, IS 13935 (BIS, 1993). Delhi PWD assessed Blocks C and D using the American Society of Civil Engineers (ASCE) standard for existing buildings, ASCE 31-03 (ASCE, 2003)

All four buildings had seismic deficiencies and required retrofitting to achieve the desired performance. Delhi government decided to retrofit Blocks C and D with exterior reinforced concrete shear walls and, as of this writing, had not reached a decision on whether to retrofit or replace Blocks A and B. If the Delhi government decides to retrofit Block A, then architectural and historic preservation issues will need to be addressed, in addition to disruption issues. The Block C and D retrofits were conservatively designed and should result in limited structural damage, repairable in a matter of months, even in the MCE. Block D is likely to achieve Immediate Occupancy performance in the DBE(Design Basis Earthquake).

Delhi Secretariat (Dilli Sachivalaya):

The building is Y-shaped in plan, as shown, with three, ten-story wings equally spaced around a central core. The building has a reinforced concrete frame with few well-connected infill walls. A solid reinforced concrete wall surrounds elevator lifts in the building's central core.



Interior partitions are chiefly lightweight concrete, rather than brick masonry. The foundation consists of piles, since the building site is less than a kilometer from the Yamuna River.In the wings, lateral resistance is provided almost solely by the frame, since the building has no RC shear walls and few masonry infill walls. The peer review panel reviewed the modeling assumptions, analysis methods, and results. The nonlinear analyses showed that the building's upper story columns were weak and prone to collapse, and that the wings would pound against the core. Participants considered two primary retrofit options: jacketing vulnerable upper story columns and allowing the wings and core to pound, or tying the wings to the core to utilize its strength and stiffness to keep the columns from failing.At the time of this writing, retrofit design was still in process.

Delhi Police Headquarters Building:

The Delhi Police Headquarters building, also popularly known as the Multi-Story Office (MSO) building. The 14-story building was constructed in three phases, as shown and is essentially three different reinforced concrete buildings separated by expansion joints 150 mm (6 in) wide.

The first phase has a core with two massive H-shaped shear walls from foundation to roof, making it very stiff. The second and third phases have flexible, moment-resisting frames and no shear walls. The peer review panel agreed on the compromise that anchorage and bracing of building utilities and furnishings would take place in the critical areas, such as the police control room. The nonlinear analyses showed that the large shear walls in Phase 1, which were initially thought to be the building's strength, were actually its biggest weakness. These walls are very stiff but do not have adequate shear capacity, and they fail in shear well before the building reaches the anticipated level of displacement demand.Indian Institute of Technology (IIT), Kanpur (the analysis consultant), Delhi PWD, and the peer review panel discussed a total of thirteen potential retrofit schemes before deciding on the recommended scheme, which consists of strengthening the Phase 1 shear walls, adding new Phase 1 shear walls, and opening the joints between Phase 1 and Phases 2 and 3.

CONCLUSIONS AND LESSONS LEARNED:

- Understanding the complex concepts involved in seismic assessment and retrofit of existing buildings requires "learning by doing," rather than just training sessions or seminars.
- Understand and be willing to apply the latest research and state-of-the art Experience but local participants may not be willing to adapt to latest changes due to lack of information and experience, engineer should encourage them by providing enough information and first hand experience o retrofit buildings.

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