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Preliminary Report of Reconnaissance Surveys in Mirpur Post 24 September 2019 Earthquake

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Executive Summary

This report summarises the findings of the reconnaissance surveys which were conducted in the Mirpur district in Azad Jammu and Kashmir after the 24 September 2019 earthquake. The magnitude of this earthquake was recorded as 5.6 on Richter scale. Photographic documentation of the damages in the surveyed areas was carried out by the survey team from the Department of Earthquake Engineering at NED University of Engineering and Technology, Karachi. The analysis of the recorded ground acceleration data indicated a peak ground acceleration of 0.36g at the Mangla Dam recording station. The building typology of the area comprised of unreinforced masonry (URM) buildings with a small proportion of reinforced concrete (RC) buildings. The former buildings types are constructed with burnt clay bricks load bearing walls. The construction of these is generally based on local expertise and experience without involving (in most cases) engineering input. As a result, these can be termed as non-engineered buildings. The damages in the URM buildings ranged from diagonal wall cracking to complete building collapse. Although reinforced concrete (RC) buildings performed better, few of them suffered damages beyond repair. Complete collapse of an RC building was also observed in Mirpur during the surveys.

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1 Introduction

Azad Jammu and Kashmir (AJK) lies in the north east of Pakistan (Fig. 1). The region faced the devastating October 2005 earthquake of Mw = 7.8 which killed nearly 73,000 people while at least 69,000 people were injured. The most affected areas in Kashmir due to this earthquake included Muzaffarabad, Poonch and Bagh. An earthquake of Mw = 5.6 struck AJK again on 24 September 2019 focusing some of those cities which were spared by the October 2005 earthquake. According to United States Geological Survey, the epicentre of this earthquake was near the city of Mirpur and was located at a shallow depth of 10 km. The earthquake caused shaking over widespread areas of Pakistan and AJK, although no damage was reported in Pakistan. The Mirpur district in AJK was badly devastated by this earthquake where extensive building and infrastructure damages were reported in the local media. A team from the Department of Earthquake Engineering at NED University of Engineering and Technology, Karachi visited the affected region from 27-29 September 2019 to conduct reconnaissance surveys and to record the damages. The team was assisted by the faculty members at Mirpur University of Science & Technology (MUST). The damages to infrastructure and buildings were studied based on visual inspection and these were documented. Building damages were analysed to study building seismic performance and failure modes.

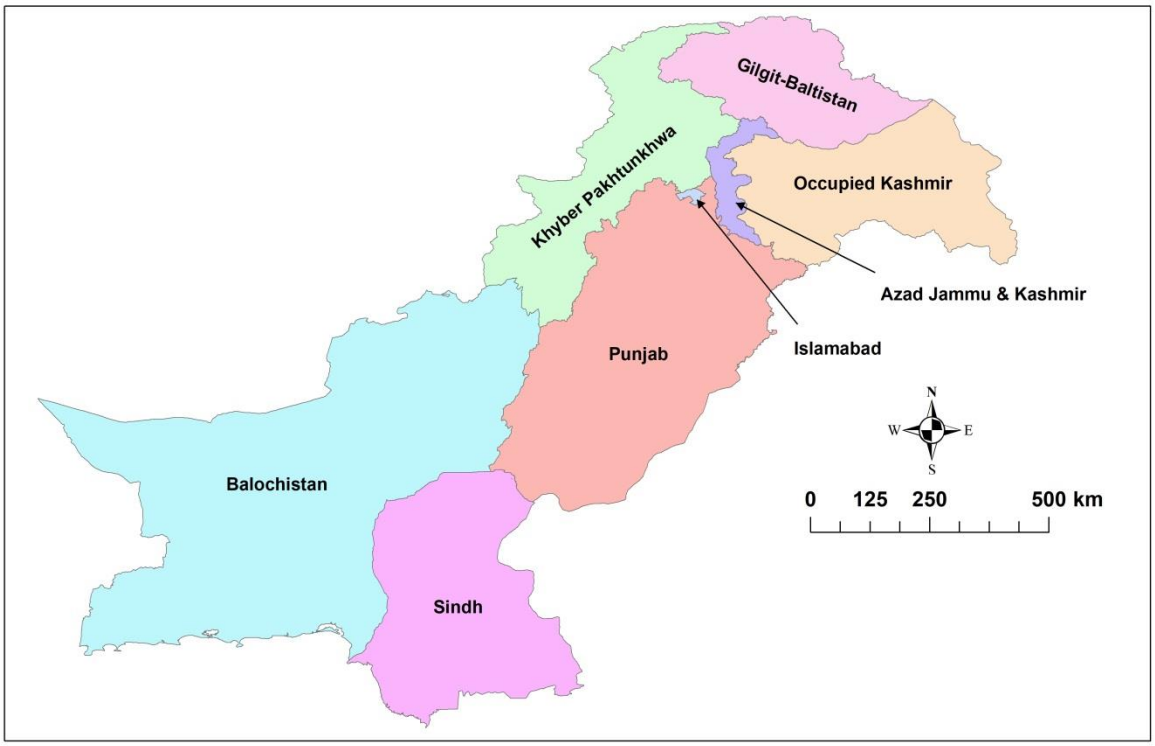

Fig. 1 Administrative division of Pakistan

2 Field Surveys

As mentioned earlier, a two-member team from the Department of Earthquake Engineering at NED University of Engineering and Technology conducted field surveys in Mirpur to record the damages caused by the 24 September 2019 earthquake. The team focused only severely damaged areas (Fig. 2) due to its smaller size. These areas were widely scattered over the Mirpur district and were selected based on the news in the local media. The team documented the damages by taking the photographs of damaged infrastructure along with their coordinates to geographically locate their positions. This report, however, presents the results of buildings surveyed in MUST and Radio Station building in Mirpur in detail by mentioning other damages briefly.

Fig. 2 Towns and villages in Mirpur district

3 Results and Discussion

3.1 Seismological Context

Strong motion acceleration sensors have been installed by Water and Power Development Authority (WAPDA) at Mangla Dam and in the settlement named as Chechian. The acceleration time histories of the main shock on 24 September 2019 as recorded at both these stations are shown in Fig. 3. It is seen in Fig. 3 that the duration of strong ground motion was very short and was limited to nearly 2.5 sec in all the three directions of ground motion. A summary of peak ground acceleration (PGA) and maximum displacement recorded at each site (Mangla Dam and Chechian) is given in Table 1.

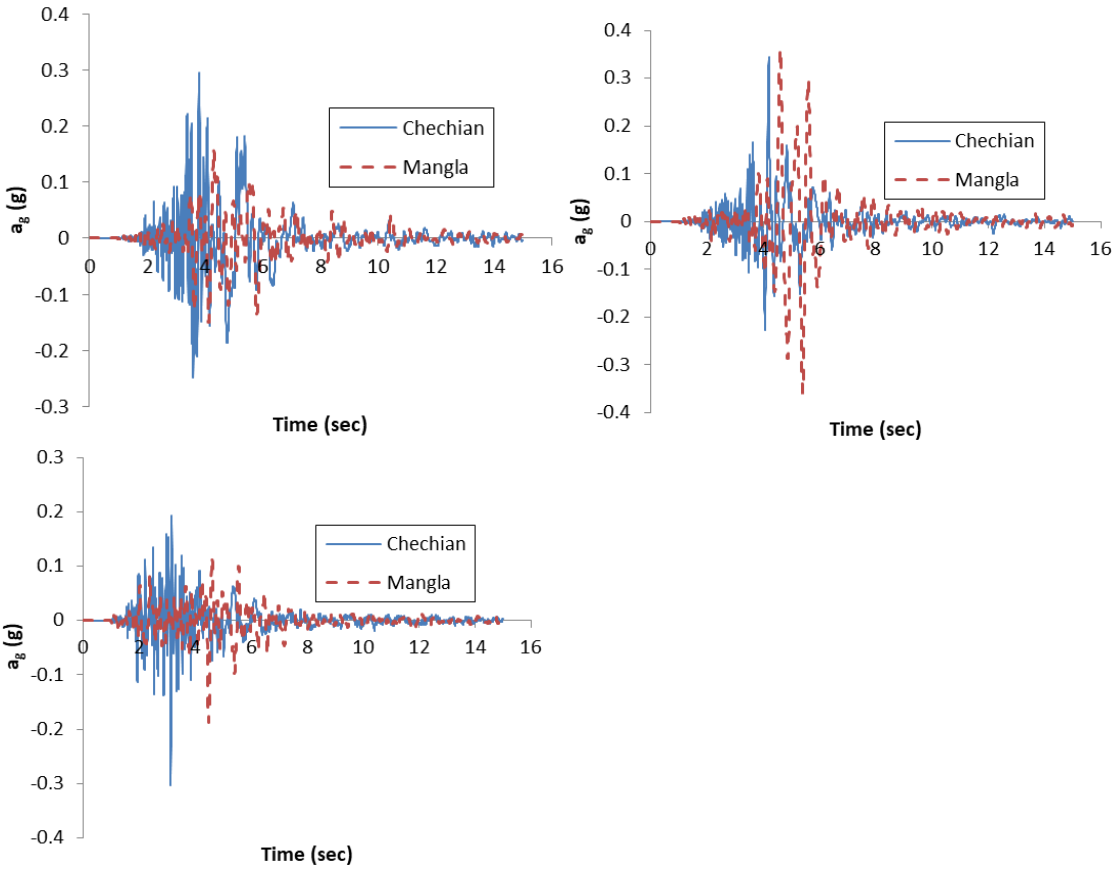

Fig. 3 Ground acceleration time history recorded at Chechian and Mangla Dam stations: (a) longitudinal direction; (b) transverse direction; (c) vertical direction

Table 1. Summary of PGA at recording stations

Component of motion	Chechian	Mangla Dam
Longitudinal direction	0.2949 (0.248)	0.1587 (0.1503)
Transverse direction	0.3443 (0.2268)	0.36 (0.3579)
Vertical direction	0.1925 (0.3041)	0.1166 (0.1878)

3.2 Observed Damages

3.2.1 Mirpur University of Science & Technology

The visited buildings in MUST include Girls Hostel, Computer Systems Engineering Department building, Home Economics Department building and Admin building. Except for Home Economics Department building the structural system for the rest of all buildings comprised on reinforced concrete (RC) frame structure. The walls in these buildings are made of clay brick masonry and are non-structural members. The structural system of the Home Economics Department building comprised of load bearing unreinforced masonry (URM) walls which constructed using burnt clay bricks. The Girls Hostel and Computer Systems Engineering are generally in good shape after the 24 September earthquake where some minor cracks in the walls were observed in these buildings. Significant cracking in the walls in the Admin building was found (Fig. 4) which is usual in URM walls during seismic ground motion. Since these walls are non-structural elements, these cracks are only safety hazard for the occupants and could be repaired to make the building functional again.

The cracks in the walls in the Home Economics Department building are similar to those observed in the Admin building (Fig. 5). The cracks were mostly in the form on diagonal cracks which were caused in the in-plane walls which are parallel to the direction of lateral seismic forces. Since the walls in the Home Economics Department building are also the structural members, these damages are a concern from the structural stability point of view. This is particularly due to the fact that these types of buildings are constructed without any engineering input in Pakistan and AJK and are classified as non-engineered construction. This building requires serious attention as repairing the cracks may not be enough to avoid any catastrophy in future. All such buildings are in urgent need of seismic retrofitting to save precious human lives during an earthquake.

Fig. 4 Cracks in walls in Admin building at MUST

Fig. 5 In-plane shear cracks in classroom in Home Economics Department building

Fig. 6 Wall cracks in Radio Station building at Mirpur

3.2.2 Mirpur Radio Station Building

The building is a two storey structure with one basement. The structural system of the building comprised of unreinforced load bearing clay brick masonry walls. It is very likely that this building is also constructed without any engineering input as the knowledge of designing masonry structures is very limited in Pakistan. This does not come as a surprise that the walls in this building also showed severe cracking due to the in-plane lateral seismic forces (Fig. 6). The cracks are very similar to those found in the Home Economics Department building at MUST which can be attributed to similar structural systems of both these buildings. This fact also requires a similar post-earthquake treatment of this building as mentioned for the Home Economics Department building above.

3.2.3 Performance of URM Structures

Apart from the buildings at MUST and Radio Station, URM structures are also used for private housing throughout Mirpur. These buildings vary in their quality of construction and sizes. The damages observed in these URM buildings ranged from cracking in the wall to the collapse of structure. The cracks were mostly in the form on diagonal cracks which were caused by the in-plane seismic forces (Fig. 7). In only a very few instances, the wall collapsed out-of-plane which were either short height

boundary or parapet walls. In some cases, the circular stair tower roof slid off the wall of the tower to fall down in the front of the house (Fig. 8). In addition, cattle shed fell down in some of the residential buildings (Fig. 9).

3.2.4 Performance of RC Structures

RC buildings largely exist in the Mirpur city area. Most of these buildings survived with damages in the infill walls which were similar to those observed in the URM structures. Nevertheless, a variety of structural damage types was also observed in the RC buildings. In this context, the mention of Gulshan-e-Jabeer building and Ahsan Medical Complex buildings is of particular significance as the structural damages in these buildings are very extensive despite the fact that these were designed by structural engineers.

Fig. 7 Residential building with diagonal wall cracks

Fig. 8 View of fallen circular roof of stair tower

Fig. 9 Collapse of cattle shed

Gulshan-e-Jabeer building is a two storeyed RC frame structure building with one basement (Fig. 10). The building is nearly 10 years old. The building of Ahsan Medical Complex is a seven storey high RC building including a mezzanine (Fig. 11). The building is only one year old. Figs. 12 and 13 show few damaged columns in these aforementioned buildings. It is seen in Figs. 12 and 13 that hinging is caused in columns at the beam-column junction which was accompanied by the buckling of the longitudinal bars. The latter is a result of insufficient confinement provided to the longitudinal bars by the spiral (circular columns) or stirrups (rectangular columns). It was also noted that the hook of the stirrups in the rectangular columns were bent 90 deg in violation of the design codes followed for the design of RC buildings.

Fig. 10 View of Gulshan-e-Jabeer building

Fig. 11 View of Ahsan Medical Complex building

Fig. 12 Column damages in Gulshan-e-Jabeer

Fig. 13 Damaged columns in Ahsan Medical Complex building

Fig. 14 shows rubbles of an RC building which was completely collapsed during to the ground shaking caused by the earthquake. The building was used as a student hostel facility by Benazir Bhutto Shaheed Medical College in the Mirpur city area. Luckily, the building was empty at the time of earthquake due to the summer holidays which avoided any human casualty.

Fig. 15 shows the view of a collapsed storey of an under construction building which has six storeys including a basement. The floor plan of the building changed after fourth storey. Although the reason of collapse cannot be ascertained with certainty, a soft storey failure of the fourth storey of the building is thought to be the reason of its collapse.

Fig. 14 Collapsed building during 24 Sep 2019 earthquake in Mirpur

Fig. 15 Collapse of a storey of an under construction building

4 Conclusions

An earthquake of magnitude 5.6 on the Richter scale struck Mirpur district in Azad Jammu and Kashmir on 24 September 2019. The maximum recorded peak ground acceleration due to this earthquake was 0.36g which was observed at the Mangla Dam seismic recording station. Unreinforced masonry (URM) is the prevalent type of construction in this area for both the residential and commercial buildings. A small proportion of reinforced concrete (RC) buildings also exists in the urban areas of Mirpur. URM buildings are constructed with load bearing walls which are made of burnt clay bricks and can be classified as non-engineered buildings as these are constructed with little or no engineering input. URM buildings suffered significant damages in the affected areas which ranged from wall cracking to the complete collapse of the buildings. The wall cracking is also extensive in some cases that requires almost new construction to restore the building to its functional state. In general, RC buildings performed better as compared to the URM buildings. Nevertheless, some of them were subjected to damages which are beyond repair. Cases of partial or complete collapse of RC buildings were also observed during the surveys of the affected region.