Geotechnical Effects of the 2015 Gorkha, Nepal Earthquake and Aftershocks, as Determined By Field Reconnaissance: A Case Study Review

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Abstract- Following the 7.8 Magnitude Earthquake in Gorkha, Nepal, the Geotechnical Extreme Event Reconnaissance (GEER) organization sent two teams to collect data regarding fault ruptures, landslides, soil failures including liquefaction, and structural damage due to geotechnical issues.

INTRODUCTION

Post-Earthquake field reconnaissance can be a beneficial tool in collecting meaningful data and observing types of geotechnical impacts throughout the affected area. This knowledge can be later utilized in seismic design for mitigation of impact from strong ground motions, fault ruptures, and more. This paper will summarize the main ideas of the article titled, "Geotechnical Effects of the 2015 Magnitude 7.8 Gorkha, Nepal, Earthquake and Aftershocks." It will also aim to relate these main ideas to the concepts learned in CE 4542, and suggest additional concepts that could be further studied.

Fault Rupture and Strong Ground Motions

It was determined that the rupture from the mainshock occurred along the Main Himalayan Thrust (MHT) fault, only extending to the base of the Main Frontal Thrust (MFT), with observed elevation of groundwater levels along the Main Boundary Thrust (MBT). There was no evidence of surface rupture or ground deformation along the MFT and MBT, which was consistent with findings from previous events in the region, with magnitudes less than 8.

Kathmandu Valley is a soft soil basin site, which puts it at greater risk for experience higher intensities of ground shaking. However, with regard to ground motion, there were some unexpected results. For example, the KATNP strong-motion station recorded low energy at short periods, despite the high magnitude of the Earthquake and the relatively close distance from Kathmandu to the rupture plane. The intensity of shaking experienced at short periods was much lower than what was anticipated from the mainshock. On the other hand, high energy was recorded for long periods, but with considerably lower amplitude than what is typically recorded at soft soil sites.

Landslides

Triggered landslides from strong ground motion shaking were the dominant form of geotechnical impact. Due to the topography of the region, cities in valleys surrounded by mountains, there are many steep slopes that are high risk hazards during times of seismic activity.

Most of the smaller landslides encountered were due to shallow, translational failures. These could be categorized as coherent slides, caused by slope failure, or slump.

However, the most devastating landslides were caused by accumulated debris falling from above. These are categorized as disrupted slides and falls, which involve sheared, broken, and disturbed earthen materials randomly mixed together and moved rapidly causing damaging slope failures.

These disrupted slides and falls had impacts at both higher and lower elevations. At Mt. Everest basecamp, ground shaking swept up snow and ice from higher surrounding peaks causing avalanches in the mountain region, and stranding many climbers. On the other hand, Langtang village, shown in Figure 1 below, experienced one of the most destructive landslides, which swirled together snow, ice and rocky debris before becoming airborne off a 500 m cliff at an estimated 100 m/s. The entire village was destroyed.

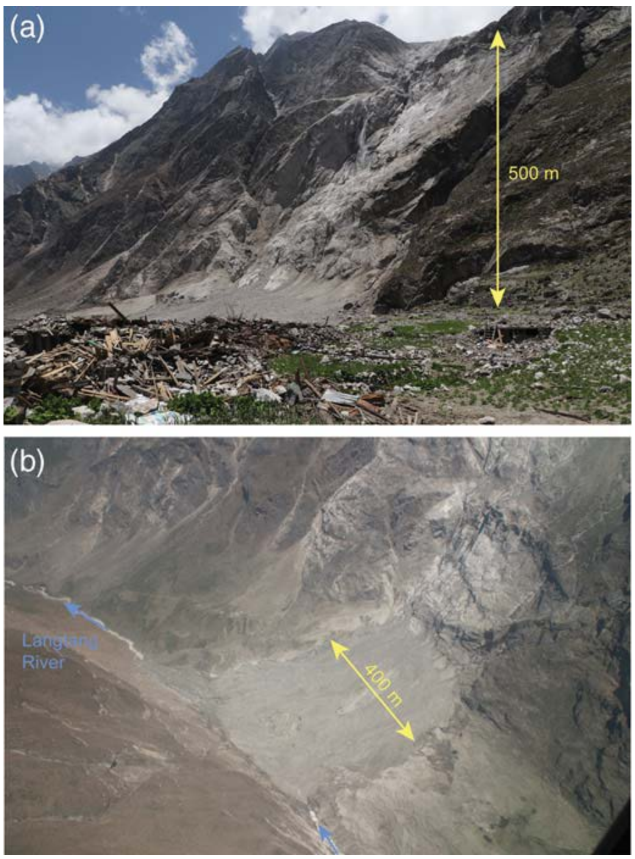

Figure 1. Langtang slope failure. (a) The cliff off of which the debris fell. (b) Aerial view of area of lower flow in slump schematic, showing area covered by debris after the slope failure. Reproduced from Moss, Robb ES, et al (2105).

Additionally, many of the larger landslides blocked off rivers and roads within valleys, creating a higher risk of flooding during the approaching rainy season. Many hydropower facilities were also severely damaged or destroyed by rock falls.

Soil Failure

Liquefaction and cyclic failure are caused by strong ground motion shaking weak soils. Some of the weakest soils in Nepal are located in sedimentary basins, such as Kathmandu Valley, due to the mountainous and steep terrain characteristic of the country. This has some relation to the concept we discussed in class known as the angle of repose, which is defined as the steepest slope at which loose material will lie without cascading down. The angle of repose increases as size of particles increases. This means that larger particles such as rocks can better resist movement at steeper slopes, whereas smaller particles such as sand are more likely to move down the slope. This causes a large amount of fine grained sands and clays to slide off the surface of the higher peaks into the valley, creating a weak soil foundation within the basin.

Though many of the soil failure sights identified experienced liquefaction, the size and scale of the effects due to liquefaction were minimal. This was attributed to a few possibilities including; the low amplitude of high frequency shaking from the mainshock, seasonal variations in, and potential withdrawal from, the groundwater table, and sediment with a fine grain-size distribution that is not susceptible to liquefaction. The most common observed form of soil liquefaction after this earthquake was in the form of sand boils.

One interesting finding was an observed lateral crack along a highway in Lokanthali, with fissures extended to a depth of 2 m and a nearly 1.5 m vertical offset, on ground sloping toward a channel (Figure 2).

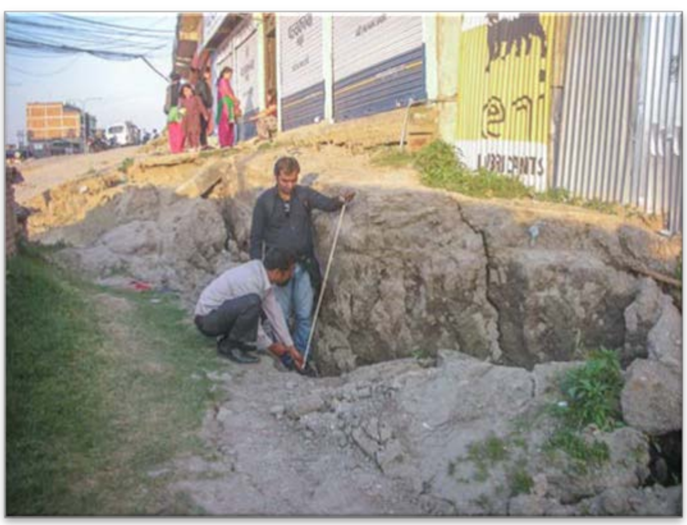

Figure 2. Measurement of a large lateral crack spreading along the highway.

Reproduced from Moss, Robb ES, et al (2015).

Initially, there was a lack of evidence for liquefaction. However, further trenching uncovered complex failure planes and buried liquefaction escape structures embedded within a thick sand layer. The slip surface from the mainshock seemed to offset this later, suggesting the occurrence of another type of earthquake-induced landslide; lateral spreads. As we discussed in class, lateral spreads generally involved weak soils due to their low residual strengths.

Structural Response Characteristics

Contrary to expectations, most of the civil infrastructure was able to withstand the shaking due to ground motions during the mainshock and aftershock. The majority of structural damage affected poorly constructed, unreinforced masonry buildings. Although the building codes in Nepal that address shear resistance in structural design, the codes are rarely enforced.

Further Study and Conclusion:

It might be relevant or interesting to further investigate the type of faulting and fault geometry that is typically within the region, and in the Gorkha area in particular. It could also be relevant to calculate and model the Peak Ground Velocity (PGV) in a response spectrum. As was mentioned in class, it is a more practical and representative measure of ground motion than PGA and PGD, it has a greater sensitivity to longer periods than PGA, and it may be better correlated with damage. Looking into dispersion effects of seismic waves, and wave propagation, might help explain some of the unexpected values for intensity of shaking at short periods, and lower amplitudes over long periods, for a soft soil site. Also, acquiring strong-motion recordings that were not readily available at the time that the article was published could be beneficial. I think focusing a bit more on the structural analysis in construction of new buildings. And enforcing building codes could prevent loss of life in the future. Also, the implementation of retaining walls near and around areas at high risk for landslides could be helpful in mitigating damage to roads and hydropower facilities during future earthquakes.

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