Fundamental properties of Kathmandu clay and seismic response

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1. Introduction

Large variation in sediment type and thickness (550m to 650m) in the Kathmandu valley of Nepal is considered to influence the geotechnical properties of the soils in the lacustrine which may cause trapping and focusing of seismic waves. The valley has experienced strong earthquakes in 1833 (M_w 7.7), 1934 Nepal-Bihar（M_w 8.2), 1988 Udayapur (M_w 6.9), 2015-5-25 Gorkha earthquake 2015-4-25 (M_w 7.8), 2015-5-12 (M_w 7.3). During these events, damages in Kathmandu valley was found to be site specific. Index properties, uniaxial compressive strength (UCS) tests and triaxial tests were carried out to study the fundamental properties of Kathmandu [KTM] clay. Based on these properties site specific seismic response of KTM clay is discussed.

2. Materials and method

Undisturbed soil samples from KTM basin (Fig. 1) were extracted from a depth of 4m. Kalimati formation (KTM0) lies in the central part of Kathmandu valley and consists of massive to very thick laminated black and grey slit and mud (Paudel et al. 2008). Gokarna formation (KTM1), (KTM2), (KTM3) is exposed in the northern part of Kathmandu valley comprising alternating layers of carbonaceous clay, silt, fine to coarse grained sands and gravel layers.

Fundamental properties of the samples were determined on the basis of the Japanese standard of soil classification. Wet sieving and hydrometer tests were used to determine the grain size distribution of the materials. Atterberg limits were determined according to JIS A 1205. Based on the gradation curve and Atterberg limits, consistency limits of each sample were determined. Organic matter content was also determined by loss of ignition method heating the samples at 550°C for 3.5 hours. Likewise, uniaxial compressive strength tests of Gokarna formation samples were carried out to determine the undrained strength. Consolidated-undrained (CU) triaxial tests on 35 mm diameter samples on KTM0 and KTM1 were also conducted with pore pressure measurement. Results obtained from these tests were used to discuss the subsoil properties of KTM clay and their relation with the seismic response.

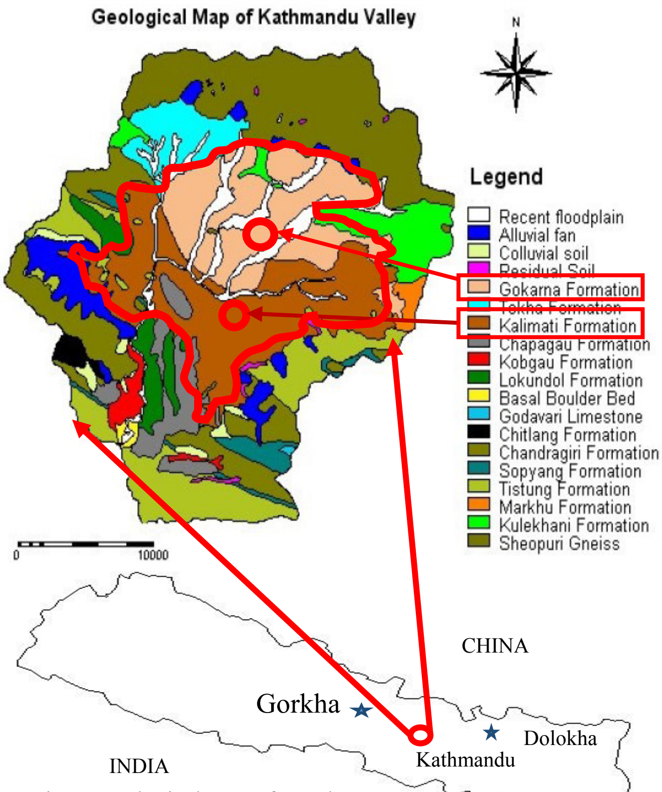

Fig 1: Geological map of study area

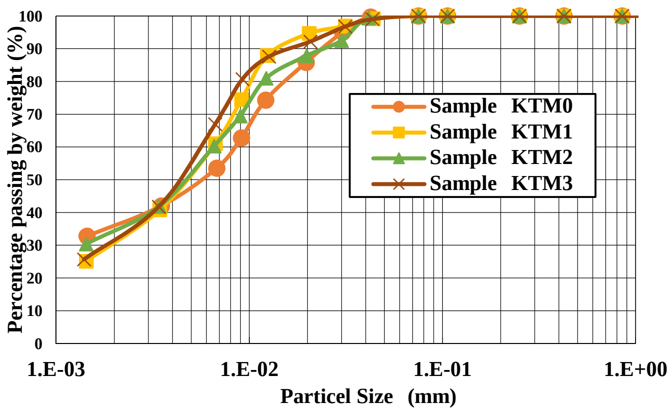

Fig 2: Grain size distribution curve of KTM clay

3. Results and Discussion

The maximum grain size obtained from the gradation curve is 43μm, as indicated in Fig 2. Average clay content (based on fraction smaller than 5μm) is 52.5%, which indicates that the soil deposit is silty-clay. Results obtained from the index properties show that the Kathmandu clay is medium (KTM0, KTM1) to highly plastic (KTM2, KTM 3) with average PI (Plasticity Index) value of 51.5%. Average organic matter content of the lacustrine clay is 8.33%, as summarized in Table 1. Although the soil deposit is lacustrine, organic matter content is low. The specific gravity of the tested samples decreases with increasing amount of organic matter content. Fig. 3 shows the compressive strength curve obtained from UCS as also summarized in Table 2. The maximum compressive strength was found at as axial strain of 10.5% to 11.5% in KTM1 and KTM2 while it was 6.8% in KTM3. The UCS tests show that the consistencies of KTM1 and KTM2 is medium while that of KTM3 is stiff in nature. The index properties and UCS test results indicate that the deposit of KTM3 has medium plasticity with highest value of undrained shear strength compared to KTM1 and KTM2. The test results indicate that deposits of clay with high PI are capable of strongly amplifying the incoming earthquake motion, however such amplification is less likely through clays which have small or medium PI (Vucetic et al. 1992). Soil deposits in the location of KTM0 and KTM1 are capable of strongly amplifying the incoming earthquake motions. Fig. 4 shows the results of CU_bar triaxial compression tests on KTM1. Test results indicate that both KTM0 and KTM1 are unconsolidated and cohesive in nature with average effective frictional angle of 30.67˚ and cohesive strength of 14.63kN/m^2. Although the internal friction angle and cohesion are identical in both the formations, the basement of Kathmandu valley is faulted and folded, and these structural features may also contribute to the basin seismic response in Gokarna and Kalimati formations.

During the recent Gorkha Earthquake of April 2015, most of the building damages were concentrated in the Gokarna formation, while in the Kalimati formation tall buildings were damaged more significantly. The damage in the Kalimati formation was concentrated on Khadka Gaon, Sitapila, banks of Bishnumati River and Nikosera (Durgesh et al. 2016). Test results show that the Kalimati formation is prone to amplification during the earthquake motion. During Michoacán earthquake (M_w 8.0) in 1985, soft lakebed deposits was amplified, which has similar geological setting as of the Kathmandu basin. Site specific damage pattern in recent earthquake shows that the lacustrine deposit of Kathmandu basin may have damping and amplifying effects depending on the variation of sediment deposit. The silty-clay particles may not be capable of transmitting the earthquake energy due to loss of cohesive strength.

4. Conclusion

In this study, fundamental properties of the Kathmandu clay were investigated keeping in view their role during earthquake shaking. The tests revealed that the Kathmandu clay is medium to highly plastic silty clay and is a soft lacustrine deposit. However, the basin exhibits site specific seismic response with strong features of amplifying and damping the earthquake motion, which depends on the local soil characteristics.

Table 1: Index properties of KTM Clay

Soil samples	Specific gravity	Clay content (%)	Plasticity Index	Liquidity Index	Organic matter content (%)
KTM0	2.613	48	44.19	88.46	7.808
KTM1	2.608	52	30.3	30.3	10.68
KTM2	2.626	52	15.93	15.93	6.22
KTM3	2.64	58	16	16	6.50

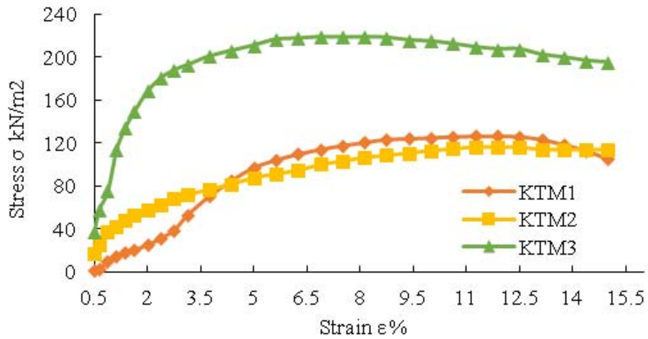

Figure 3: Results of UCS test on Gokarna formation samples

Table 2: Physical property of Gokarna formation samples from obtained from UCS

Soil samples	Dry density (g/cm^3)	Water content (%)	Degree of Saturation (%)	Void ratio	Uniaxial Compresive strength q_u kN/m^2
KTM1	1.076	51.04	97.71	1.29	126.448
KTM2	1.186	41.34	88.33	1.25	116.546
KTM3	1.223	29.27	65.76	1.20	271.769

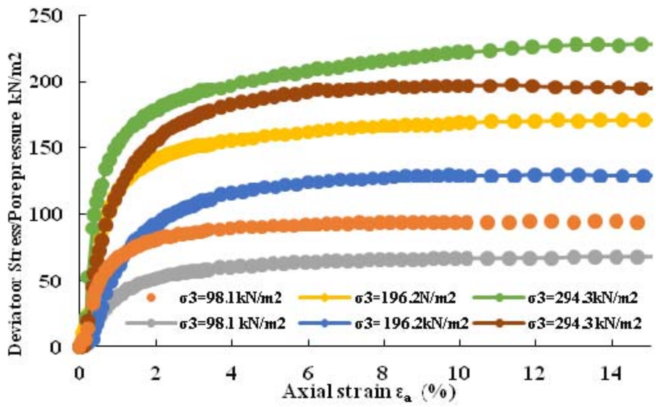

Figure 4: Results of CU_bar triaxial compression test on KTM1

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