Liquefaction Potential Analysis and Probable Remedial Measure for Existing Structure in Kathmandu Valley

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1 Introduction

Kathmandu valley lies in the center of the seismically active Himalayan arc. The studies carried out so far indicate that a big earthquake is expected in near future, which may heavily damage the historically important structures within the valley. Kathmandu valley deposit, composed mainly of the lake sediments, consists of saturated sand layers at shallow depth at different locations. Because of the presence of loosely deposited sand layers and shallow ground water table, liquefaction can be well anticipated, but the research efforts devoted in this topic are still limited.

This study puts an effort to make liquefaction hazard analysis by using empirical relations based on the field in-situ test data in Kathmandu Valley. In the second part of the study, soil desaturation by air injection is introduced as a liquefaction prevention technique, which helps strengthen the liquefiable foundation soil layer of existing residential buildings. In desaturation by air injection technique, the properties of soil are changed by artificially injecting air into the liquefiable layer. The studies carried out so far well demonstrate the effectiveness of air injection technique to desaturate a sandy soil and make it unsaturated for a long time (Okamura et al. 2011). Past test results show that the liquefaction resistance of a desaturated sand mass is quite higher than that of a saturated sand mass. Therefore, in this study, physical modeling in centrifuge was performed simultaneously with hazard analysis to observe the performance of the desaturation technique as a countermeasure to liquefaction of foundation soil of residential buildings. The centrifuge models were prepared based on the findings of the quantitative analysis carried out by using the collected SPT value (N) and residential building details from the study area (i.e., Kathamndu Valley). Factor of safety (F_L) against liquefaction was calculated by using the SPT value (N) with a scenario earthquake of magnitude 8.0 with peak ground acceleration of 300gal in some parts of the Kathmandu Valley (JICA, 2002). The centrifuge model in the laboratory also represents a typical ground section of the Kathmandu Valley. The index properties, grain size distribution and mineralogical contents of the field sand were also compared with Toyoura sand, a commercially available sand in Japan and commonly used in research work, to prepare a representative physical model in the laboratory. As Toyoura sand has quite comparable properties with the field sand, it was used to prepare the physical model in this study.

2 Quantitative analysis

In total 102 borehole data from 33 locations of Kathmandu Valley were collected and used in the analysis. In this study empirical relation based on the SPT value (N) suggested by Youd et al. (2001) was used for the F_L calculation.

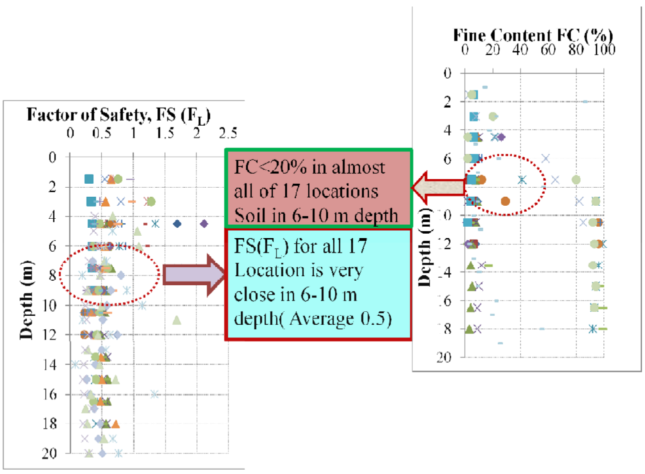

Fig. 1 Findings of the quantitative analysis considering F_L and Fine content

The quantitative analysis carried out with the collected SPT value (N) shows that different locations in Kathmandu Valley are susceptible to liquefaction (i.e., $F_L < 1$), which means the main administrative center of Nepal has high liquefaction hazard.

The determined factor of safety (F_L), relative density (D_r), the SPT value (N), and fine content (FC) through the collected borehole logs and quantitative analysis by using the empirical relation are quite comparable at 6-10m depth in 17 borehole locations of the Singhadarbar area among the 22 borehole locations as depicted in Fig.1. The soil of this depth is considered as a representative soil layer for further study. So, the ground section through these locations was taken as a reference foundation section to prepare the physical model in laboratory.

3 Physical modeling in centrifuge

Two models were prepared in the laboratory: one saturated foundation soil model (Case1) and the other desaturated foundation soil model (case2). The model structure consisted of a metal plate on top representing the building structure with an average contact pressure of 35kPa on a 6m-thick (in prototype scale) loose liquefiable sand bed, as illustrated in Fig.2. In each model, bottom 1-m layer was a dense soil layer of relative density Dr = 90%, which was used to place the air injector in the desaturated model. Remaining 6 meter layer was loose soil layer of relative density Dr = 50% in which first 4m was saturated and top 2m was unsaturated (GWT was 2m below the ground surface) as shown in Fig.2.

The prepared model was then set on the centrifuge.

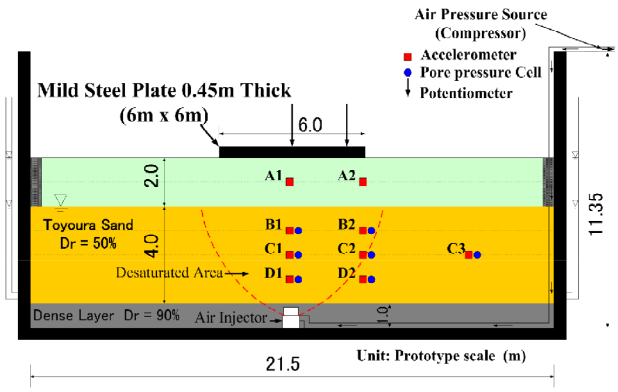

Fig 2. Desaturated Centrifuge model at 50g

The centrifuge acceleration was increased to 50g and the air was injected in Case2 through the injector as shown in Fig.2. The estimated residual degree of saturation at desaturated area was found to be 85%.

The Prepared saturated and desaturated models were tested in the centrifuge at 50g acceleration with imparting a simulated sinusoidal wave of frequency 40Hz and typical acceleration amplitude of 190gal. The test results showed that excess pore pressure (EPP) in saturated model of Case1 increased and reached the initial effective stress in a few cycles, indicating that the soil had liquefied, whereas in the desaturated model of Case2 EPP was significantly less than the initial effective stress, which indicates that the soil did not liquefy in the same location as in Case1, as shown in Fig.3.

Similarly, the measured vertical settlement is also reduced significantly in desaturated model as compared to the saturated model. The vertical settlement at the structure center was reduced by approximately 50% as shown in Fig.4.

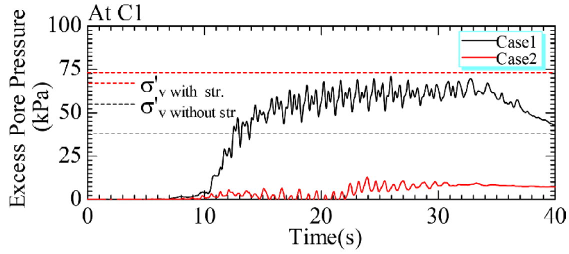

Fig 3. Excess pore pressure in saturated and desaturated model at same location

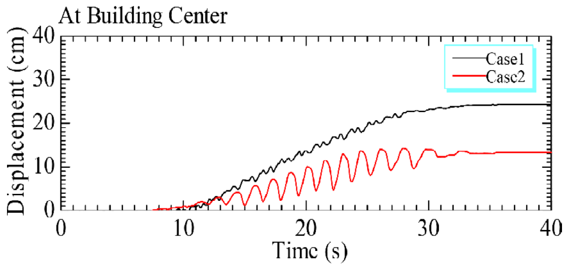

Fig 4. Vertical settlement in saturated and desaturated model at same location

4 Concluding remarks

Liquefaction hazard analysis based on the field in-situ data were carried out in this study. The factor of safety (F_L) against liquefaction was calculated for every soil layer deposit of the each borehole location. Most of the selected borehole locations have $F_L<1$, which indicates that there is high liquefaction hazard.

Similarly, the physical modeling carried out in the centrifuge shows the effectiveness of the desaturation technique by air injection in the foundation soil of existing structure. In this study, the excess pore water significantly reduced from 65kPa in Case1 to 7.5kPa in the Case2 at the same location of the model. Also, the vertical settlement reduced remarkably in Case2 as compared with Case1. It was 25cm in the structure center in Case1 while it reduced to 13cm in Case2.

All above test results show that the desaturation technique by air injection can be a better solution to control the foundation soil liquefaction and save thousands of structures standing over it in Kathmandu valley.

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