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Soil Liquefaction Effects on R.C.C. Piles

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***Abstract*— The behavior of foundations during earthquakes is often dictated by the response of its supporting soil due to the ground shaking. In general, there are two types of ground response that are damaging to structures. In one, the soil fails typically by liquefaction, such as in the 1995 Kobe earthquake. In the other, the soil amplifies the ground motion (as in 1989 Loma Prieta earthquake in California).Pile foundations are often used to transfer axial loads through soft soils to stronger bearing strata at depth. The objective of this research is to gain an insight into the failure mechanism of end-bearing piles in liquefiable soils during earthquakes.**

Thus, it is necessary to develop an analytical model that predicts the fundamental characteristics of R.C.C. Piles within a range of loading that is appropriate for the structural system. Case history of pile foundation during earthquake has been discussed and the centrifuge modeling has been done. A pile model has been developed, tested and compared with equivalent concrete pile. It is concluded that the codes of practice need to include a criterion to prevent buckling of slender piles in liquefiable soils. It is necessary to select a pile section having a margin of factor of safety against buckling under the worst credible loads.

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

Earthquakes cause damage to engineering structures (Figure 1.) and often result in loss of lives. The recent Indian earthquake at Bhuj on 26th January 2001 is estimated to have cost more than5 billion U.S. dollars but, more significantly, the death toll was more than 20,000.[1] Forecasting the exact time of an earthquake can at best reduce casualties, which at present appears to be an impossible task. Therefore, structures need to be designed to withstand the impact of an earthquake and prevent collapse, as "it is buildings that kill people, not earthquakes". [2]

Fig.1 Failure of a residential building during the 2001 Bhuj earthquake (India

Earthquakes in the past have shown the shortcomings of current design methodologies and construction practices, at the cost of structural failures and loss of lives.[3] Post earthquake investigations have led to improvements in engineering analysis, design and construction practices

II. PILE-SUPPORTED STRUCTURES STILL COLLAPSE DURING EARTHQUAKES

Structural failure by the formation of plastic hinges in piles passing through liquefiable soils has been observed in many of the recent strong earthquakes.[4] Figure 2. shows two such cases from past earthquakes. This suggests that the bending moments or shear forces that are experienced by the piles exceed those predicted by design methods (or codes of practice). All current design codes apparently provide a high margin of safety (using partial safety factors on load ,material stress which increases the overall safety factor), yet occurrences of pile failure due to liquefaction are abundant. This implies that the actual moments or shear forces experienced by the pile are many times those predicted. It may be concluded that design methods may not be consistent with the physical mechanisms that govern the failure. In other words, something is missing [5].This research investigates what is missing from the current understanding of earthquake-induced pile failure by analyzing the postulated hypothesis of the existing design codes of practice, such as the Japanese Road Association Code (JRA 1996), NEHRP (2000), and Eurocode 8 (Part 5). [6]

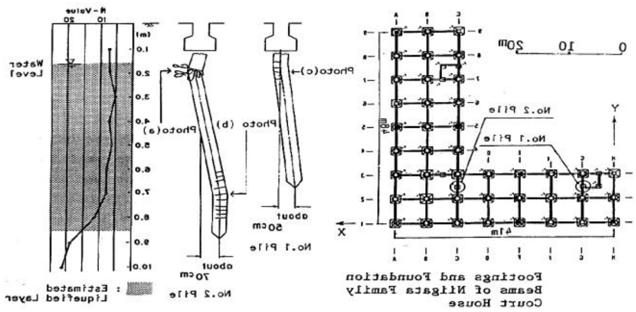

Figure 2: Pile failure of Niigata Family Court House building during 1964 Niigata earthquake

III. CURRENT UNDERSTANDING OF PILE FAILURE AND DESIGN METHODS

The current understanding of pile failure is as follows. Soil liquefies, it loses its shear strength, causing it to flow and dragging with it any overlying non-liquefied crust. These soil layers drag the pile with them, causing a bending failure [7]. This is often referred to as failure due to lateral spreading. In terms of soil pile interaction, the current mechanism of failure assumes that the soil pushes the pile. The deformation of the ground surface adjacent to piled foundations is often suggestive of this mechanism. [8]

The Japanese highway code of practice (JRA 1996) has incorporated this understanding of pile failure as shown in

Figure 1.6. The code advises practising engineers to design piles against bending failure assuming that non-liquefied crust offers passive earth pressure to the pile while the liquefied soil itself offers a drag equal to 30% of total overburden pressure

IV. EXPERIMENTAL MODELING OF SEISMIC PILE-S OIL INTERACTION IN LEVEL GROUND

Each of the centrifuge tests carried out generated data equivalent to a real earthquake that can be viewed from different angles, such as study of pile behavior or pore pressure generation and dissipation in the soil, etc.

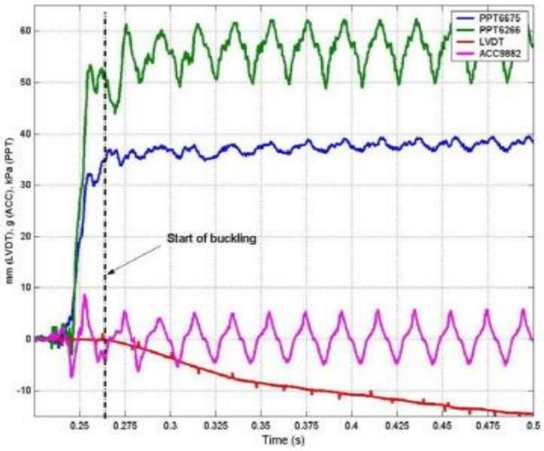

Figure 3: Package SB-05 before the test

Figure4 Surface observation after the test SB-05

V. VISUAL OBSERVATION AFTER THE TESTS

It is quite well known that the most recognised field evidence of soil liquefaction is the presence of sand boils at the ground surface following an earthquake the surface observation of the piles after the tests. It must be noted that the piles that failed had their heads rotated which is quite similar to the visual observations of the piled structures after an earthquake. This demonstrates that centrifuge modelling can reproduce physical mechanisms observed at real earthquakes. It must also be noted that the model piles in the experiments were in level ground whereas the collapsed piled structures were in laterally spreading soil[9]

Figure 5 Surface observation after the test

VI. BUCKLING INITIATION

Figure plots the time histories of input acceleration, pore pressure records and the LVDT readings. It may be noted that as shaking starts pore pressures begin to rise but the pile starts to buckle after two full cycles of loading. This confirms that the buckling is not linked to inertia .It must also be observed from the plot that the pile begins to buckle before the bottom soil is fully liquefied

Figure :6 Time histories of input acceleration, pore pressure and LVDT

VII. NEAR FIELD PORE PRESSURES

With earthquake shaking, a front of zero effective stress advances top down and at the same time the length of the pile is gradually unsupported by the soil grains. The pile would begin to buckle sideways as the advancing front reaches the critical depth thereby pushing the soil. It must be expected that the imposition of monotonic shear strains (due to pile monotonically pushing the soil) at low effective stresses in moderately dense soil will lead to an attempt to dilate, suppressed by the need for water to flow into the zone affected, which must then create a local reduction of pore fluid pressure.

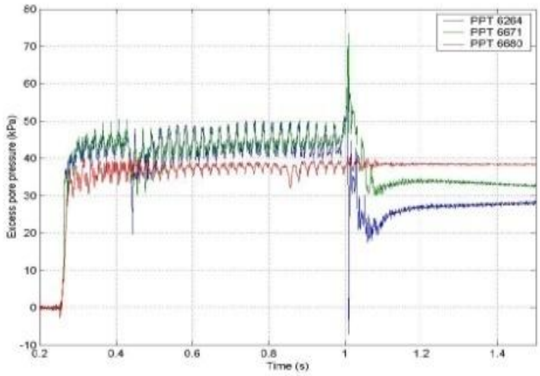

Figure 7 : Near field and far field pore pressure measurements at 52.5mm

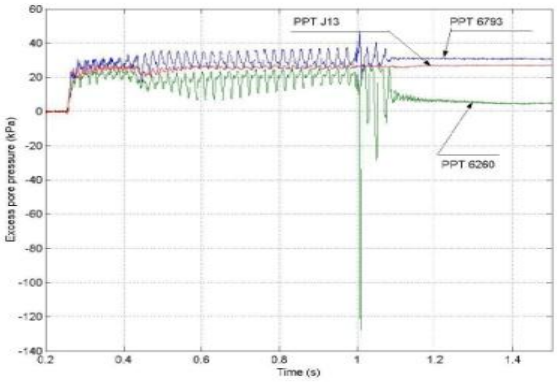

Figure 8 Near field and far field pore pressure measurements at 92.5mm depth

VIII. Discussion

The failure of the piles in the model centrifuge tests has been compared with the observed pile failure in the field case histories. This is also links the correlations obtained from the study of case histories with a theory of pile failure backed up by the centrifuge test results. A parallel has also been drawn between Eulerís classical buckling and pile buckling.

IX. Conclusions

The work presented in this paper was carried out without making the presumption that it is the bending moments induced by the lateral loads that cause the failure of piles in areas of seismic liquefaction. During seismic liquefaction, a pile foundation also continues to experience the axial load of the superstructure. Thus, the effect of axial load as the soil liquefies was carefully studied. Detailed dynamic centrifuge testing, in-depth study of case histories and analytical studies form the basis for investigating the mechanism of pile failure during seismic liquefaction. Based on these studies, the buckling mechanism has been identified as the most probable failure mechanism for pile foundations and is expected to precede failure due to lateral spreading.

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