Evaluation of Amplification Factor Considering Soil Non-Linearity including Liquefaction

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Introduction:

In this study an effort has been made to investigate peak ground accelerations (PGA) affected by different earthquake motions including soil non-linearity and liquefaction. to finally obtain a relation between the amplification factor and the ratio of the natural period of ground to the dominant period of input motions (T_g/T_b). Ground acceleration is computed using multi spring 1D model[1)] by giving different input wave motions having different predominant time periods. Liquefaction potential value of each case was computed in an effort to segregate the variation of amplification factors. But Liquefaction potential values wouldn't approve to use it for segregating the values. By computing the differences in peak ground accelerations between these values for a same site and input motion, it is observed that there is a significant change in the value which suggests that considering liquefaction ascertain us that the values computing liquefaction would give us a most appropriate value.

Analysis without considering liquefaction:

For this analysis we have used nine borehole log data and thirteen input wave motions. We have used the data of soil type and SPT N-value from the bore hole data to get the material properties for the multi-spring model element for each layer of the soil deposit.

We have first evaluated the PGA for each ground site with different input wave motions applied at the base using multi-spring model. In order to investigate the effect of input amplitude level, peak base accelerations (PBAs) were adjusted to the following specific values 100, 200, 400 and 800 gals. Whereas we have used eq.1 for the evaluation of the time period of ground (T_g) and the time period of the input wave motion (T_b) is evaluated using the Fast Fourier Transform.

$$T_g = 4 \times \sum_{i=1}^{N} \frac{h_i}{V_{s0i}} \qquad \text{eq 1}$$

where, h_i : depth of layer (i) where i = 1 to N

V_{soi} : Shear wave velocity of layer (i)

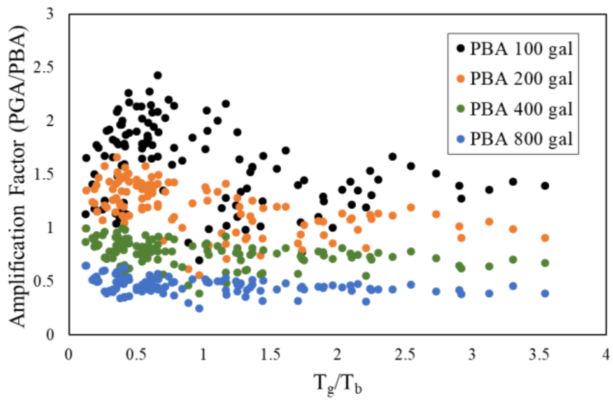

Figure 1 Plotting amplification factor against ratio of Time periods

Analysis considering Liquefaction:

PGAs were evaluated by considering liquefaction in the layers by assigning liquefaction parameters to the material properties to layers which could be liquefied. Later we have evaluated the liquefaction potential for each site under each wave motion following the specification for Highway Bridges in Japan with the information of SPT N-values and PGAs which were computed from 1D non-linear analysis. Initially we have tried to segregate the amplitude factors into different categories according to the liquefaction potential which would depend both on the soil deposit and also the input wave motion. But it is not possible to distinguish between the plots as per their liquefaction potential value. In the figure below we could observe that there is a significance change in value of amplification factors as the value of PBA changes.

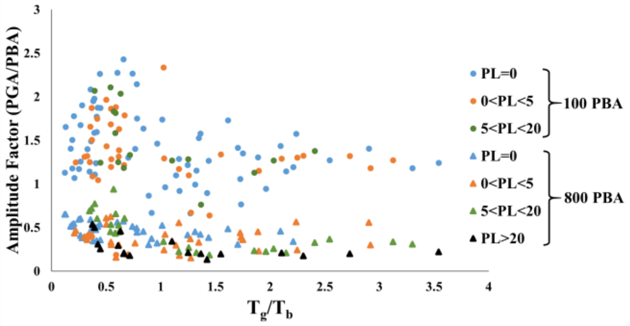

Figure 2 Plotting amplification factor against ratio of Time periods

Difference in PGAs:

We also did analysis to find the PGA when we wouldn't consider the liquefaction of the ground during an earthquake. So to know the difference in the PGAs between the liquefaction analysis and non-liquefaction analysis. In the figure below we could see that the differences in PGAs (in gals) between the analyses for each case is increasing as the PBA increases as 100, 200, 400 and 800 gals.

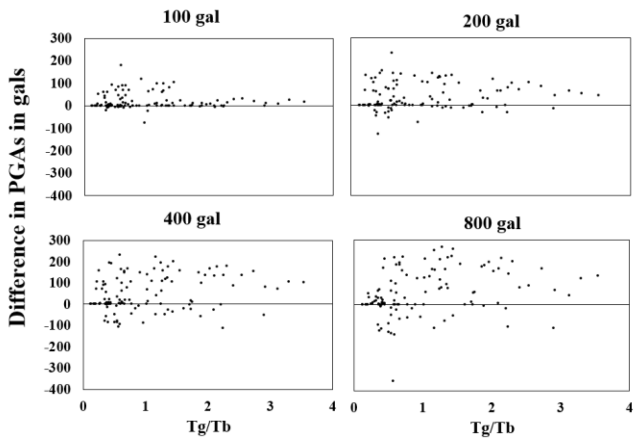

Figure 3 Difference in PGA for with liquefaction & without liquefaction vs ratio of time periods

The difference in PGAs varied from 0 to 300 gals, which would be more if the PBA is more than 800 gal. So, liquefaction in the soil deposits have a major role to play in defining the actual PGA to determine in practicality.

Excess Pore Water Pressure Ratio

So to know the reason why there is a significant difference in amplitude factors of non-liquefaction and liquefaction even though the liquefaction potential value of a certain case is zero, we have plotted the difference of amplitude factors against the excess pore water pressure ratio. Here, we can observe that there is a certain pattern in the results. When the excess pore water pressure ratio is more than 0.8 the variation in difference is just random, but between the values of 0 to 0.8 we could observe a certain trend to follow.

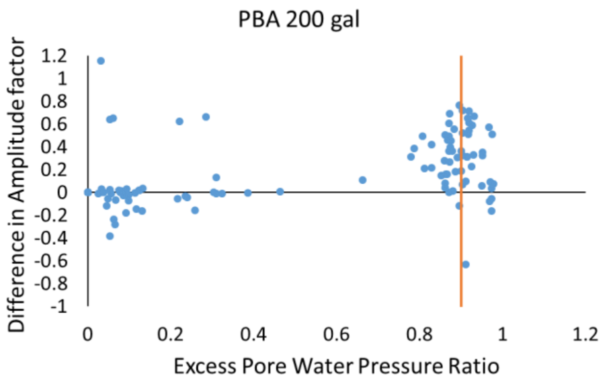

Figure 4 Difference in Amplitude factors vs Excess Pore water pressure ratio

We believe that an intense investigation is still needed and a number of numerical analysis have to be done before we could conclude a definite relation between amplitude factor and ratio of the time period of ground and predominant time period of input wave motion considering non linearity of soil and liquefaction.

References:

1) Iai, S., Matsunaga, Y. and Kameoka, T. 1992. Space Plasticity Model for Cyclic Mobility, Soils and Foundations, 32(2): 1-1