MODELING SOIL-STRUCTURE INTERACTION

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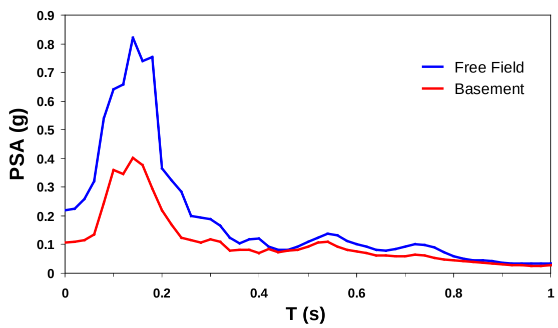
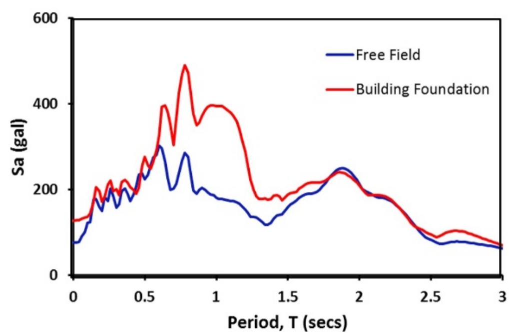
This paper offers a guided tour through the various ways of accounting for soil–structure interaction (SSI) in design and analysis, ranging from a complete analysis of the combined system of structure, foundation and surrounding soil to approximate models of the combined system. The focus is on three types of structures: bridges on pile foundations, tall buildings with several levels of underground parking and large basement slabs with shallow embedment.
When we conduct an analysis of the total soil–structure system, the effects of SSI are implicitly included in the analysis and reflected in the structural response. No special consideration of SSI is required. However, although this type of analysis feasible, engineers rarely use it in practice because the structural analysis programs used by structural engineers cannot handle the nonlinear soil continuum directly. There are powerful commercial programs available that can do complete analyses, but the learning curve is steep and the computational time is too long for the designers' requirements except for special projects. Therefore, it is necessary to uncouple the computational model of a structure from the soil and to include SSI effects by appropriate springs and dashpots. We present some of the problems in doing this effectively in the paper.

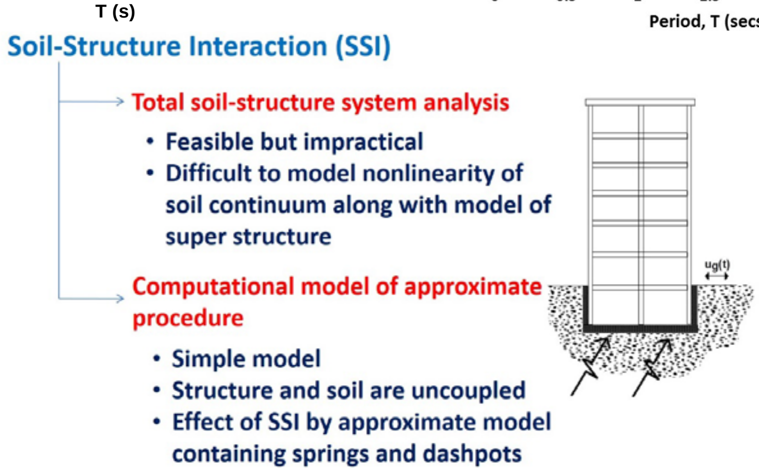
Base Slabs: FEMA440 presented the empirical equation below, based on field data that seems to show that base slabs always reduced the free field motions as in Figure 1. However, we found that of 99 free field – base slab motion pairs, 33 pairs showed base slab amplification of the base motions as in Fig.2.

$$RRS_{bsa} = 1 - \frac{1}{14100}\left(\frac{b_e}{T}\right)^{1.2}$$

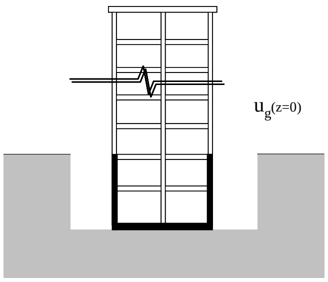
Where:
- RRS = ratio of the base lab spectrum to the free field spectrum;
- b_e = equivalent radius;
- T = spectral period.

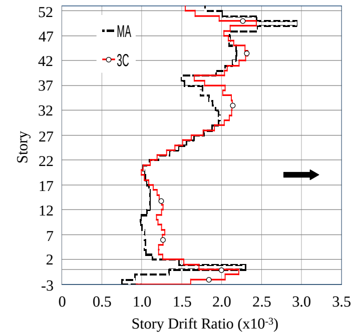


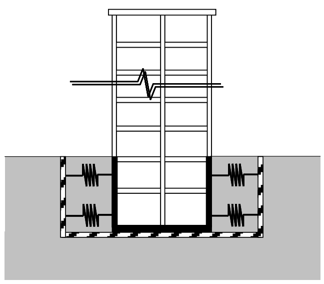


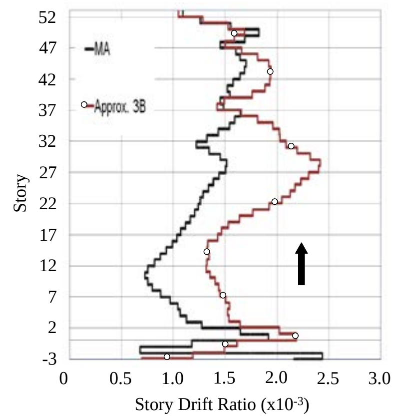


Red lines indicate best solution, validated by recorded motions during an earthquake. The very crude model gave a good result. A seemingly better and more detailed model gave a bad result. If recordings had not been available, there was no way to recognize which was the better model. This is an endemic problem with simplified modelling of complex problems.









A common approach to sub-structuring a complex SSI system such as a bridge on pile foundations is to evaluate the kinematic stiffness of the pile foundation and use the associated kinematic motions as input to the superstructure. This approach leads to overestimation of the foundation stiffness as shown below and also neglects the inertial effects of the superstructure on the ground motions