Chapter 6

6. Nonlinear Behaviour of frame with pile foundations with and without Interface Element

6.1 GENERAL INTRODUCTION

In the previous chapter a dynamic soil-pile structure interaction analysis has been carried out on a pile supported framed structure to understand the effects of nonlinear soil yielding. In this chapter analysis has been done to study the effect of interaction between pile and soil by modeling an interface element. Soil-pile structure system (Figure. 5.2) as discussed in chapter 5 is considered. Linear structure and pile responses are assumed in all cases with the nonlinear soil yielding and interface effects.

Few quantitative conclusions can be made from this study by considering the effect of the pile supported framed building on linear and nonlinear soil models with and without interface elements. For each case the response will be converted into frequency domain to understand shift in frequency of the pile soil system and pile supported framed building, thus conclusions are drawn regarding the inclusion of soil foundation interaction effect in the structure analysis.

6.2 METHODOLOGY AND IMPLEMENTATION

As discussed in the previous chapters, in this thesis direct approach is used, where the pile, soil and structure system are modeled together in a single step. For this purpose a three dimensional Finite Element Method is used for modeling the soil-pile structure interaction using SAP 2000.

In this chapter effect of relative movement of soil and pile that is debonding / separation and rebonding of pile and soil is considered. To account for the discontinuous behavior at soil-structure interface many methods like use of thin continuum elements, linkage elements like discrete
springs, special interface or joint elements, etc., are used generally (David et al., 1999). The details of the interface modeling are discussed in the following sections of the chapter.

SAP 2000 is used to model the separation / debonding of the pile, for that the “Gap element” in Link / Support properties is selected. For the Gap element the force deformation relation as given in Eq. 2.1 is used. To model this gap element two input parameters has to be specified one the spring constant and d the gap separation. The spring constant or contact stiffness $k$ should be always 2 times stiffer than surrounding element, so the value has been taken as 50 kN/m, with the gap separation of 0.01m.

For the foundation model considered in this analysis, there are 4 pile groups with 2X1 piles for each group. To understand the interface behavior of pile and soil, the Gap elements are provided on either side of the pile for all pile groups (Figure. 6.1). To make the analysis simple, the gap separation is modeled only in the direction of load application, here as the load is applied in x direction, so Gap elements are also provided in that direction with the same gap for the full depth of the pile.

![Figure. 6.1 3D Soil Foundation Interaction Model with Linkage / Gap element](image-url)
6.3 PARAMETRIC STUDY

In the following section a parametric study has been conducted to understand the interface behavior of pile and soil by modeling a linkage element between them. The NS component of Elcentro earthquake is given as input for the transient analysis in the following section.

6.3.1 Pile with and without interface elements

To study the effect of soil and foundation interaction, the foundation as designed in the previous chapter for the framed structure is considered (Figure 6.1). Figure 6.2 and Figure 6.3 show the response and Fourier Transform of the soil foundation interaction (FI) system with and without link elements. From the results it has been observed that there is a minute increase in response for the analysis with and without link elements for the properties considered in this study.

But there is a drastic difference in the behavior, when the state of stress of soil foundation system is observed for two cases, with (Figure 5.9) and without link elements (Figure 6.4). This may be

![Figure 6.2 Comparison of acceleration response at pile cap with and without link element (FI) under May 18, 1940 Elcentro Earthquake (NS)]
Figure 6.3: Comparison of Fourier amplitude spectrum of pile cap with and without link element (FI) under May 18, 1940 Elcentro Earthquake (NS).

Figure 6.4: Stress of pile 1 under cap 1 for FI with link elements under May 18, 1940 Elcentro Earthquake (NS).
because of loss of contact between pile and soil. The pile and soil are behaving independently and so there is not much of soil resistance to the piles.

6.3.2 Pile supported frame buildings with and without interface elements

A pile supported framed structure as shown in Figure. 6.1 is considered for the soil foundation structure interaction (SFSI) analysis in this section. Figure. 6.5 and Figure. 6.6 show the response and Fourier Transform of the SFSI with and without link elements. From the response we can clearly see that there is an increase in response for the analysis without link elements. But in reality due to loss of contact between pile and soil during strong ground motion, there will be much decrease in response. So by considering all these effects in our analysis makes our prediction close to reality.

As the contact stiffness and Gap separation assumed in this case is not measured by modeling the actual stiffness of contact between pile and soil. A detailed analysis of this has to be done to have a good understanding on this behavior. Also this behavior can be modeled by assuming various contact stiffness and gap separations along the depth of pile.

![Comparison of acceleration response of top floor with and without link elements under May 18, 1940 Elcentro Earthquake (NS)](image)

Figure. 6.5 Comparison of acceleration response of top floor with and without link elements under May 18, 1940 Elcentro Earthquake (NS)
6.4 CONCLUSIONS

In this chapter the seismic response of pile supported structure is studied by modeling the contact between pile and soil using Interface Element.

When only Foundation interaction is considered for the cases with and without Interface elements, because of the Gap formation between pile and soil under dynamic loading there is a drastic reduction in the stress values for the case with link elements (4 times reduction).

The acceleration response of top floor has been reduced by two times, when contact between pile and soil has been modeled. Also there is an increase in Fourier amplitude by 4.5 times in case of response of top floor without link element.

So to have a good understanding of SFSI behaviour under seismic loading a detailed analysis by modeling the contact between pile and soil has to be done. Neglecting this behavior makes the over estimation in assessing the strength of foundation.

Figure. 6.6 Comparison of Fourier amplitude spectrum of top floor with and without link element under May 18, 1940 Elcentro Earthquake (NS)