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Effect Of Soil Structure Interaction On Response Of Structures - A Review Article

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Abstract:
In this research article under seismic loading effects the soil underneath and it causes development of stresses in soil which in turn shown an impact on the frame intact. The stresses in the soil effects the structure motion and in reverse the structure motion alters the soil response. This is called Soil-Structure-Interaction. A stress developed in the soil finds a way to move to free space, whereas when a frame located on a soil mass receives the total stresses through foundation and delivers direct and shear stresses through its grain mass and this grain skeleton behaviour depends on many factors like void ratio and confining pressure. These effects are to be considered most important as they show heavy impact on the super structure. The seismic effect on the super structure depends mainly on soil amplification effect, inertial and kinetic interaction.
KeyWords: Soil Structure Interaction, Response, Amplification, Inertial Interaction Kinetic Interaction.

I.INTRODUCTION

Seismic effects cause structural elements in contact with soil are subjected to displacement due to movement caused by vibrations. This influences the response of structure and in cyclic action influences the response of soil mass.

The main critical factors affecting soil structure are free field displacement, free field rotation and inertia. The type of structure such as soft and sands effects the structures in a specific way. For example multi storey building structures located on poor soil were effected severely compared to low rise buildings located on the stiff soil.

II. REVIEW ON LITERATURE

Jonathan et al. (1999) has evaluated inertial soil structure interaction effects concerned with seismic response. From the studies it was concluded that standard building codes considered under influence of site conditions, foundation embedment, flexibility and foundation impedance shape. Using Northridge earthquake data (1994) system identification techniques and analysis procedures were implemented to empirically evaluate SSI effects using strong motion data from a broad range of sites.

Mindlin (1994) has studied structure subjected to earthquake loads. He has studied and presented the results for a plate subjected to tangential loads in lateral displacement. From his studies lateral stiffness K_h of a rigid,circular membrane which is infinitely stiff in its mother plane and flexible in transverse direction so as vertical contact stresses are elicited.

$$K_h = \frac{8Ga}{2-v}$$

$$\tau_{xz} = \frac{P_x}{2\pi a\sqrt{a^2-r^2}}$$

He found that with xz τ being the contact stress, which is parallel to the applied tangential load Px.

Zemochkin and Sinitsyn (1962) has analysed a frame with raft foundation assuming uniform soil pressure. Deflection in the raft were calculated by considering the compatibility of displacements at number or points below raft.

Sommer (1965)has analysed the frame considering soil mass as half elastic space and foundation as one dimensional beam/Slab. Considering this compatibility conditions were applied at interface by dividing into number of equal size elements and supports were applied at element centres. Support reactions were calculated applying unit displacement and equilibrium equations were established. Displacements derived were used in equilibrium equations to get new support reactions and contact pressures.

Matinmesha (2011) has analysed two dimensional plane strain finite element using Abacus for soil structure interaction. Seismic frequencies were differed as low, medium and high. The analysis has shown that loose soils amplies earthquake waves on the SS interface. From his studies it was found that seismic waves travel from bed rock through different soils changing their frequencies thereby effecting the superstructure.

Priyanka (2012) has done research on soil-structure interaction on multi storied building with different types of foundations. It was found that type of soil mass allowing the passage of seismic waves and type of super structure influences the response of ground motion.Storey drift,Base shear, column reactions and moments were found and were presented.

Ravikumar C Reddy and Gunneswara T D Rao(2012) has studied about the effect of soil interaction on drift and rotation of column footing junction and moments and shears of the frame. An RCC frame with plinth beam supported on pile footings were considered for this test and vertical loads were assigned in static condition. Conventional analysis and Finite element analysis was done and compared the results were compared. For Finite element analysis, nonlinear vertical springs were assigned along the pile depth and at the tip of pile. ι-z curves and p-y curves were drawn for the pile group. From the results it was concluded that bending moments and shear forces were reduced in finite element analysis compared to conventional analysis.

N.siva Prasad Rao, Ravikumar C Reddy and Gunneswara T D Rao (2013) has studied the effect of soil structure interaction for an RCC frame with plinth beam supported on pile group embedded in cohensionless soil. Conventional design and nonlinear finite element analysis was done for the frame and was compared with conventional analysis results. Factors such as shears, moments, drifts and rotations were drawn for comparision study. From the results and comparision statement it was concluded that decrease in rigidity of plinth beam reduces the shear force and bending moment of frame. Also it was concluded that soil structure interaction should be considered in designing of frames.

III.MECHANICAL AND PASSIVITY EFFECTS

Any structure resting on soil mass can be under influence of two effects namely mechanical kinematic and inertial effects.These mechanical or kinematic effects are due to difference in seismic wave propagation which is due to difference in density and elasticity of soil mass though out the length of wave passage. These seismic waves can be influenced by soil mass properties in reflecting and refracting and also changes their direction and angle of collision. Structure mass hasno effect on soil structure interaction. SSI considers effects like size and shape of structure, type of foundation, seismic wave intensity and angle of collision.

Passivity effects are those effects combined with dynamic behaviour of super structure, sub structure and soil mass. Soil mass having its own elastic and inertial properties influences in increasing degree of freedom.

Enhancing in number of degrees of freedom allows seismic energy to be dissipated and hysteric deforming of soil mass.

A.Static Load Effects on SSI

Lot of studies has been done in a very straight and simple way considering frames in three dimensional frame model. Few studies were conducted considering the effects of soil structure interaction. From the studies it was observed that 2D frames has shown deviated results than the actual ones compared to space frames. So it can be understood from the studies that the forces, moments and reactions are obviously effective when compared to conventional analysis.

B.Dynamic Loading Effect on SSI

Apart from the consideration of fixed supports to super structure in dynamic analysis, Assigning of flexibility property to the supports decreases the stiffness of structure and enhances the period of structure for which the results can be observed from response spectrum curve. This change in natural period of structure also influences the seismic response of the structure. In addition to this soil mass assigns damping to thebehaviour of structure. These effects are considered to be important in analysing any structure considering SSI effects from many studies.

IV.SOIL MODELLING

Soil is typically modelled in two ways for SSI studies.

1. Spring modelling

Assigning springs at footing and soil mass junction typically gives flexibility to the soil mass. Translation and rotation of soil in both the axes defines the simulation and effect of flexibility.

2. Elastic continuum method

Soil is modelled as solid member assigning all possible mechanical properties such as Young's modulus, poison's ratio, ultimate compressive strength and density of soil etc. Footing and soil mass junction i.e., bonding is assigned once after modelling the frame depending on the available options in respective software.

V.FRAME & FOOTING MODELLING

In the three dimensional structure the beams and columns are modified as per the literature survey. Slabs and walls are modelled as 4 or 8 noded plate or shell elements. The bottom slab elements are designed as a pile cap.

Isolated footings are modelled as fixed supports whereas pile footings were modelled as six noded beam elements assigning spring constants.

VI.SOIL STRUCTURE INTERACTION ANALYSIS-APPROACH

There are three approaches for Soil Structure Interaction studies

1. Half-Space Theory

a) Direct Approach

In this approach soil and structure were modelled as one element subjected to kinematic and inertial effects. Kinematic effects are due to rigid supports and inertial effects are due to vibrations developed resulting in base shear and base moment.

b) Indirect Approach

In this approach, half of the space is replaced by springs or lumped mass and dashpots. This is effective approach in dynamic SSI analysis even when complex structures were considered. When it comes to sub structure approach, SSI can be done in step wise procedure which is by using principle of superposition free field deformation and dynamic response of foundation system were isolated.Number of studies were done to find the effect of SSI on dynamic response of structures.

2. Analytical Methods

a) Winkler Approach

A system of identical and independent linearly elastic springs were used to represent the soil mass system in this approach. Basic problem in this approach is to determine the stiffness factor of elastic springs.

b) P-y Method.

A numerical model with nonlinear springs were assumed simulating the soil mass. Pressure (P) and deflections (y) are determined considering may factors like type of soil, type of foundation, shape of footing, Friction, depth etc.,

c) Elastic Continuum Method

In this approach, behaviour of soil mass is assumed as 3D elastic solid material and deflections were assumed to be confined in the loaded zone only. Soil mass is considered as semi-infinite material for convenience of analysis.

3. Numerical Methods

a) Finite Element Method

b) Finite Difference Method

c) Boundary Element Method

Numerical methods are considered in analysing large and complex structures easily by considering boundary conditions and using governing differential equations.

VII.CONCLUSION

From the literature survey, it can be concluded that Soil-Structre Interaction plays an important role in deciding the performance and response of the structure in present day's infrastructure world. It can be stated that SSI is a special field of seismic engineering as seismic waves generated impacts the ground to oscillate and thereby developing cyclic stress effects between structure and soil. From the analysis approach, there are several approaches in analysing soil structure interaction viz., direct approach, indirect approach and numerical approach. From the literature review it can be observed that numerical approach as FEM is most prevalent and approximate method to perform soil structure interaction analysis as nonlinear soil properties and many types of material behaviour can be considered and assigned to the frame during analysis.

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