PROPERTIES FOR NONLINEAR SOIL STRUCTURE INTERACTION ANALYSIS FOR SHALLOW FOUNDATION

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ABSTRACT

The formulation of a soil structure interaction problem begins with identifying the underlying design variables which are primarily varied during the analysis process. In design, construction and maintenance of any Engineering system, Engineers have to take many technological and managerial decisions at several stages. Structural deflections are the process of finding the conditions that give the maximum or minimum value of a function. A design problem usually involves many design parameters of which some are highly sensitive to the proper working of the design. The nonlinear soil structure reactions along the circumference and on the base of the beam are modeled realistically by using suitable translational and rotational nonlinear interaction springs. Dynamic Analysis is used to find stress-strain in a soil structure interaction once the loading on the structure is known. Resulting load path change in the system could become a major source of discrepancy between the measured load and the load in the actual system. The proposed measurement technique by using the whole soil structure interaction component altered, as its own load cell. The dynamic engineering properties for soil and structure are considered as variable for analysis. The soil and structural response model are developed in the behavior of dynamic loading.

Keywords: Soil Properties, shear wave velocity, Shallow foundation.

Dynamic Soil Properties

To measure the dynamic properties for the emergency situation the dynamic analysis of shallow foundation for various structures can be analyzed. Shear wave velocity and cyclic plate load test can be used to measure the dynamic analysis.

Soil Mass

The soil mass below the foundation is layer by layer size for the continuity and compatibility in stress –strain for X, Y, Z direction. The soil mass is assumed to be nonlinear for the study. Bearing capacity, properties of soil and properties of hard rock are discussed in Table1,2 and 3.

Table – 1 Bearing Capacity

Bore Hole No	Sample Depth (m)	Unit Weight (kN/m^3)	Angle of Friction Ø°	Cohesion C (kN/m^3)	Allowable Bearing capacity (kN/m^2)
1	5	18.95	6	41	125
	10	18.95	6	41	137
	15	18.95	6	41	141
	20	18.95	6	41	146
	25	18.95	6	41	149
	30	18.95	6	41	152
2	5	18.65	8	39	103
	10	18.65	8	39	112
	15	18.65	8	39	119
	20	18.65	8	39	121
	25	18.65	8	39	126
	30	18.65	8	39	132

Table – 2 Properties of Soil

S.No	Description	Value
1	Grain size Distribution-Fines %	65
2	Atterberg's Limits	
	L.L %	74
	P.L %	26
	Shrinkage Limit %	17
3	Specific gravity	2.63
4	Permeability(cm/sec)	2.95×10^{-7}
5	Compaction Properties	
	Optimum Moisture content (%)	23.5
	Maximum Dry Density(g/cc)	1.83
6	Swell Characteristics	141
7	Free Swell Index (%)	High
8	IS Classification	CH

Table – 3 Properties of Hard Rock

Bore Hole No.	Depth (m)	Specific Gravity	Water Absorption (%)	Compressive strength (kg/cm^2)
1	45	2.233	10.75	107
2	45	2.455	10.45	102

The effective of shear wave velocity is considerate for foundation dimensions, overburden pressures from the structure, nonlinear effects and the calculation of the foundation stiffness and damping.

Structure on shallow foundation

Shallow foundation of 350x350x450m has been modeled using thick R.C. C, to simulate the Soil Structure Interaction effects for the layered soil. The properties of soil have adopted and calculated, are shown in Table-4. The spring stiffness values for vertical, horizontal, rocking and twisting motions are calculated as per Richart and Lysmer model. The whole area is covered with linear and nonlinear springs are applied.

Table- 4 Spring stiffness for various types of soil

Stiffness of soil spring (kN/m)				
Soil Type	Hard	Dense	Stiff	Soft
Horizontal *Longitudinal Direction*	79395673	16348716	4135675	3125109
Horizontal *Lateral Direction*	81393210	1834190152	4287140	3012853
Vertical	96017651	21783590141	378301726	4591035
Rocking(about Longitudinal Direction)	129836710	3891026704	172427181	123841810
Rocking(about Lateral Direction)	193825701	3450284502	490138104	114561801
Torsion	71303891	649132102	1023481902	30158315

Description of soil and foundation

Field response analysis of soil profile is Hard, Dense, stiff, soft was considered. The properties of this soil are given in Table- 5.

Table – 5 Properties of Hard, Dense, Stiff & Soft

Type of Soil (Description)	Shear wave Velocity Vs (m/sec)	Shear Modulus (kN/m^2)	Elastic Modulus 'E' (kN/m^2)	Poisson's ratio (μ)
Soil 1(Hard)	850	71863.56	121.2x 10^4	0.5
Soil 2(Dense)	575	56342.5	73.5 x 10^4	0.4
Soil 3(Stiff)	435	47831.7	51.7 x 10^4	0.39
Soil 4(Soft)	320	10345.7	26.7 x 10^4	0.35

In situ and laboratory test results

In situ tests was carried out, including pressure meter tests, down-hole seismic, and cross-hole seismic and cross-hole tomography to determine compression and shear wave velocities through the ground profile. The vertical wave velocity with depth gave a useful indication of variations in the nature of the strata between the borelogs. Basic laboratory classification tests (moisture content of soil and rock, Atterberg limits, particle size distribution and hydrometer) and laboratory tests for determining physical properties (porosity tests, intact dry density, specific gravity, particle density) and chemical properties were carried out. In addition, unconfined compression tests, consolidation test, point load index tests, and drained direct shear.

Field investigation and site characterization

The investigations involved the drilling of 2 boreholes to a maximum depth of about 30 m below ground level. Standpipe piezometers were installed to measure the ground water level which was found to be relatively close to the ground surface, typically at a level of 2.5m DMD. The ranges of measured SPT N values are summarised in Table 1. There was a tendency for N values to increase with depth, beyond an elevation of about -51m DMD.

Table 1: Measured SPT Values

Elevation m	Range of SPT Values
0 to -1	0-32
-1 to -7	40-300
-7 to -15	30-150
-15 to -25	50-270
-25 to -35	130-250

Winkler Model

The soil medium as linear or non-linear elastic springs and it is a idealized soil medium. It is adequate suitable for computational purpose. This type of model is used to study the geotechnical analysis for the soil behavior and structural response of the modeling. it can be specify the boundary condition

Geotechnical and structural Model

Force-deformation behaviour is assigned to the spring representing the lateral stiffness of the system .The parameters for the assessment of the settlement characteristics of the soil foundation system are the values of the Young's modulus of the strata for structural behaviour under dynamic loading. In a non-linear analysis, the values of ultimate bearing capacity of the foundation would be required, in this paper; non linear elastic analyses have been undertaken using dynamic analyses. It's experienced the non linearity up to the maximum load level. Attention has thus been focussed on evaluating relevant values of Young's modulus for each stratum. As a first, the relative stiffness of the various soil layers values has been assessed by considering values of the Young's Modulus from the following data:

1. Pressuremeter tests (first loading, second loading, first reload, second reload cycles);
2. Resonant column tests (Initial, 0.0001%, 0.001%, 0.01% strain levels),

3. Triaxial Stress Path Tests (0.01% and 0.2% strain levels),
4. Geophysics tests

Calculating Displacements of Joints

To display the failure mechanism the spring model has been developed for calculating the displacements of the joints of the failure mechanism. The displacements of footing column joint are obtained relative to the support. The members connected to the joint and identified whether it's a plastic hinge exist at the end of these members. If the known set of plastic hinge rotations at the base, the displacements of the joint under consideration are found by successive translation and rotation about that joint. The stress- stain results are obtained from the one-dimensional beam model.

Specification of foundation model for consideration of base SSI

Elements of Structures	**Dimensions (mm)**
Column c/s	450 x 450
Footing (Lx B x Tk.)	350 x 350 x 150
Column Height	400

Structural properties

Concrete Material	
Young's Modulus E_c	20650 Nmm^2
Density	2250 kg/m^3
Poisson's Ratio	0.17
Compressive Strength	20 N/mm^2
Reinforcing Steel	
Young's Modulus E_s	200000 N/mm^2
Yield Strength f_y	450 N/mm^2

Structural nonlinearity is considering foundation response will satisfy the structural response and soil structure interaction effects. Non-linear force displacement of the structure gives a more effects to the soil.

Shear wave velocity

The initial shear wave velocity increases, the variation in the response modification factors reduces, such that the response modification factors approaches to 1.1.It known as increase in initial shear wave velocity with respect to the stiff foundation condition. Soil-structure systems are forced to a more to that of the corresponding base systems. Due to large reduction in total displacement and structural drift may occur and for a very small amplification is expected for structural acceleration and structural distortion.

Displacements

Table 6 shows the various reading on the depth and displacement the Figure- 1 represents displacement and the depth graph. Displacement along X axis (denoted in mm) and depth along Y axis (denoted in mm) it also denotes that when depth increases displacement also increases. This displacement depends on loadings in the layered soil.

Table 6 Displacement vs Depth

Displacement (mm)	**Depth (mm)**
-	0
15	200
30	400
67	600
87	800

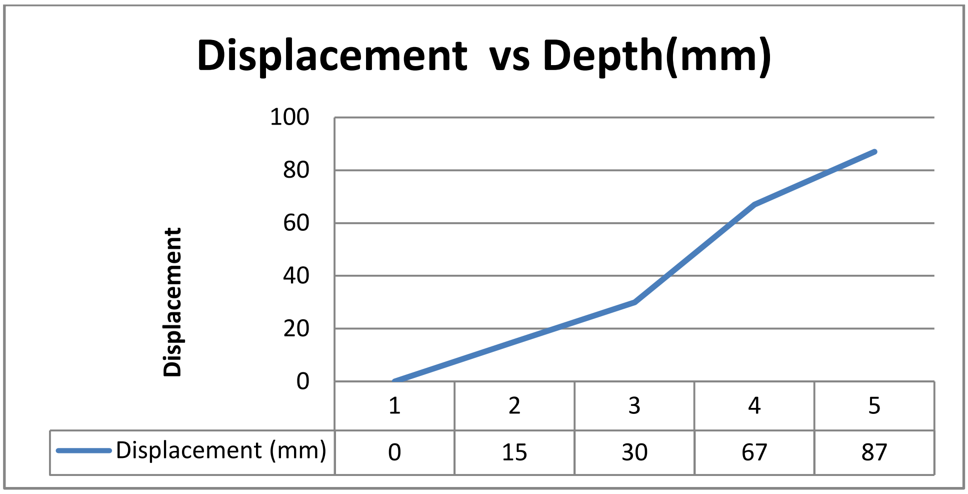

Figure-1 Displacement vs Depth

Base Shear

The lateral force occur at the base of the structure due to an earthquake is called as base shear. The base shear of the structure can be affected by the ground motions with respect to different layered soil conditions. Base shear results of the shallow foundation with fixed base and flexible base are shown in Table – 7. For the base shear the soil model will decrease the range from 5 % to 8% in comparison with the fixed base, the spring model range is 11 % to 16%.

Table – 7 Base shear for Flexible and Fixed Base

Soil Type		Base Shear kN
Flexible Base	Hard	509.51
	Dense	631.84
	Stiff	719.45
	Soft	861.45
Fixed Base	Hard	732.89
	Dense	792.85
	Stiff	861.45
	Soft	964.93

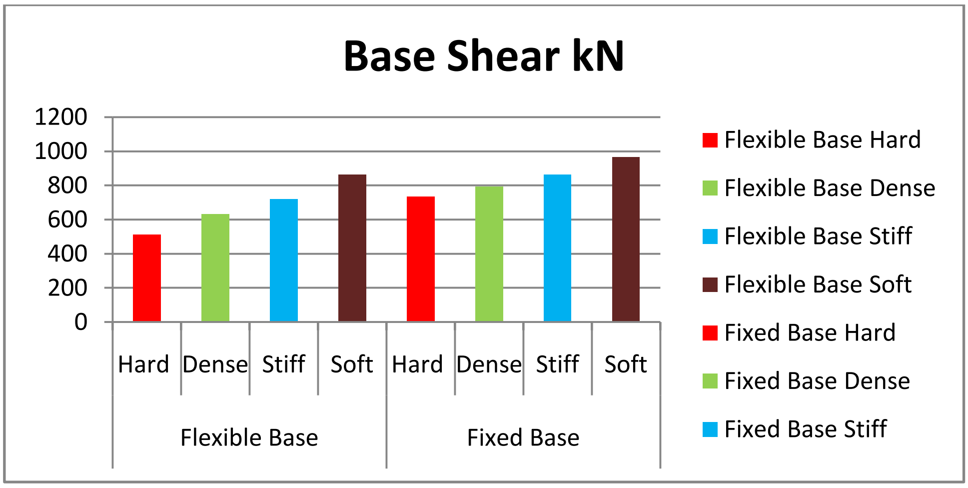

Fig.1 Base shear comparison of shallow foundation for Flexible and Fixed base condition.

Conclusion

The structure was modeled by soil foundation using springs; the effect of the soil structure interaction was considered the displacement and acceleration of the building. The nonlinear governing equations have been achieved. The displacement of winkler foundation is more sensitive for non-linear analysis. Nonlinear model can be misleading in the prediction of foundation deformation.

References:

1. Wilson.L.E., “Three dimensional static and dynamic analysis of structures”, Computers and Structures Inc., Berkeley, California, USA, 2002.
2. Zamman, M.M., Desai, C.S., Drumn.E.C., “ Interface model for dynamic soil structure interaction”, Journal of Geotechnical Engineering, Vol. 110, No.9 pp.1257 – 1272, 1989
3. Medland,I.C., and Taylor,D.A., “Flexural Rigidity of concrete column section”, Journal of Structural Engineering Division, ASCE, Vol.97 No.ST2, pp. 573 – 586, 1971.
4. Dasaka S.M ,Aniruddh Jain ,Kolekar. Y.A., “Effect of Uncertainties in the Field Load Testing on the Observed Load–Settlement Response”-“ Indian Geotechnical Journal”, vol 03,pp 294–304,2014
5. Nii Allotey and M.Hesham El Naggar.,“Generalized dynamic Winkler model for nonlinear Soil-structure Interaction”, Journal of Canadian Geotechnical, Vol.45, pp. 560 – 573, 2008.