SOIL STRUCTURE INTERACTION RESPONSE OF COMPLEX INDUSTRIAL STRUCTURES

Satyendra P. Gupta[I] and Mani Kant Gupta[I]

SUMMARY

Equivalent soil springs are used to study the response of structures including the effect of soil structure interaction. Large scatter has been found in the values of equivalent soil spring stiffnesses obtained by different methods. Dynamic response with different earthquake excitations have been studied for complex structures over a range of interest of soil springs.

INTRODUCTION

Structural analysis in preliminary and invariably in final stages of design too, generally assumes that the structure is rigidly founded. This involves an assumption that the foundation and superstructure remains uncoupled during vibrations and are independent of each other's influence. Since soil is deformable the flexibility of foundation should be included in the analysis and its inclusion generally increases the time period of the structure. Industrial structures are invariably being designed as a multistoreyed reinforced concrete building with complex frames. Discontinuities in the floor slabs and columns are special features of these systems and hence mathematical modelling is complicated. In this study the variation in the soil stiffnesses as obtained by field and analytical technique have been examined. The response of complex structures of different dimension under different earthquakes have been presented.

STRUCTURES STUDIED

The structures considered are multistoried reinforced concrete industrial structures having discontinuities in the floors and with complex frames. Three different structures of raft areas 371.38, 1000 and 2940 sqm. with different heights are studied.

EQUIVALENT SOIL SPRING STIFFNESS

Soil structure interaction effect is studied by replacing soil by equivalent translational and rotational springs. Indian Standard Institution (IS:5249-1969) recommends for carrying out free and forced vibration tests on a standard concrete block for determination of coefficient of elastic uniform and nonuniform compression and shear, which inturn are used for computing equivalent soil springs (Gupta and Gupta, 1978). The values of equivalent soil springs shows a scatter on variation of the size of the test concrete block. In this study the structures are assumed to be founded on raft foundation on medium soil and for determination of equivalent soil springs test data on four concrete blocks have been utilized. The values of coefficient of elastic uniform shear as found from four block tests varied from 1.41 to 1.75 kg/cm^3. The equivalent soil springs computed by the method Gupta and Gupta (1978) for different raft areas are given in Table 1. Elastic half space theory has also been used for determining the soil springs. In this method determination of shear modulus and Poisson's ratio of the soil is required. The shear modulus can reasonably be estimated by taking into

I Department of Earthquake Engineering, Roorkee University, Roorkee, India.

account the type of soil, density, confining pressure and strain level (Seed 1970). The shear modulus obtained from block test and as calculated by Seed's method were comparable. In this study a value of 3120 t/m^2 for shear modulus and 0.33 for poisson's ratio have been chosen. Using elastic half space theory Whitman and Richart (1967), Parmelee (1967) and Veletsos and Verbic (1974) have given formulae for determining soil springs. The values of equivalent soil springs calculated by these formulae have also been given in Table 1.

SEISMIC ANALYSIS

The dynamic analysis of the complex structures have been carried out under the assumption that the structure is vibrating as a block in one of the the principal directions with fixity at ground level. Soil structure interaction effect has been included by introducing lateral and rotational soil springs at the base of the structure. "Figs. 1 and 2" shows the mathematical model for structure A for fixed base condition and including soil springs for both the principal directions respectively. "Figs. 3 and 4" shows the model for structure B.

DISCUSSION AND CONCLUSION

Table 1 shows a wide scatter in spring stiffnesses from different methods. It is observed that the values obtained for equivalent translational as well as rotational springs from block tests are invariably higher than those from elastic half space theory. The difference in the stiffness values have been found in this study to increase with the increase in base area of the structure. Table 2 shows the shear variation at different levels in structure A and Structure B for El Centro and Taft earthquakes for fixed and flexible base conditions. It is seen that when effect of soil structure interaction is included in the analysis, the shear in longitudinal direction for structure A is reduced for both El Centro and Taft excitations. In all other cases the shear has been found to increase when flexibility of foundation is included in the analysis. This indicates that shear value may increase or decrease on inclusion of soil structure interaction effect. This increase is on account of large deformation caused in the structure due to the soil interaction.

REFERENCES

Gupta M.K. and Gupta, Stayendra P. (1978), "Effect of Soil Stiffness as Determined by Block Test on Structural Response", Proc. Cent. Am. Conf. on Earthquake Engg., San Salvador, Central America.

Indian Standard Institution, (IS:5249-1969), "Method of Test for Determination of Insitu Dynamic Properties of Soil", ISI, New Delhi.

Parmelee R.A. (1967), "Building Foundation Interaction Effects", Journal of the Engineering Mech. Divn., ASCE, Vol. 93, EM2.

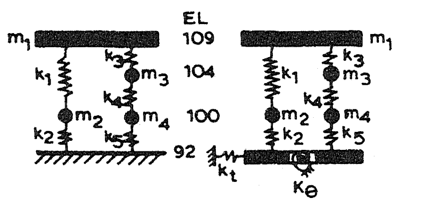
Seed H.B. and Idriss I.M. (1970),"Soil Moduli and Damping Factors for Dynamic Response Analysis", Report No. EERC 70-10, Berkeley, California.

Veletsos A.S. and Verbic B. (1974), "Basic Response Functions for Elastic Foundation", Jr. Engg. Mech. Div., ASCE, Vol. 100, EM2.

Whitman R.V. and Richart F.E. Jr., (1967), "Design Procedures for Dynamically Loaded Foundations", Journal of the soil Mech. and Foundation Divn., ASCE, Vol. 93, SM6.

TABLE 1 - EQUIVALENT SOIL SPRING STIFFNESSES

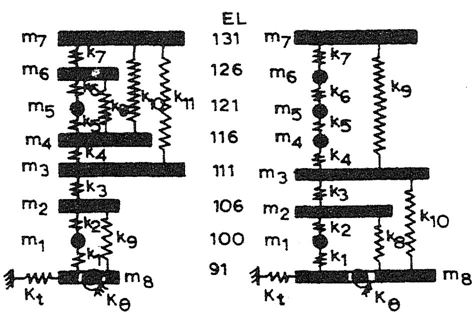
BASE AREA sqm.			TRANSLATIONAL STIFFNESS t/m	ROTATIONAL STIFFNESS Longitudinal tm/rad	Transverse tm/rad
371.38	Field	Block 1	523650	140000000	22682000
		Block 2	571900	153000000	24800000
		Block 3	605350	162100000	26261000
		Block 4	649920	173900000	28167000
	Elastic	Whitman	159931	37528224	16040289
	Half	Parmelee	166771	26410162	6747135
	Space	Veletsos	162464	26410162	6747135
1000	Field	Block 1	1410000	1016374000	162619000
		Block 2	1540000	1110083000	177613000
		Block 3	1630000	1174958000	187993000
		Block 4	1750000	1261458000	201833000
	Elastic	Whitman	246697	162980000	65194028
	Half	Parmelee	273708	145060000	36718519
	Space	Veletsos	266639	145060000	36718519
2940	Field	Block 1	4145400	5856759300	2108433300
		Block 2	4527600	6396744200	2302827900
		Block 3	4792200	6770579900	2437408700
		Block 4	5145000	7269027500	2616849900
	Elastic	Whitman	440997	575010000	345000000
	Half	Parmelee	469323	434990000	202190000
	Space	Veletsos	457201	434990000	202190000



FIXED BASE
FIG.1

WITH SOIL INTERACTION
FIG.2

STRUCTURE A - DYNAMIC MODEL LONGITUDINAL AND TRANSVERSE DIRECTION



TRANSVERSE DIRECTION
FIG.3

LONGITUDINAL
FIG.4

STRUCTURE B - DYNAMIC MODEL WITH SOIL INTERACTION

TABLE 2 - COMPARISON OF SHEAR (IN TONNES) AT VARIOUS LEVELS

Elevation	Direction	Fixed Base Condition El Centro	Fixed Base Condition Taft	Soil Interaction Condition El Centro	Soil Interaction Condition Taft
			STRUCTURE A		
104–109		1742	186	289	32
100–104	Longitudinal	1513	184	305	33
Base		2102	226	632	70
104–109		3326	216	4068	701
100–104	Transverse	3380	220	4068	701
Base		4921	320	5686	980
			STRUCTURE B		
126–131		1192	205	795	145
121–126		2126	365	1473	268
116–121		2923	502	2364	430
111–116	Longitudinal	3974	681	3894	708
106–111		6127	1051	6899	1255
100–106		7335	1258	8556	1559
Base		8265	1418	9705	1766
126–131		1576	272	1602	276
121–126		2614	468	2745	478
116–121		3381	601	3019	529
111–116	Transverse	4476	783	4656	808
106–111		6341	1112	6818	1180
100–106		7415	1279	8005	1385
Base		8203	1433	8901	1540