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Response of P.E.B with isolated footing considering SSI

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Abstract - *In order to study structural behaviour of any structure, it is prominent to study the effects of soil structure interaction (SSI). In present study, attempt have been made to study the influence of soil structure interaction on Pre Engineered Building (P.E.B). Usually the structural behaviour is analysed assuming the fixed support conditions at the base of structure. In conventional method the foundation flexibility of soil mass is ignored which is likely to affect the structural response of building. The soil flexibility is integrated in the analysis of structure using Winkler's spring model approach. For analysis P.E.B with 15m span is considered with equal bay spacing. Three different soil strata's i.e. hard, medium and soft are used for SSI study. The analysis is carried out in STAAD Pro.V8i software using response spectra of IS 1893-2002. The effect of SSI on various parameters like base shear,lateral displacement, etc are studied and discussed. To get real behaviour of superstructure the subgrade must be modelled adequately well. The study reveals that the SSI significantly affects the performance of the structure.*

Key Words: Soil Structure Interaction (SSI), Pre engineered building (P.E.B), Equivalent static method,etc.

1.INTRODUCTION

An earthquake is a shaking of the ground caused by sudden rupture and movement of large tectonic plates. The Indian sub-continent has a history of devastating earthquakes. After Killari (1993), Jabalpur (1997), and Bhuj (2001) earthquake it is clear that no part of the country is free from the seismic hazard. The main reason for the high intensity of earthquake in India is because of the movement of Indian plate towards the Eurasian plate at the rate of 49mm per year approximately. Geographical statistics shows that the India has almost 54 percent of land vulnerable to seismic hazards.

The advance countries like USA, Japan are already constructing the structures which can resists the earthquake of magnitude 7 and above. Unfortunately in India not much awareness has been created in society, about the importance of constructing earthquake resisting structures.

1.1 Soil structure interaction:

Most of the civil engineering structure involve some type of structural element having direct contact with ground. There are many circumstances in civil engineering for which interaction between structure and ground has to be considered prominently. This encourages the interaction between structural engineers & geotechnical engineers. During to external lateral forces such as earthquake the structural displacement & ground displacement both are interdependent on each other. It is impossible to depart the correlation between structures & ground motion. It can be easily understand that the interaction between soil and structure can indeed affect the performance of the structure during earthquake particularly structure founded on relatively flexible soils.

Soil structure interaction is the general phenomena involved in the behaviour of structure which interacting with soil medium in response to the lateral loading imposed on the structure. The phenomena may be defined as "The process in which the response of soil influences the motion of respect to structure influence the response of the soil is termed as SSI". This phenomena deals with interaction between structure & sub soil

1.2 Need of soil structure interaction:

In India from last few decades there is significance increase in the infrastructural development of country. Since the structure are huge and heavy the effect like SSI are to be considered during the design procedure of such structures. The effect of SSI on structure is not considered in early stage of construction practices. But since last 3-4 decades it has achieved prominent importance to consider the SSI while designing the structure. The effect of SSI for light structure can be neglected but its effect on heavy structure like high rise buildings, bridges, tall chimneys, nuclear power plants (NPP), elevated highways becomes prominent for better performance of structure during earthquake.

Many researchers have suggested different methods to study the effect of soil structure interaction during last few decades. Winkler's spring model (1867) represents the soil medium as of identical but mutually independent, closely spaced, discrete, linearly elastic springs. George G Gazetas (1991) has presented complete set of algebraic formulas and dimensionless charts for readily computing the dynamic stiffness of springs which represents the soil medium.[8]

1.3 Objective of study:

The primary objective of this work is to study the response of Pre engineered building by equivalent lateral force method using STAAD Pro.V8i software. The study has been carried out to investigate the influence of soil structure interaction with equal bay spacing in P.E.B, also to understand the influence of SSI on the performance of P.E.B considering three different soil strata's.

2 Structural modelling

For the analysis of work a Pre engineered building with 15m span is considered. The behaviour of this building is studied during earthquake excitation forces considering the soil structure interaction. The building is 11m high and length is 30m, height of crane girder is 8m. Building is symmetrical along both the X and Z-axis having 5 bays along Z-axis and 3 bays along X-axis, each bay of 6m. Isolated footings are considered to be resting on three types of soil strata's namely, hard soil, medium soil, and soft soil.

Table-1 : Soil Elastic Constants

Soil type	Modulus of Elasticity (kN/m²)	Unit Wt. (γ)	Poisson ratio (μ)
Hard	65000	16	0.3
Medium	35000	16	0.4
Soft	15000	16	0.3

2.1 General data of building

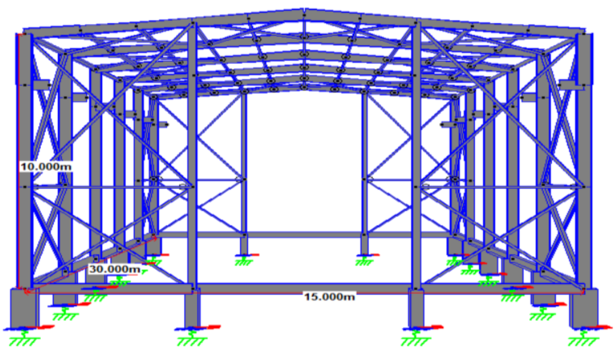

Fig-1: Elevation

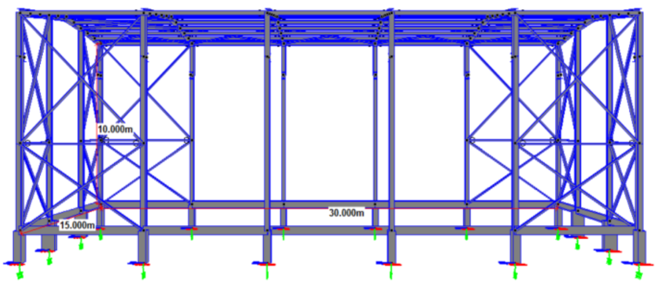

Fig-2: Side view

Table -2: Geometric and material properties of building

Description	Data
Number of Bays in X direction	3
Number of Bays in Z direction	6
Bay width in X direction	6m
Eave height	10m
Section used for main frame	Tapered I section
Foundation type	Isolated

2.2 Winkler's spring model

Soil structure interaction is carried out by using Winkler's approach [1] by considering equivalent springs with six degree of freedom (fig.3) which represents the soil medium. Each spring has specific stiffness which depends upon the properties of respective soil conditions. The stiffness is calculated by George Gazetas formulas[8] and shown in table 3.

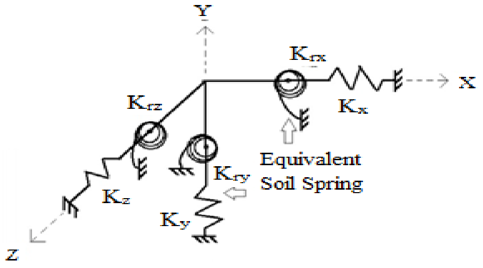

Fig-3: Equivalent spring stiffness.

Where, Kx, Ky, Kz = Stiffness of equivalent soil springs along the translational DOF along X, Y and Z axis. Krx, Kry, Krz= Stiffness of equivalent soil springs along the rotational DOF along X, Y and Z axis.

Table -3: Spring stiffness formulas (G Gazetas)

Degrees of freedom	Stiffness of equivalent soil spring
Horizontal (lateral)	$[2GL/(2-\nu)](2+2.50\chi^{0.85})$ with $\chi = A_b/4L^2$
Horizontal (longitudinal)	$[2GL/(2-\nu)](2+2.50\chi^{0.85})-[0.2/(0.75-\nu)]GL[1-(B/L)]$ with $\chi = A_b/4L^2$
Vertical	$[2GL/(1-\nu)](0.73+1.54\chi^{0.75})$ with $\chi = A_b/4L^2$
Rocking(about longitudinal)	$[G/(1-\nu)]I_{bx}^{0.75}(L/B)^{0.25}[2.4+0.5(B/L)]$
Rocking (about lateral)	$[G/(1-\nu)]I_{by}^{0.75}(L/B)^{0.15}$
Torsion	$3.5G\, I_{bz}^{0.75}(B/L)^{0.4}(I_{bz}/B^4)^{0.2}$

Table- 4 : Calculated Spring Stiffness For Soil Springs

Degrees of freedom	Calculated Stiffness of soil springs (kN/m)		
Soil Type	Hard	Medium	Soft
Horizontal (lateral direction)	108984.37	59765.6	32843
Horizontal (longitudinal)	108984.37	59765.6	32843
Vertical	146605	80395.83	43700
Rocking (about longitudinal)	8727.83	5757.42	4775.2
Rocking (about lateral)	8727.83	5757.42	4775.2
Torsion	95588	63715.46	52845.5

3. Parametric study

The effect of different base condition on performance of P.E.B is studied considering soil structure interaction (SSI). Effect of SSI on P.E.B is carried out considering the following parametric study.

3.1 Base shear

The variation of base shear for different soil conditions is represented as follow;

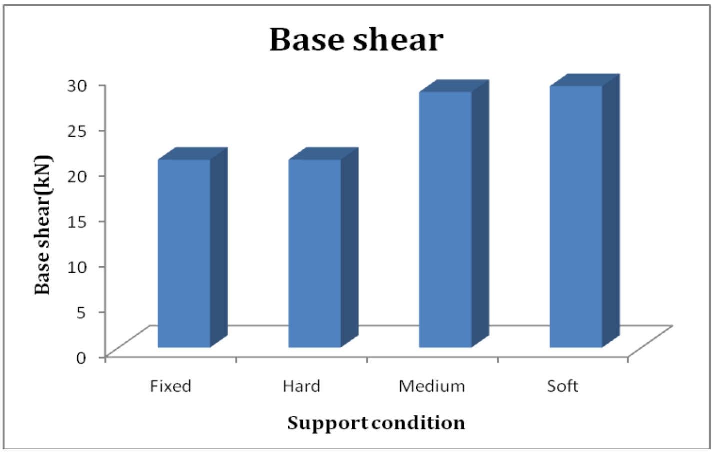

Chart -1: Base shear for different Soils.

3.2 Lateral deflection

The variation of lateral deflection for different types of soil conditions is represented as follow;

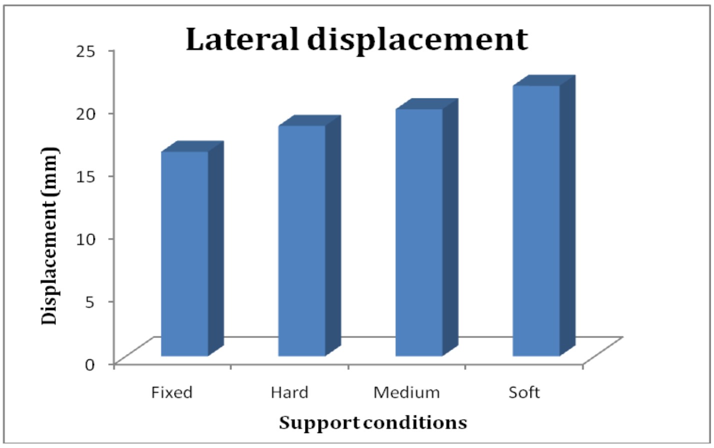

Chart -2: Lateral displacement for various soils.

3.3 Column moment

The variation of Column moment for different types of soil conditions is represented as follow;

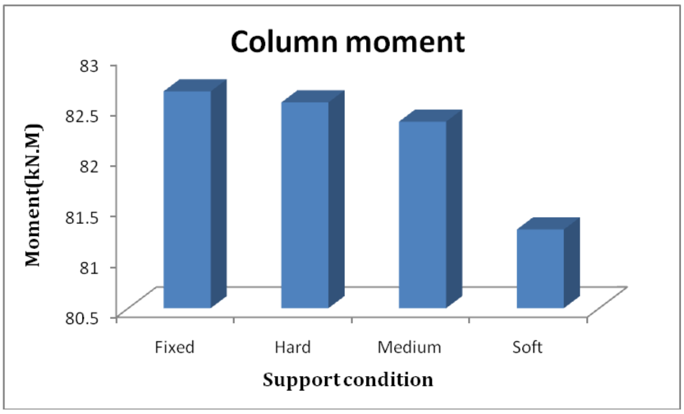

Chart -3: Column moment for different soil.

4. CONCLUSIONS

1. Base shear and lateral deflection for soft soil is 39.15% and 32.28% less as compared to fixed support condition.

2. Column moment of structure increases due to SSI effect. It increases with the flexibility of soil, column moment is main parameter while designing P.E.B structure. Thus evaluation of this parameter without considering SSI effect may cause severe error in design of P.E.B

3. Considering SSI effect is prominent for steel structure building since support conditions on site are not rigid, it possess some flexibility due to different soil conditions.

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[10] IS 1893(part I) :2002-criteria for earth quake resistant design of structures.

[11] IS : 875 (Part 3) : 1987-design imposed loads (other than earthquake) for buildings and structures.

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