International Journal of Ethics in Engineering & Management Education
Website: www.ijeee.in (ISSN: 2348-4748, Volume 4, Issue 12, December 2017)

# "Study on foundation system considering soil structure interaction subjected to seismic loading."

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**Abstract: Effect of soil structure interaction on foundation system during an earthquake is an important issue to be considered while designing a structure as it is known that the structures are supported on soil. When a structure is subjected to an earthquake excitation the response of the structure is affected by interactions between the linked systems: structure, foundation and the soil. S.S.I evaluates the response for change in motion of the ground. The movement of the ground structure system is influenced by type of soil as well as by the type of foundation. Tall buildings are designed and analysed to meet the provision of relevant codes of practice. The Indian code of practice for seismic analysis IS1893:2002 gives response spectrum for different soil conditions.**

**The present study is on foundation system with S.S.I effect and without S.S.I effect subjected to seismic loading. The structures were analyzed by Response spectrum method using STAAD Pro software. The response of building frames such as Lateral deflection & vertical displacement at supports while considering S.S.I for RC building frame with different support and soil conditions were shown. A conventional G+10 storied building when rests on different soils having sub grade modulus ranges from 12000KN/m2/m to 60000KN/m2/m were chosen for the study. The influence of soil- structure interaction of RC frame with isolated footing, isolated pedestal footing, strap footing conditions are compared with the results obtained when the column footing joint is assumed to be fixed at the base and its behaviour is assumed to be completely independent of foundation and supporting soil. By considering S.S.I, there is variation in the natural period of the structure. Depending on the soil characteristics S.S.I may either increase or decrease the response of the structure.**

***Keywords:* STAAD, S.S.I, LDA, Soil, Storeyed, RC**

## (I) INTRODUCTION

Footings are designed to transmit column or wall loads loads to the soil without exceeding its safe bearing capacity, to prevent excessive settlement of the structure to a tolerable limit, to minimize differential settlement, and to prevent sliding and overturning. The settlement depends upon the intensity of the load, type of soil, and foundation level. Where possibility of differential settlement occurs, the different footings should be designed in such away to settle independently of each other. Foundation design involves a soil study to establish the most appropriate type of foundation and a structural design to determine footing dimensions and required amount of reinforcement. Because compressive strength of the soil is generally much weaker than that of the concrete, the contact area between the soil and the footing is much larger than that of the columns and walls.

Foundations can be rigid or flexible. Bearing capacity is used to design rigid foundations but sub grade reaction is used for flexible foundations.

The more generic form of the equation can be written as:

$K_s = (I\ q_a)/\delta$

Where, I = Safety factor

qa is the allowable bearing capacity

δ is the allowable soil settlement

From above equation, it is evident that the appropriate safety factor must be used and the Ks value can be better compared with ultimate bearing capacity rather than the allowable bearing capacity. The important factor is the assumedallowable settlement assumed as 25mm for the calculated bearing capacity. Therefore for soil with SBC 500, SBC 400, SBC 300 ,SBC 200 and SBC 100 have SGM of 60000kN/m2/m,48000kN/m2/m,36000kN/m2/m, 24000kN/m2/m & 12000kN/m2/m.

## (II).OBJECTIVE OF THE PROJECT

The Objective of the present study is to study the foundation system with the effect of soil structure interaction due to seismic loading.

The following are steps followed in the present study:

1. The seismic analysis of the ten storeyed RC framed structures modelled with fixed base by using Linear Static Analysis and Linear Dynamic Analysis at seismic zone II.
2. The seismic analysis of the ten storeyed RC framed structures modelled with different footings considering Soil Structure Interaction by using Linear Static Analysis and Linear Dynamic Analysis at seismic zone II.
3. Comparison of Lateral Displacement, Vertical Displacement and Natural Period of the structure for RC framed structures modelled with Isolated Footing, isolated, pedestal footing, Strap Footing and structure with fixed base at seismic zone II obtained by linear static and LDA.

## (III). METHODOLOGY

The plan of the ten Storeyed reinforced concrete building shown in the Figureure 3.1.The column to column distance is taken as 6m.

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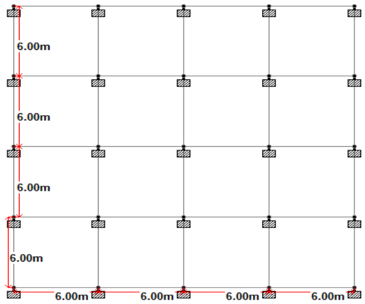


Figure 3.1: Plan of the RC framed structure

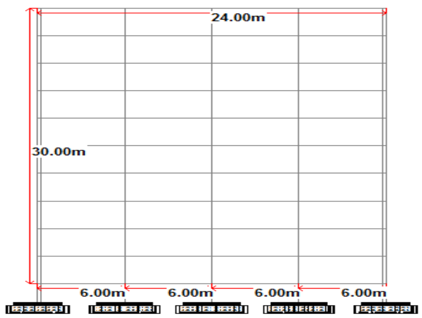


Figure 3.2: Elevation of the RC framed structure with Isolated Footing

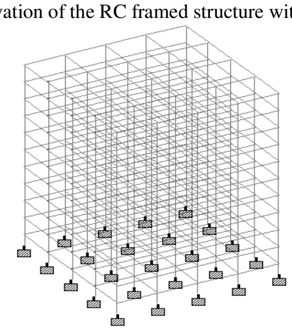

Figure 3.3: Isometric view of the RC framed structure with fixed base

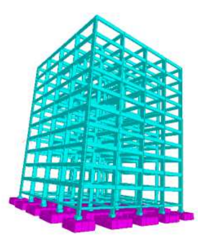

Figure 3.4: 3D view of the RC framed structure with IPF (all dimensions in m)

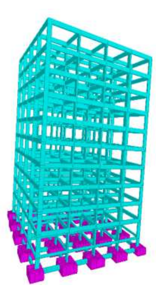

Figure 3.5:3D view of the RC framed structure with SF (all dimensions in m)

**Preliminary Data**

Table 3.1: Preliminary Data of the ten storeyed RC frame.

| | |
|---|---|
| Number of Storey | 10 |
| Floor to Floor Height | 3.0 m |
| Thickness of Slab | 150 mm |
| Depth of the footing | 1100mm |
| Grade of Concrete & Steel | M25 & Fe415 |

## (IV).REVIEW OF LITERATURE

**Tavakoli.H.R, Naeej.M and Salari.A, (2011)8**studied to investigate the effect of near fault and far fault earthquake motions on the response of reinforced concrete structures considering soil-structure interaction. In detail, a series of linear time-history analysis was carried out for three example buildings. The effects of soil-structure interaction were evaluated for a 3-story building, a 7-story building and a 15-story building. The ordinary moment resisting frame system was considered for all example buildings as lateral force-resisting system. For all buildings time-history analysis were performed under 3 example earthquake motions: Tabas, Kobe and Loma Prieta. The buildings were supported on soft and stiff soils with 100m/s and 900m/s shear wave velocity respectively.

**BahadorBagheri, EhsanSalimiFiroozabad and MohammadrezaYahyae (2012)2** As the world move to the accomplishment of Performance Based Engineering philosophies in seismic design of Civil Engineering structures, new seismic design provisions require Structural Engineers to perform both static and dynamic analysis for the design of structures. While Linear Equivalent Static Analysis is performed for regular buildings up to 90m height in zone I and II, Dynamic Analysis should be performed for regular and irregular buildings in zone IV and V.

**Jenifer Priyanka, N.Anand and S.Justin, (2012)5** studied the effect of lateral force on tall buildings with different type of irregularities. An attempt made in this study to understand the behavior of tall buildings subjected to lateral forces for different soil conditions. Ten Storeyed building with various spacing of columns such as 2.5m, 4m and 5m of buildings with different irregularities like Vertically irregular, Mass irregular and Stiffness irregular, were analyzed using the software STAAD Pro. The top storey lateral deflection due to seismic load of these buildings was compared with regular building configureuration for different soil conditions.

**Amar R Chougule and S SDyavanal(2013)1** studied the effect of soil structure interaction on multi Storeyed buildings with various foundation systems. Also studied the response of multi Storeyed buildings subjected to seismic forces with rigid and flexible foundations subjected to seismic forces were analysed under different soil conditions like hard, medium and soft. A conventional G+6 Storeyed building when rests on different soils is chosen for the study. The influence of soil

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structure interaction was compared with the structure to be fixed at the base.

**Chinmayi H.K and Jayalekshmi B.R. (2013)4** focused on SSI analysis of a symmetric 16 story RC frame shear wall building over raft foundation subjected to seismic loading. The transient analysis of structure-soil-foundation system is carried out using LS-DYNA software. Earthquake motion in time domain corresponding to zone III of IS 1893:2002 design spectrum is used to excite the finite element model of soil-structure system. For integrating the SSI effect, four types of soils based on shear wave velocity are considered. Responses in terms of variation in NP, base shear and deflection obtained from the analysis of the SSI model are compared with that obtained from conventional method assuming rigidity at the base of the structure. The results showed that the SSI effects are significant in altering the seismic response.

## (V).RESULTS AND DISCUSSIONS

**LINEAR STATIC ANALYSIS:**

**LATERAL DISPLACEMENT AND VERTICAL DISPLACEMENT**

**COMPARISON (I)**: Lateral Displacement and Vertical displacement of RC frame with Fixed support and with IF, IPF and SF considering SGM 12000kN/m2/m.

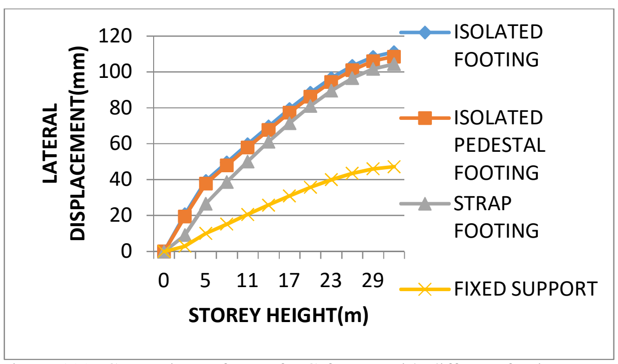


Figure 1(a): Comparison of LD of RC frames with different footing conditions considering SGM 12000kN/m2/m obtained by LSA.

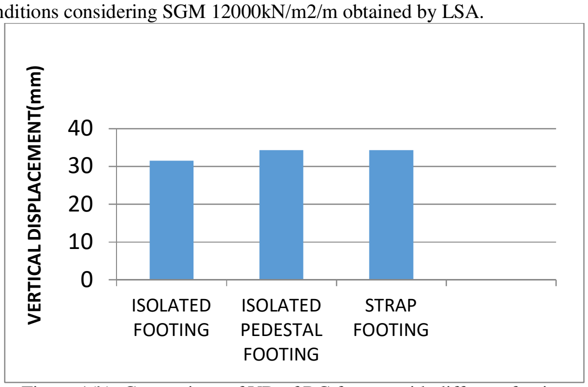


Figure 1(b): Comparison of VD of RC frames with different footing conditions considering SGM 12000kN/m2/m obtained by LSA.

COMPARISON (II) : Lateral Displacement and Vertical displacement of RC frame with Fixed support and with IF, IPF and SF considering SGM 24000kN/m2/m

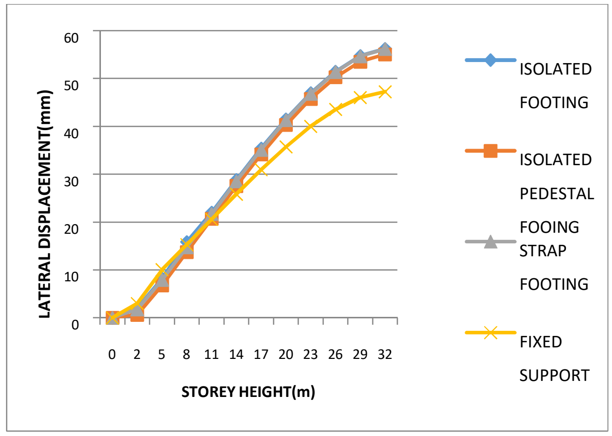


Figure 2(a): Comparison of LD of RC frames with different footing conditions considering SGM 24000kN/m2/m obtained by LSA.

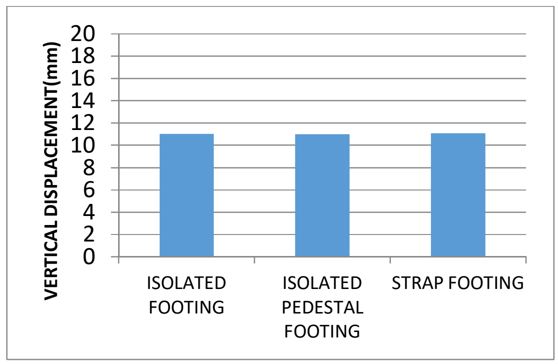


Figure 2(b): Comparison of VD of RC frames with different footing conditions considering SGM 24000kN/m2/m obtained by LSA.

COMPARISON(III) : Lateral Displacement and Vertical displacement of RC frame with Fixed support and with IF, IPF and SF considering SGM 36000kN/m2/m.

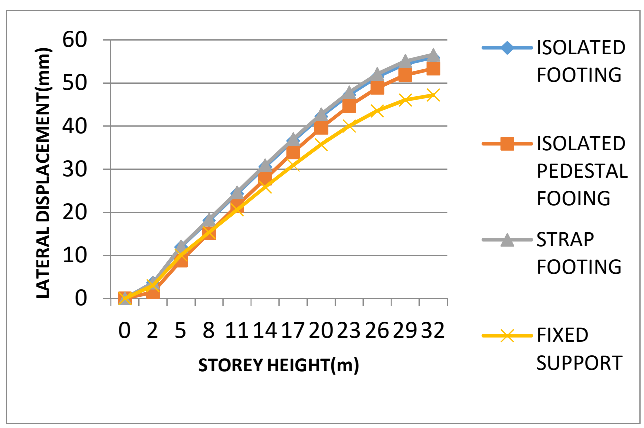


Figure 3(a): Comparison of LD of RC frames with different footing conditions considering SGM 36000kN/m2/m obtained by LSA.

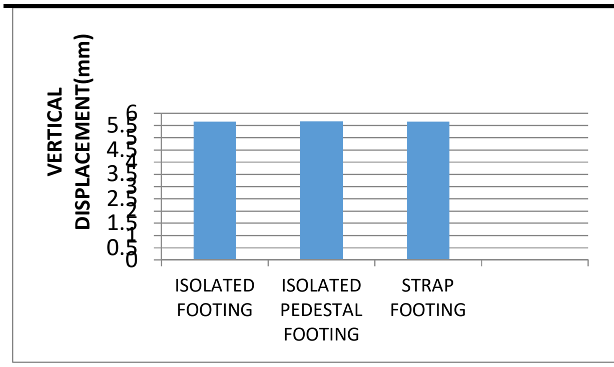


Figure 3(b): Comparison of VD of RC frames with different footing conditions considering SGM 36000kN/m2/m obtained by LSA.

COMPARISON (IV): Lateral displacement and Vertical displacement of RC frame with Fixed support and with IF, IPF and SF considering SGM 48000kN/m2/m.

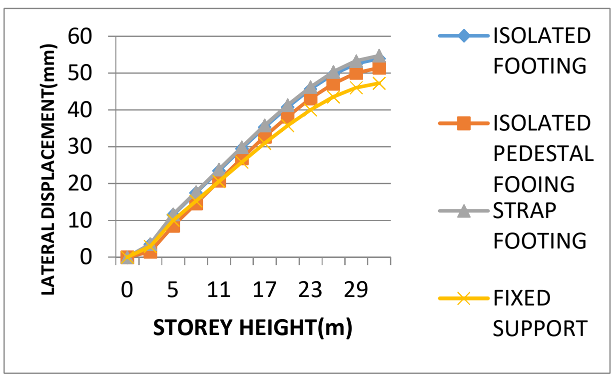


Figure 4(a): Comparison of LD of RC frames with different footing conditions considering SGM 48000kN/m2/m obtained by LSA.

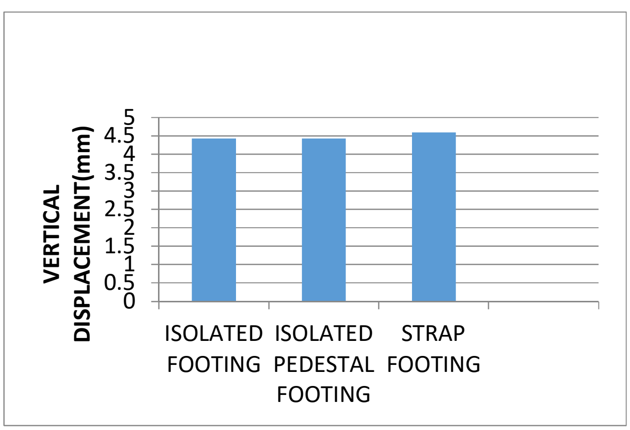


Figure 4(b): Comparison of VD of RC frames with different footing conditions considering SGM 48000kN/m2/m obtained by LSA.

COMPARISON (V) : Lateral displacement and Vertical displacement of RC frame with Fixed support and with IF, IPF and SF considering subgrade modulus 60000kN/m2/m.

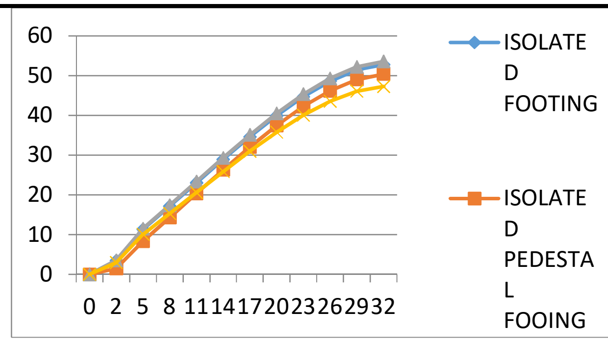


Figure 5(a): Comparison of LD of RC frames with different footing conditions considering SGM 60000kN/m2/m obtained by LSA.

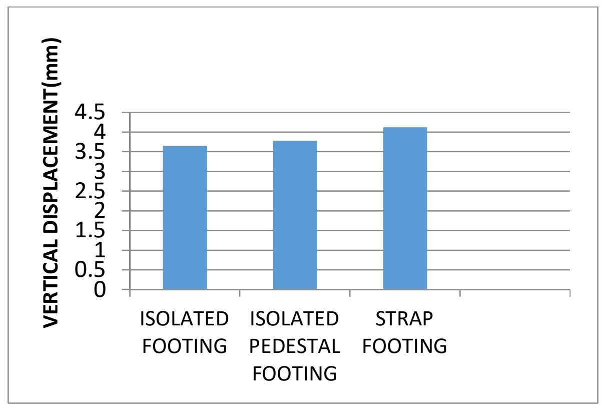


Figure 5(b): Comparison of VD of RC frames with different footing conditions considering SGM 60000kN/m2/m obtained by LSA.

**LINEAR DYNAMIC ANALYSIS**:

LATERAL DISPLACEMENT

COMPARISON (I) : Lateral Displacement of RC frame with Fixed support and with IF, IPF and SF considering subgrade modulus 12000kN/m2/m.

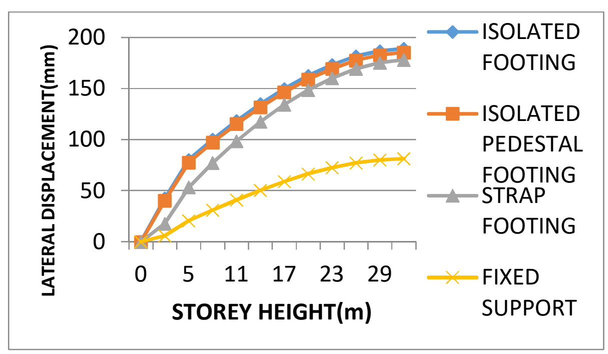


Figure 6: Comparison of LD of RC frames with different footing conditions considering SGM 12000kN/m2/m obtained by LDA.

COMPARISON (II) : Lateral Displacement of RC frame with Fixed support and with IF, IPF and SF considering subgrade modulus 24000kN/m2/m.

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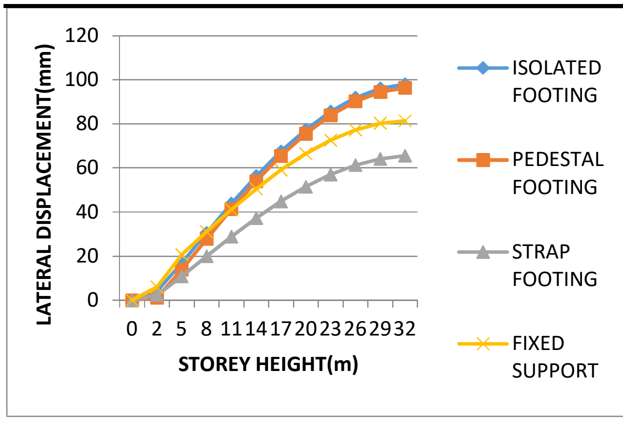


Figure 7: Comparison of LD of RC frames with different footing conditions considering SGM 24000kN/m2/m obtained by LDA.

COMPARISON (III) : Lateral Displacement of RC frame with Fixed support and with IF, IPF and SF considering subgrade modulus 36000kN/m2/m.

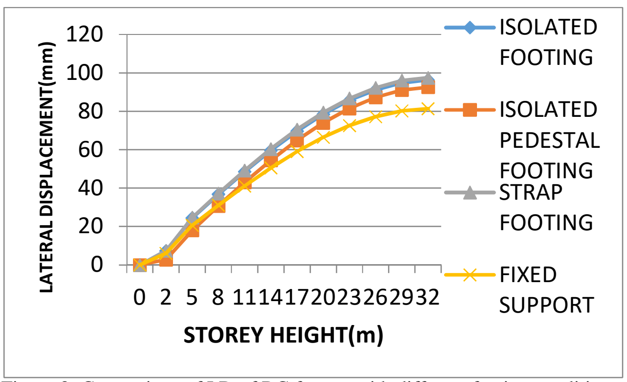


Figure 8: Comparison of LD of RC frames with different footing conditions considering SGM 36000kN/m2/m obtained by LDA.

COMPARISON (IV) : Lateral Displacement of RC frame with Fixed support and with IF, IPF and SF considering subgrade modulus 48000kN/m2/m.

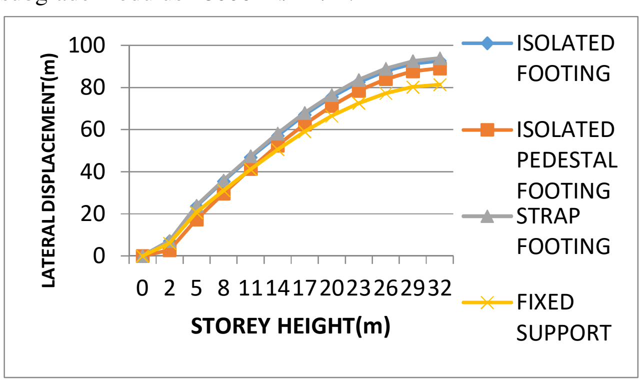


Figure 9: Comparison of LD of RC frames with differentfooting conditions considering SGM 48000kN/m2/m obtained by LDA.

COMPARISON (V) : Lateral Displacement of RC frame with Fixed support with IF, IPF and SF considering subgrade modulus 60000kN/m2/m.

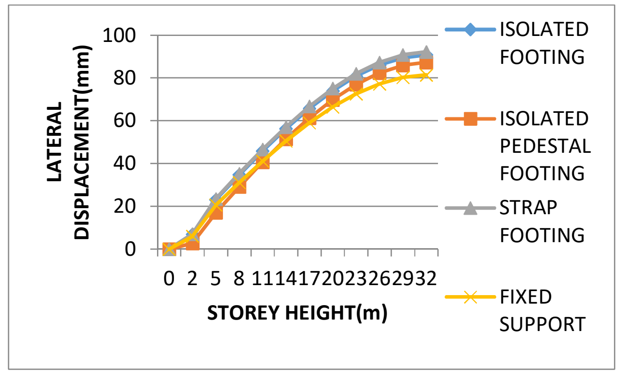


Figure 10: Comparison of LD of RC frames with different footing conditions considering SGM 60000kN/m2/m obtained by LDA.

**NATURAL PERIOD at Six Mode Numbers**

The Natural Period of RC framed structure considering different soil conditions are noted at the default six modes and these values are compared by the bar charts.

COMPARISON (I) : Natural Period of RC frame with IF, IPF and SF considering subgrade modulus 12000kN/m2/m and Rc framed structure with fixed support without considering SSI effect.

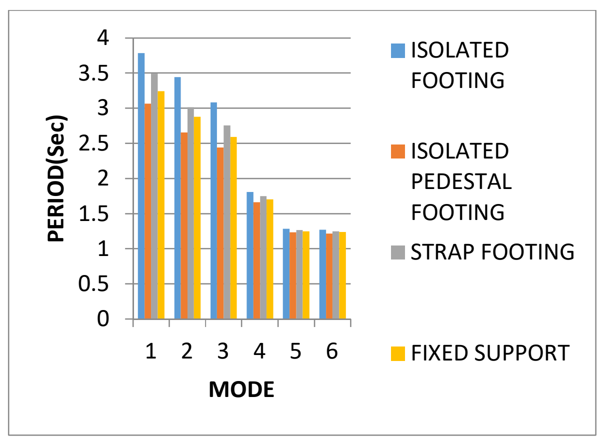


Figure 11: Comparison of NP of RC frame with fixed base and the frame with different footing conditions considering subgrade modulus 12000kN/m2/m.

COMPARISON (II): Natural Period of RC frame with IF, IPF and SF considering subgrade modulus 24000kN/m2/m and RC framed structure with fixed support without considering SSI effect.

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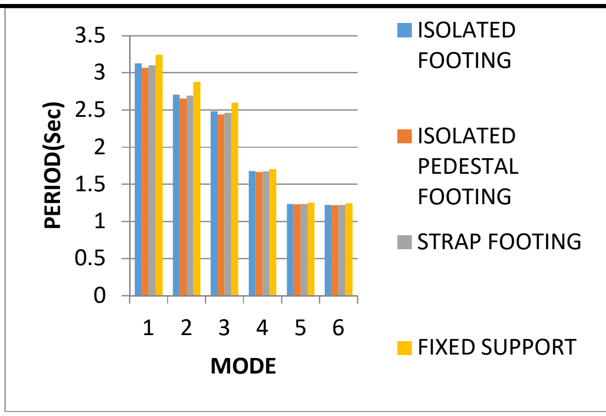


Figure 12: Comparison of NP of RC frame with fixed base and the frame with different footing conditions considering subgrade modulus 24000kN/m2/m.

COMPARISON (III) : Natural Period of RC frame with IF, IPF and SF considering subgrade modulus 36000kN/m2/m and RC framed structure with fixed support without considering SSI effect.

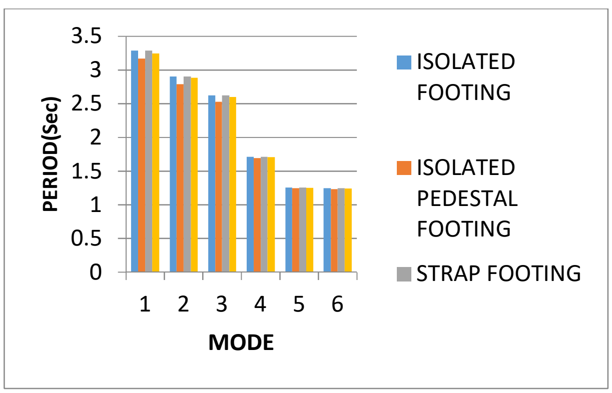


Figure 13: Comparison of NP of RC frame with fixed base and the frame with different footing conditions subgrade modulus 36000kN/m2/m.

COMPARISON (IV) : Natural Period of RC frame with IF, IPF and SF considering subgrade modulus 48000kN/m2/m and RC framed structure with fixed support without considering SSI effect.

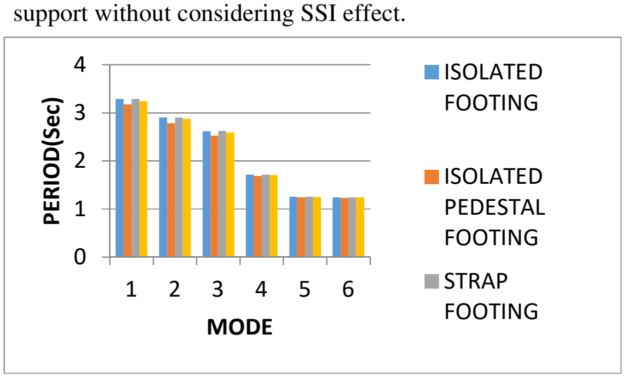


Figure 14: Comparison of NP of RC frame with fixed base and the frame with different footing conditions subgrade modulus 48000kN/m2/m

COMPARISON (V): Natural Period of RC frame with IF, IPF and SF considering subgrade modulus 60000kN/m/m2 and RC framed structure with fixed support without considering SSI effect.

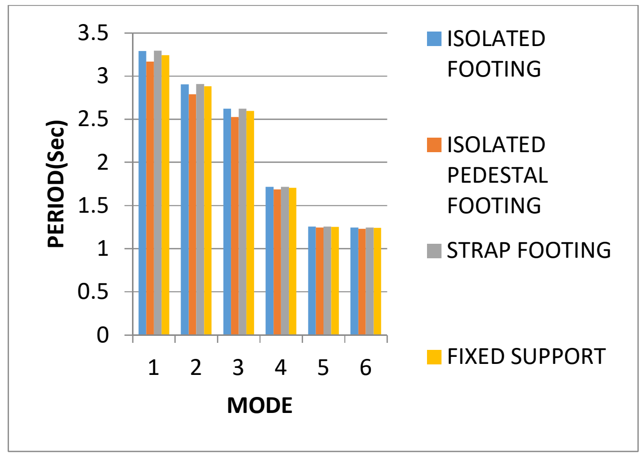


Figure 15: Comparison of NP of RC frame considering SBC500 with different footing conditions subgrade modulus 60000kN/m2/m.

## (VI) CONCLUSIONS:

The following conclusions were drawn from the study:

1) 1.It was observed that there was an increase in LD of RC frame with IF, Pedestal footing and SF considering SGM 12000kN/m2/m are 57%, 56% & 54% obtained by linear static analysis and 57%, 56%& 54% obtained by Linear dynamic analysis when compared to the RC framed structure with fixed support.
2) 2. It was observed that there was an increase in LD of RC frame with IF, IPF and SF considering SGM 24000kN/m2/m are 16%, 14% & 15% obtained by linear static analysis and 17%, 15%& 17% obtained by linear dynamic analysis when compared to the RC framed structure with fixed support.
3) 3. It was observed that there was an increase in LD of RC frame with IF IPF and SF considering SGM 36000kN/m2/m are 15%, 11% & 16% obtained by linear static analysis and 15%, 12%&16% obtained by linear dynamic analysis when compared to the RC framed structure with fixed support.
4) 4. It was observed that there was an increase in LD of RC frame with IF, IPF and SF considering SGM 48000kN/m2/m are 12%, 8% &13% obtained by linear static analysis and 12%, 8.6%&13% obtained by linear dynamic analysis when compared to the RC framed structure with fixed support.
5) 5. It was observed that there was an increase in LD of RC frame with IF, IPF and SF considering SGM 60000kN/m2/m are 10%, 6%, &11% obtained by linear static analysis 10%, 7% &11% obtained by linear dynamic analysis and when compared to the RC framed structure with fixed support.

6) 6. It was observed that there was a decrease in VD of frame with IF and IPF considering SGM 12000kN/m2/m is 9% &13% when compared to the RC framed structure with strap footing.
7) 7. It was observed that there was a decrease in VD of frame with IF and IPFs considering SGM 24000kN/m2/m are 0.57% &0.64 % when compared to the RC framed structure with strap footing.
8) 8. It was observed that there was a decrease in VD of frame with IF and IPFs considering SGM 36000kN/m2/m are 0.35% & 0.3% when compared to the RC framed structure with strap footing.
9) 9. It was observed that there was a decrease in VD of frame with IF and IPF considering SGM 48000kN/m2/m soil with SBC400 are 3.8% & 3.8% when compared to the RC framed structure with strap footing.
10) 10. It was observed that there was a decrease in VD of frame with IF and IPF considering SGM 60000kN/m2/m are 13% & 9% when compared to the RC framed structure with strap footing.
11) 11. In view of the observations, there is decrease in NP which implies that there was an increase in the stiffness for RC frames with pedestal footing compared to the RC frames with IF, SF with different soil conditions & the RC framed structure with fixed support without considering SSI effect.

The response obtained from the analysis considering SSI is compared with the response obtained without considering SSI effect. From the study it is concluded that the response of the structure considering SSI is different from the response of the structure without considering SSI. Depending on the type of soil the SSI may either increase or decrease the response of structure.

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