

Influence of Pile Geometry and Elasticity Property on Response of Foundation System Subjected to Combined Loads

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ABSTRACT: The pile groups are one particular type of deep foundation. The piles are subjected to combined axial and lateral loads, axial loads are due to the self-weight and other imposed loads. The lateral loads are due to impact of ship, wave action, wind and earthquake forces. The present study emphasize on behaviour of pile group for these combined loads. Seismic analysis is carried out on the building as per IS 1893 (part1)-2002 using SAP 2000 software the lateral forces are developed. The pile group is modelled in the same software as FEM models and analysis is done for combined loads. The deflection is compared for IS 2911 part1 (sec1/sec2) and 2.67D spacing pile group model. The influence of different spacing values like 2.67D, 3D, 3.33D on deflection is compared, from results it is found that as spacing increases the value of deflection decreases. The effect different pile configuration by changing number of piles and length, the variation in deflection is also studied. The variation of stresses in different pile groups is compared. The influence of Young's modulus of RCC on deflection is also studied and the deflection reduction factor is calculated in the present study.

KEYWORDS: Pile Group, Cohesive soil, Pile configuration, Spacing, Deflection, Stress Diagram.

I. INTRODUCTION

The function of foundation is to transmit loads from superstructure to soil medium. The foundation shall be classified as shallow foundation and deep foundation. The foundation in which depth is equal or less than its width is known as shallow foundation, whereas depth is greater than the width then it's a deep foundation according to Terzaghi. When soil at or near the ground level is not capable of supporting a structure, and to transfer the loads to firm strata below, deep foundations are required. The building which are to be construct in soft soils especially in clay soils and seismically active areas requires great attention towards foundation in such case the foundation needs to safe against lateral loads along with the axial loads.

A deep foundation is generally more expensive than a shallow foundation. It would only be accepted in situation where shallow foundation is not feasible. In some situation fully compensated floating raft may found to be more economical than a deep foundation. In some situation, the soil may be strengthened by using available methods to make it suitable for a shallow foundation.

Pile Foundation

A structural member made of steel, concrete or wood is known as pile. A single or a group of vertical structural members is called as piled foundation, which may be driven or drilled deep enough to achieve adequate capacity to support the external column loads. A pile may be driven into the soil or cast in-situ by digging a hole and then fill it with concrete.

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The purpose of piles is to carry the loads to the soil of high shearing strength at competent depth and behaves as a compression or tension members when wind and wave forces are act on the structure in addition to vertical thrust.

Pile Cap

A thick concrete slab provided on top of piles to transfer the load from column to piles is called pile cap. It forms the part of the foundation system. The pile cap distributes the load from column to the individual piles. The pile cap should be rigid enough so that imposed loads distribute equally on all piles. The cap should be deep enough to allow sufficient anchorage for column and pile.

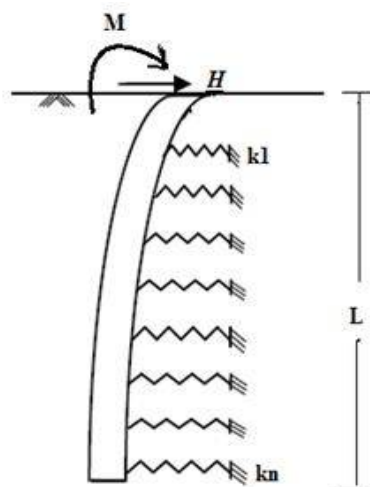
Laterally loaded piles

Piles are sometimes subjected to lateral loads due to wind pressure, water pressure, earth pressure, earthquake etc. It is generally assumed that lateral load will be carried by vertical piles only, but when horizontal load is large, inclined known as batter piles may be used to resist lateral load.

II. RELATED WORK

A 5 Storey Building, orthogonal in two directions on level ground is considered for the present study. The building was considered to be located in zone V with an ordinary moment resisting frames, and soil type as III as per IS 1893: 2002. The building was modelled by using SAP 2000 software. The Gravity and seismic analysis was carried out and reactions were obtained for design of pile foundation. Piles were modelled as 8 noded solid elements to carry out the FEM analysis. The Details of the performed work is given below

1. A symmetric 5 storey building, each bay of 4m in two direction is considered. The total plan dimension is 24mx24m. The beam and columns are modelled as frame elements. The loads are considered as per IS 875 part 3 and which are applied to the building and analysis is done using SAP 2000 software package.
2. After the analysis of building maximum column reactions are obtained. By considering cohesive soil, and pile as combined end bearing and friction pile, the load carrying capacity of pile is calculated using IS 2911-2010 code.
3. The deflection of pile head is estimated as per the code.
4. The laterally loaded pile has been analysed by considering beam supported by an elastic medium, this was introduced by Winkler. In the present study Winkler assumption was considered.



a. Winkler model

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5. The soil spring values are calculated and then the pile group is modelled in the same software. The pile cap is divided into 0.15m elements and pile is modelled as 8 noded element and divided into 0.5m elements along the length. The details of spring value is given below.

Spring Link	Spring value (kN/m)		
	$U_1(x)$	$U_2(y)$	$U_3(z)$
L1	1031	-	-
L2	2061	-	-
L3	2061	99.31	99.31
L4	2061	58.17	58.17
L5	2783	-	-
L6	3814	-	-
L7	3814	99.31	99.31
L8	3814	58.17	58.17

6. The spring values are applied to the pile group model and analysis is done.
7. The different pile configurations are modelled and analysed. The details of pile configuration is given below

Details	Length (L)	Diameter (D)	No of piles	Spacing
Pile Group 1 (P1)	7 m	0.45 m	9	2.67 D
Pile Group 2 (P2)	7 m	0.45 m	9	3 D
Pile Group 3 (P3)	7 m	0.45 m	9	3.33 D
Pile Group 4 (P4)	10.5 m	0.45 m	6	2.67 D
Pile Group 5 (P5)	12.5 m	0.45 m	5	2.67 D
Pile Group 6 (P6) E_{RCC}	7 m	0.45 m	9	2.67 D

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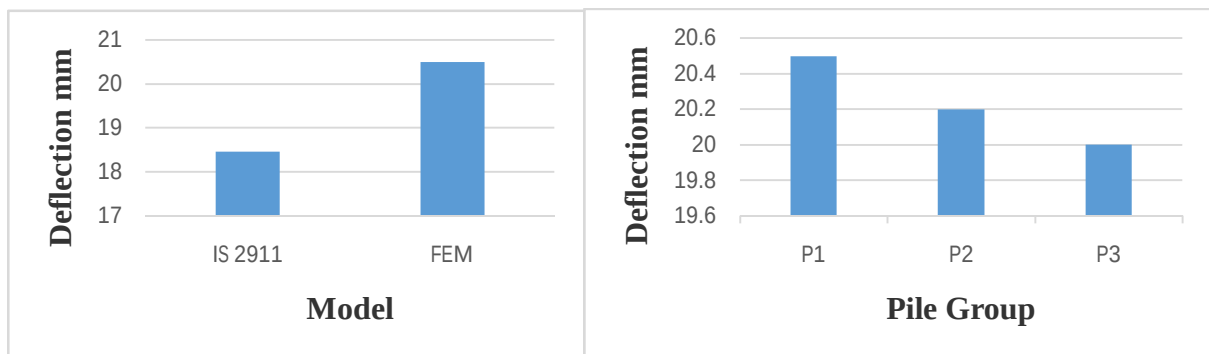
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III. RESULTS

The seismic analysis is done on the building from which the axial and lateral reactions are obtained. The piles groups are modelled as FEM models and the analysis is done for these combined forces. After the analysis of pile Groups, the deflection and stress variation in the models are obtained for different pile group models and which are compared. The obtained results which are plotted below

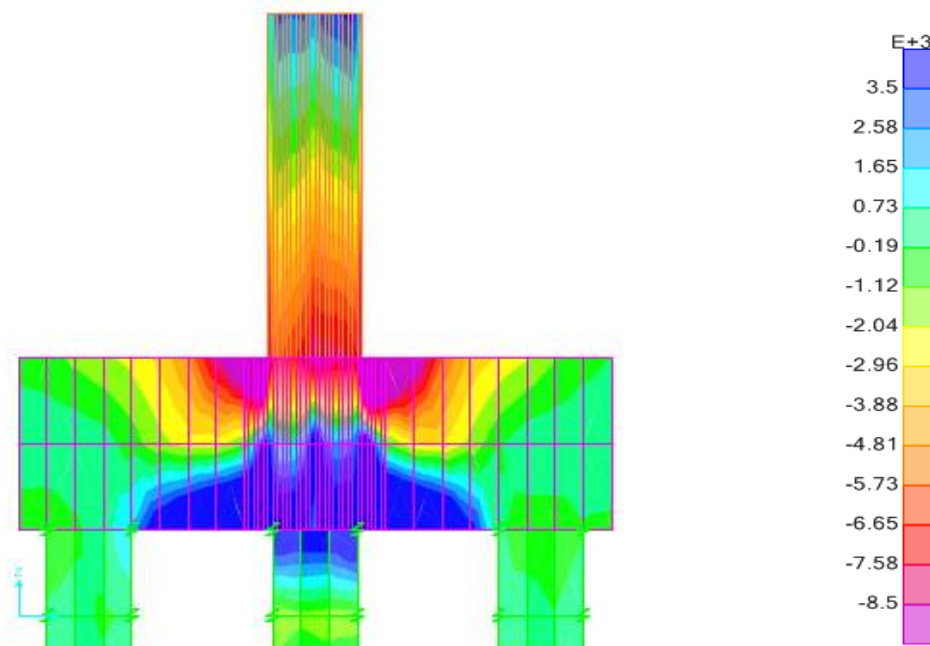
Deflection



a. Deflection between IS code and FEM model

b. Variation of deflection for different pile group

Stress Diagrams



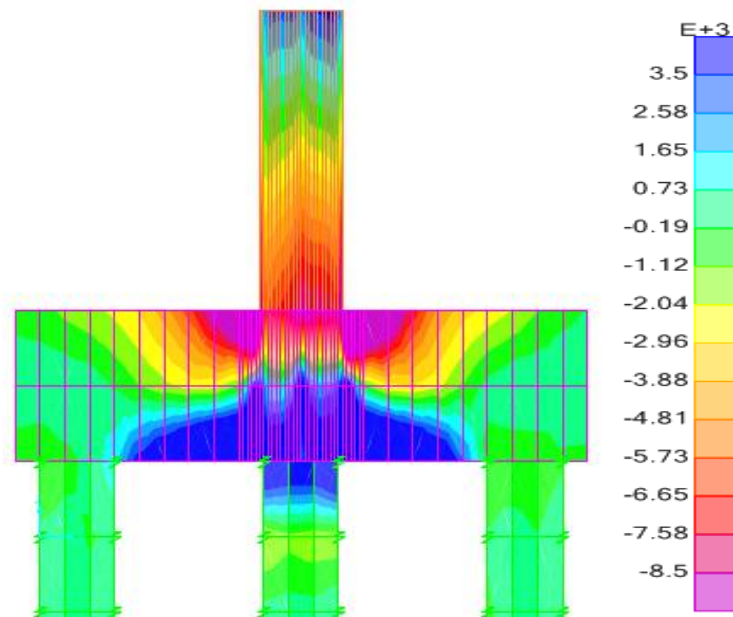
c. Stress diagram for P1 pile group

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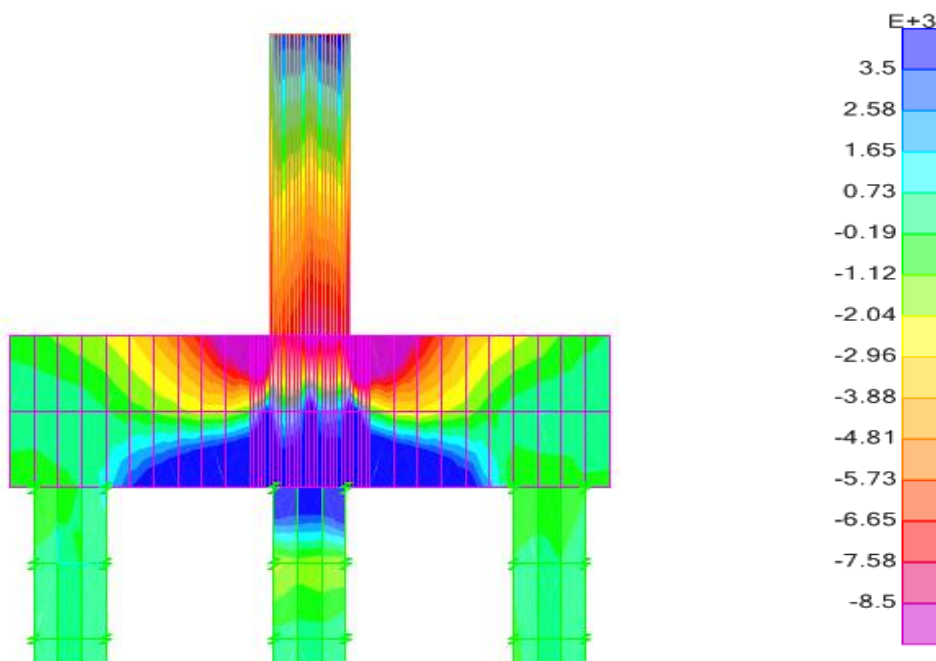
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d. Stress diagram for P2 pile group



e. Stress diagram for P3 pile group

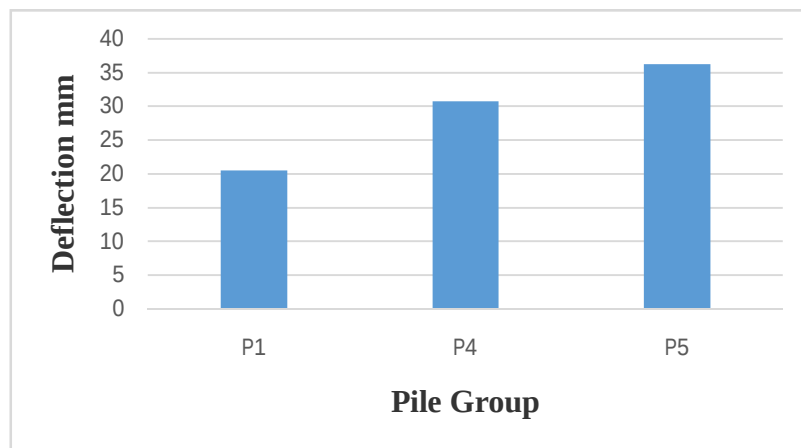
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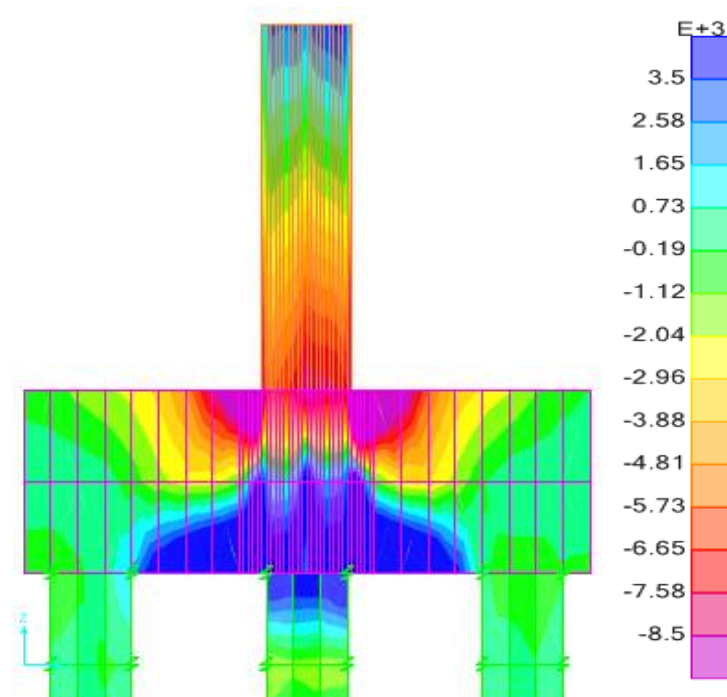
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Deflection



f. Variation of deflection for different pile configuration

Stress Diagram



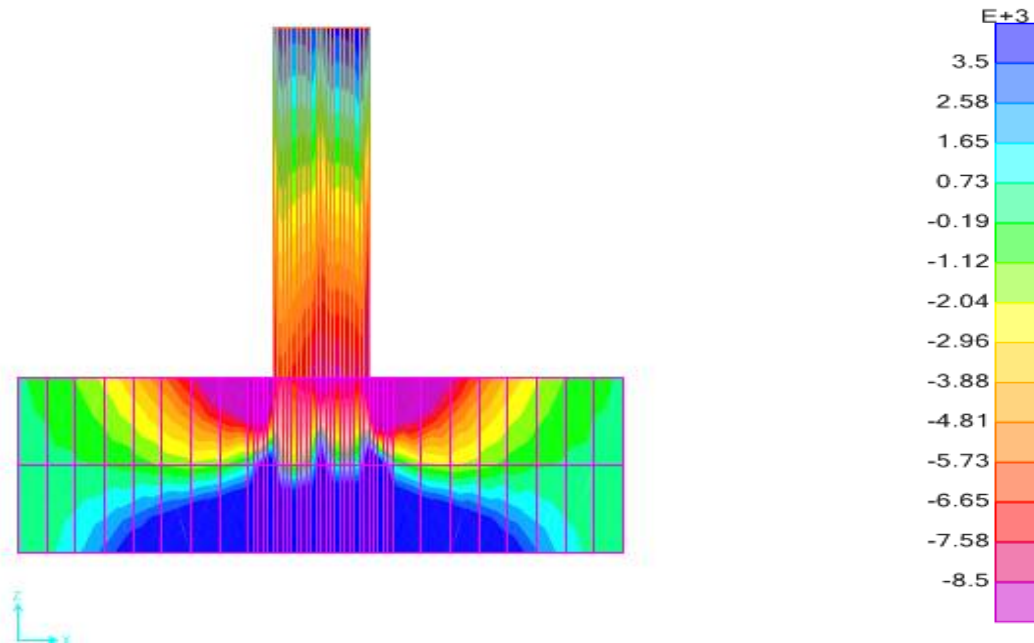
g. Stress diagram for P1 pile group

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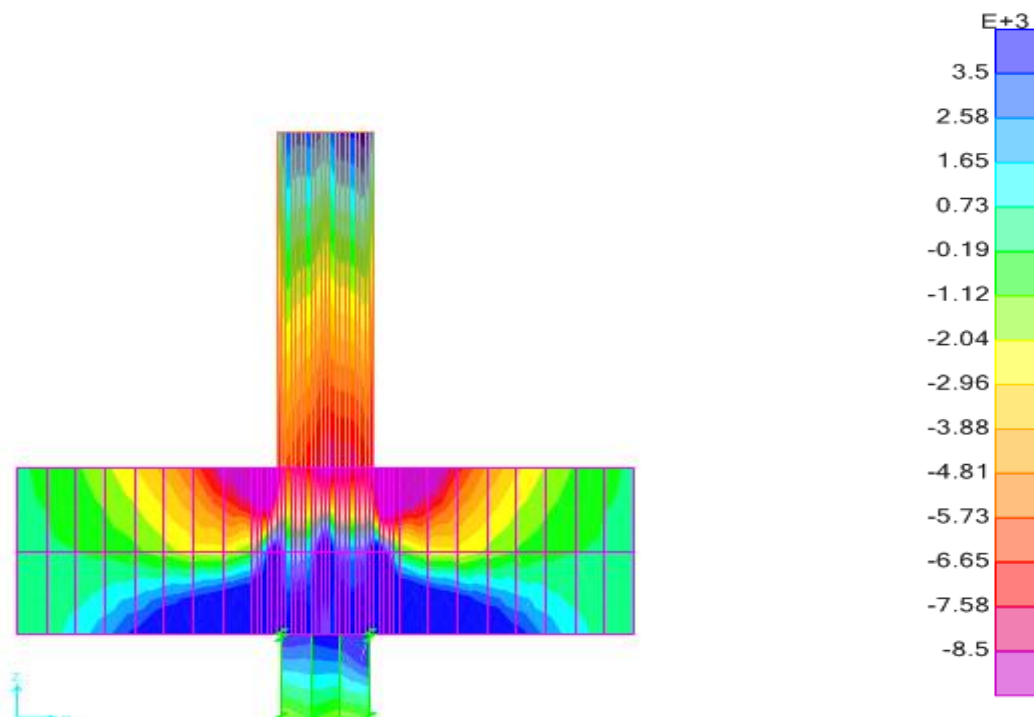
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h. Stress diagram for P4 pile group



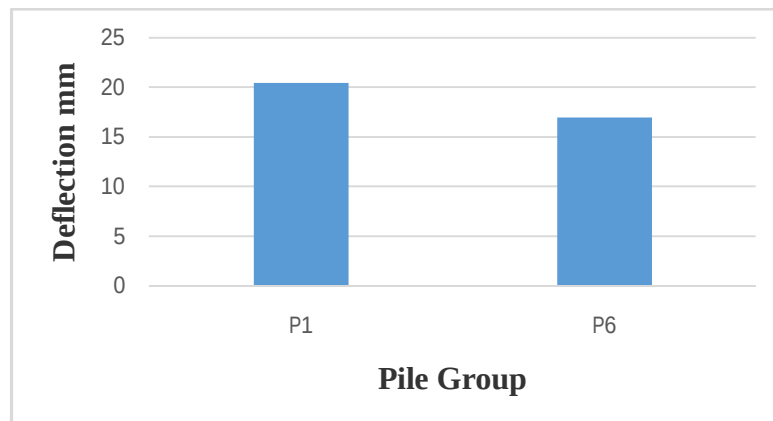
i. Stress diagram for P5 pile group

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j. Variation of deflection for pile groups by the influence of young's modulus

Effect of spacing between the piles

The deflection difference of 2 mm is observed between theoretical value from IS 2911-2010 and FEM model. The value of deflection reduces from 20.5 mm to 20 mm when pile spacing changes from 2.67D to 3.33D. The reduction in pile deflection is around 0.48 % for 3D spacing and 2.43 % for 3.33D spacing. As the value of spacing between the piles increases, the deflection of pile head decreases. The volume of soil increases as the spacing between the piles increases their by reduces deflection.

By observing to the stress diagram it is clear that the stress in the pile group P1 is more compared to P2 and P3 pile group. The reason is, as the spacing between piles increases the area of pile cap also increases, the area of pile cap for pile group P1 is less compared to pile group P2 and pile group P3 as we know stress is going to reduces as the area increases. But there is no much decrease in stress is observed in all 3 pile groups.

Effect of different pile configuration

The Pile group configuration is changed, that is P4 and P5, by changing the length of pile and number piles but carries the same load as the previous pile group carries. The deflection was compared to P1 group piles. The deflection is 30.8 mm in P4 and 36.3 mm in P5 group. The deflection increases by 50.24 % for group P4 and 77.07 % for P5 group. The value of deflection increases due to the increase in length of pile that leads to slenderness of pile.

There is an increase in stress for P4 pile group as compared to P1 group. This is because the area of pile cap for P4 group is less compared to P1 group. There is no much difference in stress variation is observed between P1 and P5.

Effect of modulus of elasticity of RCC on deflection

The value of deflection when the modulus elasticity used is as per IS 456 is 20.4 mm. For the same pile group when modulus of elasticity obtained based on experimental equations the deflection is 17 mm. The deflection of pile head can be reduced by using modulus of elasticity of RCC which is function of p_t . The deflection of pile head is reduced by 17 %.

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IV. CONCLUSION

- The deflection decreases as the spacing value increases. The increase spacing leads to increase volume of soil between the piles and their by reduces stresses in soil hence reduces pile head deflection.
- The deflection is then compared for different pile configuration by changing length and number of piles. For increase in deflection the reason may be because of increased length leads to the slenderness of piles.
- From the stress diagram we conclude that stress is reduced as the spacing between piles increases. But decrease in stress is in small range. The exceeded value of permissible stresses can be reduced by providing reinforcement as well as increasing grade of concrete.
- The modulus of elasticity is calculated for RCC by experimental equations and which is applied to the model. The deflection is found to be reduced by 17 % compared to model which is having modulus of elasticity applied as per IS 456-2000, i.e. $5000 \sqrt{f_{ck}}$. The decrease in deflection due to the stiffness of pile increase as young's modulus (E) increases and deflection is inversely proportional to the value of E.

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