A comparative study on vertical settlement of a multi-storied building supported by pile group embedded in various soils

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Abstract— Most of the building frames are supported on combined footings, isolated footings, raft, pile foundations depending on the amount of load and the nature of supporting sub soil. Generally the multi storied buildings constructed on week strata at shallow depth are supported on pile foundations. The problem of interaction becomes more complex when soil, foundation and structure have to be modeled with equal rigor. The methods to solve the soil structure interaction problem can be grouped as direct approach, substructure approach.

I. Direct Approach:

Direct approach is one in which the soil and structure are modelled together in a single step accounting for both inertial and kinematic interaction. Inertial interaction develops in structure due to own vibrations giving rise to base shear and base moment, which in turn causes displacements of the foundation relative to free field. While kinematic interaction develops due to presence of stiff foundation elements on or in soil causing foundation motion to deviate from free-field motions. Substructure Approach Substructure method is one in which the analysis broken down into several steps that is the principal of superposition is used to isolate the two primary causes of soil structure interaction that is inability of foundation to match the free field deformation and the effect of dynamic response of structure foundation system on the movement of supporting soil. In the analysis and design of engineered structures in the past, it was assumed that the foundation of structure was fixed to a rigid underlying medium (Zhang et al. (1998), Celebi (2001)). In the last few decades, however, it has been recognized that Soil Structure Interaction (SSI) altered the response characteristics of a structural system because of massive and stiff nature of structure and, often, soil softness. Various studies have appeared in the literature to study the effect of SSI on dynamic response of structures such as nuclear power plants, high-rise structures and elevated highways (Maheshwari et al., 2004, Boominathan et al., 2004, Jaya et al., 2009, Wegner et al., 2009). The following section discusses the critical review on the SSI analysis of framed structures supported on pile foundations.

II.Substructure Approach:

Substructure method is one in which the analysis broken down into several steps that is the principal of superposition is used to isolate the two primary causes of soil structure interaction that is inability of foundation to match the free field deformation and the effect of dynamic response of structure foundation system on the movement of supporting soil. In the analysis and design of engineered structures in the past, it was assumed that the foundation of structure was fixed to a rigid underlying medium (Zhang et al. (1998), Celebi (2001)). In the last few decades, however, it has been recognized that Soil Structure Interaction (SSI) altered the response characteristics of a structural system because of massive and stiff nature of structure and, often, soil softness. Various studies have appeared in the literature to study the effect of SSI on dynamic response of structures such as nuclear power plants, high-rise structures and elevated highways (Maheshwari et al., 2004, Boominathan et al., 2004, Jaya et al., 2009, Wegner et al., 2009). The following section discusses the critical review on the SSI analysis of framed structures supported on pile foundations and raft foundation.

A. Soil Structure Interaction Under Static Loading

Numerous studies have been made on the effect of soil structure interaction under static loading. These studies have considered the effect in a very simplified manner and demonstrated that the force quantities are revised due to such interaction. Several studies, experiments and research works have been carried out since a long time all over the world to understand and to evaluate the effect of pile soil interaction. References have shown the load-settlement behavior of the soil using ANSYS software whereas Ref. Baleshwar Singh used PLAXIS software. Experimental work has been done using pile with soil. Many other literatures were studied on the soil structure interaction. Many other literatures were studied on the soil structure interaction. All the paper restrains their work upto the soil settlements behavior. Very few authors have done their research on behavior of high rise building along with the soil pile interaction. Hence, taking in view all the research the further study in this paper is carried out on high rise building. Therefore, the author is trying to find the actual behavior of the structure with the soil pile interaction and normal foundation in terms of displacements.

III.LITURATURE REVIEW

Although numerous works have been done on interaction analysis of frame structure resting on combined footings, isolated footings, etc., not much of work has been done interaction analysis of frame structure resting on pile foundations (Ingle and Chore 2007) except a few studies as described in the following section. The work on frame structures supported on pile foundations was first started by Buragohain et al. In 1977 who evaluated the space frames resting on pile foundation by means of stiffness matrix method in order to quantify the effect of soil-structure interaction using simplified assumptions. In his study, the pile cap was considered to be rigid, with the neglection of of its stiffness. The stiffness matrix for the entire pile group was derived from the principle of superposition using the rigid body transformation. The foundation stiffness matrix was then combined with the superstructure matrix to perform the interactive analysis which was carried out in single step to assess the effect of soil structure interaction on the response of structure in terms of changes in member forces and settlements.

After that Cai et al. in 2000 developed a three-dimensional nonlinear Finite element subsystem methodology to study the seismic soil–pile–structure interaction effects in which the plasticity and work hardening of soil have been considered by using δ* version of the HiSS modelling. Based on their studies it has been concluded that with- plasticity- based soil model, the motion of the pile foundation deviated significantly from the bedrock motion and this departure from the ground motion should not be over looked in evaluating the seismic kinematic response of pile-supported structures. Also it has been observed that the output of the pile head motion revealed an interesting phenomenon that although the bedrock input is horizontal there is some vertical acceleration on the pile heads (column bases). In Cai et al. work the analysis was carried out on fixed boundary conditions and also damping in the foundation subsystem was neglected. Fixed boundary condition does not give the actual response as there will be lot of reflections coming back and soil damping also plays a major role in soil structure interaction analysis. tall building by considering the non-linear soil-pile interaction, in which a 20-storey building is examined as a typical structure supported on a pile foundation using DYNAN computer program, leading to the conclusion that the theoretical prediction for tall buildings fixed on a rigid base without soil-structure interaction fails to represent the real seismic response, since the stiffness is overestimated and the damping is underestimated.

Besides in 2003 Lu et al., studied the dynamic soil structure interaction of a twelve storey framed structure supported on raft pile foundations using ANSYS, in which the influence of the following parameters soil property, rigidity of structure, buried depth, dynamic characteristics on SSI is studied. It has been observed that effect of SSI on displacement peak value of structure is greater with increase of structural rigidity.

Ingle and Chore (2007) reviewed the soil-structure interaction (SSI) analysis of framed structures and the problems related to pile foundations, and underscored the necessity of interactive analysis to build frames resting on pile foundations by more rational approach and realistic assumptions. It was suggested that flexible pile caps along with their stiffness should be considered and the stiffness matrix for the sub- structure should be derived by considering the effect of all piles in each group. However, the basic problem of the building frame is three dimensional in nature. Although a complex three-dimensional finite element approach, when adopted for the analysis, is quite expensive in terms of time and memory, it facilitates realistic modelling of all the parameters involved. Along these lines, Chore and Ingle (2008 a) presented a methodology for the comprehensive analysis of building frames supported by pile groups embedded in soft marine clay using the 3D finite element method.

The effect of various foundation parameters, such as the configuration of the pile group, spacing and number of piles, and pile diameter, has been evaluated on the response of the frame. The analysis also considered the interaction between pile cap and soil. It has been concluded that with the increase in pile spacing and number of piles in a group, displacement at top of frame decreases. In addition, with the increase in diameter of piles, displacement at top of frame decreases for any spacing owing to the increased stiffness of pile group at higher diameter. Also the effect of soil structure interaction (SSI) is significant on bending moment, i.e. SSI is found to increase the maximum positive bending moment by 14.01 % and maximum negative bending moment by 27.77 %.

Chore and Ingle (2008 b) reported an interaction analysis on the space frame with pile foundations using the finite element method, wherein the foundation elements were modelled in the simplified manner as suggested by Desai et al. (1981). The pile cap was idealized as two dimensional plate elements, the piles as one dimensional beam elements, and the soil as linearly elastic independent springs. In this way, the three dimensional pile foundations can be replaced by an assembly of one dimensional beam elements, two dimensional plate elements and equivalent springs. The memory requirement is about one tenth of that required by a three dimensional modelling, making it rather easy to simulate the original complex problem.

In the studies made by Chore and Ingle (2008 a, b), an uncoupled analysis (sub-structure approach) of the system of building frame and pile foundation was presented. By this methodology, a building frame was analysed separately with the assumption of fixed column bases. Later, equivalent stiffness was derived for the foundation head and used in the interaction analysis of the frame to include the SSI effect. More recently, Chore et al. (2009) presented an interaction analysis for the building frame resting on the pile group using a coupled approach, i.e., by considering the system of building frame - pile foundation - soil as a single combined unit. Although such an analysis is computationally uneconomical, fair agreement has been observed between the results obtained using coupled and uncoupled approaches.

Chore et al. in 2010 studied the effect of soil-structure interaction on a single-storey, two-bay space frame resting on a pile group embedded in the cohesive soil (clay) with flexible cap (Fig. 2). For this purpose a three dimensional Finite Element analysis is carried out using substructure approach. A parametric study has been conducted to study the effects of pile spacing, pile configuration, and pile diameter of the pile group on the response of superstructure for different pile tip conditions. The displacement at the top of the frame is less for fixed base condition and increases by 42 to 103% when the SSI effect is incorporated. Likewise, with the increase in pile spacing, the top displacement of the frame decreases. The effect of end conditions at the pile tip is significant as well on the displacement. Though the displacements obtained for the pinned tip and fixed tip are less than those for the free tip, the end condition does not have appreciable effect for parallel configuration.

In the work of Chore et al. actual interaction with the soil and foundation has been neglected by replacing the soil with springs. Similarly, the combined effect of kinematic and inertial interaction is also neglected by the substructure analysis.

More recently Deepa et al. in 2012 did a Linear static analysis using commericial package NISA on a four bay twelve storey RCC frame structure resting on pile foundations, from which it has been observed that SSI effects increased the responses in the frame upto the characteristic depth and decerased when the frame has been treated for full depth.

Vivek et al., in 2012 presented a review on interaction behavior of structure-foundation-soil system. In which he gave a brief description of research done by various researchers on linear, nonlinear, elasto-plastic, plastic soil structure interaction effects under static and dynamic loading conditions. As the well known reason why our structures are always safe against gravitational loads and various damages to them (structures and foundations) is mainly because of lateral motion. In the following section, the various analytical methods available for single and group piles (not the review) has been outlined by discussing the advantages of one over the other.

Pile Foundations

Pile foundations, the oldest method of construction for overcoming the difficulties of foundation on soft soils, are used to support bridges, high rise structures, offshore platforms, marine structure etc. Significant damage was caused to pile supported structures in the past during major earthquakes. Since then extensive research has been carried out and several analytical and numerical procedures have been developed to determine the static and dynamic response of piles subjected to horizontal or vertical loads. Meanwhile, full scale experimental observations on the pile’s behaviour and numerous model testing have been carried out.

In this paper an attempt is made to discuss the details of RCC frame bulding layed on the clayey and sandey soil with isolated foundation and pile foundation in PLAXIS 2D finite element software.

Many works have been done to explore the benefits of using pozzolanic materials in making and enhancing the properties of concrete.

M.D.A. Thomas, M.H.Shehata et al. have studied the ternary cementitious blends of Portland cement, silica fume, and fly ash offer significant advantages over binary blends and even greater enhancements over plain Portland cement.

Sandor Popovics have studied the Portland cement-fly ash - silica fume systems in concrete and concluded several beneficial effects of addition of silica fume to the fly ash cement mortar in terms of strength, workability and ultra sonic velocity test results. Jan Bijen have studied the benefits of slag and fly ash added to concrete made with OPC in terms of alkali-silica reaction, sulphate attack.

L. Lam, Y.L. Wong, and C.S. Poon in their studied entitled Effect of fly ash and silica fume on compressive and fracture behaviors of concrete had concluded enhancement in strength properties of concrete by adding different percentage of fly ash and silica fume.

Tahir Gonen and Salih Yazicioglu studied the influence of binary and ternary blend of mineral admixtures on the short and long term performances of concrete and concluded many improved concrete properties in fresh and hardened states.

Mateusz Radlinski, Jan Olek and Tommy Nantung in their experimental work entitled Effect of mixture composition and Initial curing conditions on the scaling resistance of ternary concrete have find out effect of different proportions of ingredients of ternary blend of binder mix on scaling resistance of concrete in low temperatures.

S.A. Barbhuiya, J.K. Gbagbo, M.I. Russeli, P.A.M. Basheer studied the properties of fly ash concrete modified with hydrated lime and silica fume concluded that addition of lime and silica fume improve the early days compressive strength and long term strength development and durability of concrete.

Susan Bernal, Ruby De Gutierrez, Silvio Delvasto, Erich Rodriguez carried out Research work in Performance of an alkali-activated slag concrete reinforced with steel fibers. Their conclusion is that The developed AASC present higher compressive strengths than the OPC reference concretes. Splitting tensile strengths increase in both OPCC and the AASC concretes with the incorporation of fibers at 28 curing days.

Hisham Qasrawi , Faisal Shalabi, Ibrahim Asi carried out Research work in Use of low CaO unprocessed steel slag in concrete as fine aggregate.Their conclusion is That Regarding the compressive and tensile strengths of concrete steel slag is more advantageous for concretes of lower strengths. O. Boukendakdji, S. Kenai, E.H. Kadri, F. Rouis carried out Research work in Effect of slag on the rheology of fresh self-compacted concrete. Their conclusion is that slag can produce good self-compacting concrete.

Shaopeng Wu, Yongjie Xue, Qunshan Ye, Yongchun Chen carried out Research work in Utilization of steel slag as aggregates for stone mastic asphalt (SMA) mixtures. Their conclusion is that The test roads shows excellent performances after 2-years service, with abrasion and friction coefficient of 55BPN and surface texture depth of 0.8 mm.

Tahir Gonen,Salih Yazicioglu carried out research work in the influence of mineral admixtures on the short and long term performance of concrete, hence concluded that silica fume contributed to both short and long term properties of concrete, where as fly ash shows its beneficial effect in a relatively longer time. As far as the compressive strength is concerened, adding of both silica fume and fly ash slightly increased compressive strength, but contributed more to the improvement of transport properties of concrete.

M. Maslehuddin, Alfarabi M. Sharif, M. Shameem, M. Ibrahim and M.S Barry carried out experimental work on comparison of properties of steel slag and crushed limestone aggregate concretes, finally concluded that durability characteristics of steel slag cement concrete were better than those of crushed limestones aggregate concrete. Some of physical properties were better than of crushed lime stones concrete.

J. G. Cabrera and P. A. Claisse carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the flow of oxygen is described by the Darcy equation, but the flow of water vapour is not. The different mechanisms of transmission cause the transmission rates for oxygen to be spread over a far greater range than those for water vapour with some of the SF samples almost impermeable to oxygen.

Houssam A. Toutanji and Tahar El-Korchi carried out experimental work on Oxygen and water vapour transport in cement pastes, hence concluded that the increase in compressive strength of mortar containing silica fume as a partial replacement for cement, greatly contributes to strengthening the bond between the cement paste and aggregate. It was also demonstrated that super plasticizer in combination with silica fume plays a more effective role in mortar mixes than in paste mixes. This can be attributed to a more efficient utilization of super plasticizer in the mortar mixes due to the better dispersion of the silica fume.

Jigar p. patel carried out experimental work on broader use of steel slag aggregate in concrete, hence concluded that durability of steel slag aggregates concrete under freeze-thaw environment was the main goal in this research, as there was a belief that the steel slag aggregates have expansive characteristics and would cause cracking in concrete.

Rahul, Jamsheed, Shanil, Geo and Jagdeesh Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material has been emphasized. Waste can be used to produce new products or can be used as admixtures so that natural resources are used more efficiently and the environment is protected from waste deposits. Marble stone industry generates both solid waste and stone slurry. Whereas solid waste results from the rejects at the mine sites or at the processing units, stone slurry is a semi liquid substance consisting of particles originating from the sawing and the polishing processes and water used to cool and lubricate the sawing and polishing machines. Stone slurry generated during processing corresponds to around 40% of the final product from stone industry. This is relevant because the stone industry presents an annual output of 68 million tonnes of processed products. Therefore the scientific and industrial community must commit towards more sustainable practices. There are several reuse and recycling solutions for this industrial by-product, both at an experimental phase and in practical applications. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled. The physical, chemical and mechanical properties of the waste are analyzed.

Ke Ru Wu, et al, (2001) The impact of the type of coarse aggregate on the strength of concrete is more significant in HSC. In HSC about 10-20% higher compressive strength and split tensile strength are obtained with crushed quartzite compared to marble aggregate. In concretes with a target strength of 30MPa, strength differences between concretes made with different coarse aggregates are reduced. It is suggested that the high strength concrete with lower brittleness can be made by selecting high strength aggregate with low brittleness.

Hassan A. Mohamadien Marble powder material (MP) is a very fine powder, obtained as a by-product of marble during the sawing and the shaping, and not recycling it due to environmental problems in the world. The possibility of using it and silica fume (S.F) separately as partial replacement of cement on mortar were studied and evaluated based upon the percentage of the partial cement replacement with both marble powder and silica fume separately. Four types of mortar mixture with same workability, cement to sand ratio of 1:3 and water to cementitious materials ratio of 0.4 were prepared marble powder and silica fume used in mixes separately, once as a partial replacement of cement content and another as an addition to the mix proportion. Replacement and addition ratio of both marble powder and silica fume with cement content separately at 0%, 5%, 10%, 15%, 20%, 30% and 50 % by weight were investigated. The mechanical properties of mortar were measured in terms of compressive strength at 7 and 28 days and it was observed that the strength developments at 7, and 28 days and the highest development rate of compressive strength was observed at 15% replacement ratio for each the marble powder and silica fume separately.

Narayana.P.S.S. et al, (2004) The improvement in compressive strengths at 28 days with 5% addition of micro silica is 20% more compared with 0% addition. The strength increases with age of the concrete for various other parameters of micro silica. The addition of micro silica has improved the resistance of concrete to the attack of acids and sulphates. The percentage weight loss will be less at 20% addition of micro silica in H2S04, HCL and Na2SO4.

Mehta.P.K. (1997) He concluded that the durability is not an intrinsic property of concrete. It is a holistic criterion dependent not only on environmental exposure conditions but also on structural design parameters, characteristic of concrete making materials, mix proportions, and processing methods. Deterioration of concrete structures before the end of their designed service life can be prevented by a holistic approach, which covers all the important factors influencing durability.

Wee.T.H. et al, (2000) One of the main causes of deterioration in concrete structures is its exposure to harmful chemicals that may be found in nature, such as in contaminated ground water, industrial effluents and sea water. The most aggressive chemicals that effect durability of structures are chlorides and sulphates.

Rakesh Sakale et. al. [1] studied the replacement of cement by waste glass powder in steps of 10%, 20%, 30% and 40% respectively by volume of cement and its effects on compressive strength, split tensile strength, workability and flexural strength are determined. It is found that the compressive, flexural and split tensile strengths of concrete increase initially as the replacement percentage of cement by glass powder increases and become maximum at about 20% and later decrease. The workability of concrete reduces monotonically as the replacement percentage of cement by glass powder increases. The replacement of cement up to about 20% by glass powder can be done without sacrificing the compressive strength.

Oluko et. al. [2] investigated the compressive strength of Compressed Stabilized Earth Block (CSEB) by partially replacing the cement (stabilizer) in the block with Waste Glass Powder (WGP) and it was found from the results that, as WGP is added to compressed stabilized earth block, its strength reduces. Although, the strength for CSEB without waste glass had the highest strength, CSEB with WGP indicated strengths higher than 3N/mm2 recommended as minimum strength for CSEB at 28 days for the percentage of replacements used in this study, the highest of which was 60%. No optimum value was observed for WGP addition to the CSEB as replacement for cement, however, sufficient strengths good enough for handling at early stages of the CSEB whether at particle size of 150 μm or 75 μm were achieved at 20% replacement of cement with WGP in CSEB. It could be concluded that the role of WGP in CSEB is more of filler than a binder.

Shuhua Liu et. al. [3] carried out a research to ascertain the inhibitory effect of waste glass powder (WGP) on AlkaliSilica Reaction (ASR) expansion induced by waste glass aggregate. These studies showed that there is ASR risk with an ASR expansion rate over 0.2% when the sand contains more than 30% glass aggregate. However, WGP can effectively control the ASR expansion and inhibit the expansion rate induced by the glass aggregate to be under 0.1%. The specific surface area of WGP and the ASR expansion have an anti-correlation, which leads the pozzolanic reaction more intense and faster and higher inhibitory effect on ASR expansion. The ASR expansion can be controlled in a safe range when WGP content is 10%, 20% and 30% with its specific surface area greater than 1137.40, 604.37 and 71.34m2/kg, respectively, or with low average particle size according to the calculation.

Raghavendra K. and Virendra Kumara K. N [4] investigated about the compressive strength, split tensile strength and water absorption of M40 grade of concrete mixes with 20% constant replacement of waste glass powder in cement and partial replacement of waste foundry sand in fine aggregate. From the test results, strength was achieved very less on 7th and 14th days but it increases on the 28^{th} day. High strength values were found at 40% replacement level in strength parameters. The compressive strength and split tensile strength of concrete at 7, 14 and 28 days increases initially as the percentage of replacement of waste glass powder and waste foundry sand increases and becomes maximum at a proportion respectively around A40, A40.

Ana Mafalda Matos [5] aimed to evaluate the use of waste glass powder in powder type SCC. It could be concluded that waste glass powder can be used successfully in SCC further improving chloride penetration and water absorption by capillarity, maintaining strength levels. Although soda lime glass presents a high alkali content, use of ground waste glass as cement replacement in mortar, improved resistance to ASR. These results corroborate the pozzolanic nature of glass powder and its behaviour with time. Although glass powder is a little coarser than cement, it still brings advantages when incorporated in cement.

Jitendra B. Jangid and A.C. Saoji [6] studied the replacement of Glass Powder varying partially from 0 to 40%, at interval of 10% and tested for its Workability, Compressive Strength, Split Tensile Strength, Alkalinity test, Density Measurement, Water Absorption test, Volume of permeability test and Ultrasonic Pulse Velocity test for the age of 7, 28 and 56 days and was compared with those of conventional concrete. The overall test result showed that Waste Glass Powder could be utilized in concrete as a good substitute of cement. It was also found that Workability of concrete decreases as percentage of glass powder increases. Slump value of experiment's concrete ranges from 60 to 80 mm highest compressive strength was observed when GlassLiquid Powder (GLP) replacement is about 20%. Highest split tensile strength was observed when GLP replacement is about 20%.

Ashutosh Sharma and Ashutosh Sangamnerkar [7] showed that waste glass, if ground finer than 600μm shows a pozzolanic behaviour. It reacts with lime at early stage of hydration forming extra CSH gel there by forming denser cement matrix. Thus early consumption of alkalis by glass particles helps in the reduction of alkali-silica reaction hence enhancing the durability of concrete. Numbers of test were conducted to study the effect of 5%, 10% and 15% replacement of cement by glass powder on compressive strength and durability. The particle size effect was evaluated by using glass powder of size 600μm-100μm.The results showed that the maximum increase in strength of concrete occurred when 10% replacement was done with glass powder. Then found result

- Conventional concrete shows a 3 days compressive strength as 9 N/mm and 2.5% replacement of glass powder in cement increased the compressive strength by 37% in 3 days.
- 10% replacement of glass powder increment increased the compressive strength by 52.6% in 3 days.
- 5615% replacement of glass powder in cement increased the compressive strength by 39.8% in 3 days.

M. Adaway and Y. Wang [8] aimed to determine the level of glass replacement resulting in optimal compressive strength. Three concrete samples were tested at 7 and 28 days for glass replacement proportions of 15, 20, 25, 30 and 40%. Compressive strength was found to increase up to a level of 30% at which point the strength developed was 9% and 6% higher than the control after 7 and 28 days respectively. This demonstrates that concrete containing up to 30% fine glass aggregate exhibits higher compressive strength development than traditional concrete. The optimum percentage replacement of sand with fine glass aggregate was determined to be 30%.Compressive strength was found to increase with the addition of waste glass to the mix up until the optimum level of replacement.

Veena V. Bhatt and N. Bhavanishankar Rao [9] studied the influence of replacement of cement by glass powder and found that there was an increase of 27% strength after replacing 20% glass powder, when w/c ratio was kept constant. Slump test was carried out and the slump was found to be 70 to 72mm even with 20% replacement. It was also found that with the increase in glass content, percentage of water absorption decrease. Considering the strength criteria, the replacement of cement by glass powder is feasible upto 20%.

IV.METHODOLOGY

Analytical Methods for Single Piles:

Single piles are mainly used for coastal structures such as mooring and berthing piles, but usually formed in groups. However, tall buildings, offshore platforms, quays, viaducts, and bridge piers are generally built on pile groups. The difference between the behaviour of single piles and pile groups is that pile group response is influenced by the nonlinear pile-soil-pile interaction, the effect of the pile cap, the spacing of piles, and the arrangement of piles with respect to the direction of applied force (Charles et al. 2001). So in order to have a good understanding on the group behaviour, first the single pile behaviour is discussed followed by group pile behaviour. Analytical methods to predict lateral deflections, rotations and stresses in single pile can be grouped under the following four headings

1) Winkler Approach
2) P-Y Method
3) Elastic Continuum Approach
4) Finite Element Method

Winkler Approach:

The Winkler approach, also called the sub grade reaction theory, is the oldest method to predict pile deflections and bending moments. - The approach uses a series of unconnected linear springs to model the soil with stiffness, Kh, expressed in units of force per length squared (FL-2). The behaviour of a single pile can be analysed using the equation of an elastic beam supported on an elastic foundation (Hetenyi 1946), which is represented by the 4^{th} order differential beam bending equation.

$$E_p I_p \frac{d^4 u}{dz^4} + Q\frac{d^2 u}{dz^2} = -w = -pd = -K_h u d$$

$$E_p I_p \frac{d^4 u}{dz^4} + Q\frac{d^2 u}{dz^2} + K_h u d = 0 \qquad (1)$$

Where E_p Pile modulus of elasticity
Q Axial load on pile
I_p Pile cross section moment of Inertia
d Pile diameter
w Soil reaction per unit length over the pile(distributed load)
p Soil pressure over the pile
K_h Soil lateral subgrade reaction modulus
u Lateral deflection of pile at point x along the length of the pile

Solutions to Eq (1) have been obtained by making assumptions simplification regarding the variation of Kh with depth. The most common assumption is that Kh is constant with depth for clays and Kh varies linearly with depth for sands. Poulos and Davis (1980) and Prakash and Sharma (1990) provided tables and charts that can be used to determine pile deflections, slopes, and moments as a function of depth and non-dimensional coefficients for a constant value of Kh with depth.

Despite its frequent use, the method is often criticized because of its theoretical shortcomings and limitations. The primary shortcomings are the modulus of sub grade reaction that is not a unique property of the soil, but depends intrinsically on pile characteristics and the magnitude of deflection; and the method is semi-empirical in nature; axial load effects are ignored and the soil model used in the technique is discontinuous. That is, the linearly elastic Winkler springs behave independently and thus displacements at a point are are free from being influenced by displacements or stresses at other points along the pile.

McClelland and Focht (1956) augmented the sub grade reaction approach using finite difference techniques to solve the beam bending equation with nonlinear load versus deflection curves to model the soil. Their approach is known as the p-y method of analysis. This method has gained popularity in recent years with the availability of powerful personal computers and commercial software such as COM624 (Wang and Reese 1993) and LPILE Plus3.0 (Reese et al., 1997). A brief summary of the p-y method of analysis is presented in the following section.

P-Y Method:

The p-y approach to analysis of response of laterally loaded piles is essentially a modification (Horvath 1984) of the basic Winkler model, where p is the soil pressure per unit length of pile and y is the pile deflection. The soil is represented by a series of nonlinear p-y curves that vary with depth and soil type. An example of a hypothetical p-y model is shown in Fig. 3. The method is semi- empirical in nature because the shape of the p-y curves is determined from field load tests. Reese (1977) has developed a number of empirical curves for typical soil types based on the results of field measurements on fully instrumented piles. The most widely used analytical expression for p-y curves is the cubic parabola, represented by the following equation.

$$\frac{p}{p_{ult}} = 0.5\left(\frac{y}{y_{50}}\right)^{1/3} \qquad (2)$$

where p_{ult} Ultimate soil resistance per unit length of pile

y_{50} Deflection at one - half of the ultimate soil resistance

The deflections, rotations, and bending moments in the pile are calculated by solving the beam bending equation using finite difference or finite element numerical techniques.- The pile is divided into a number of small increments and analysed using p-y curves to represent the soil resistance. In this representation, the axial load in the pile, Q, is implicitly assumed constant with depth, to simplify computations. This assumption does not adversely affect the analysis because Q has very little effect on the deflection and bending moment (Reese 1977).

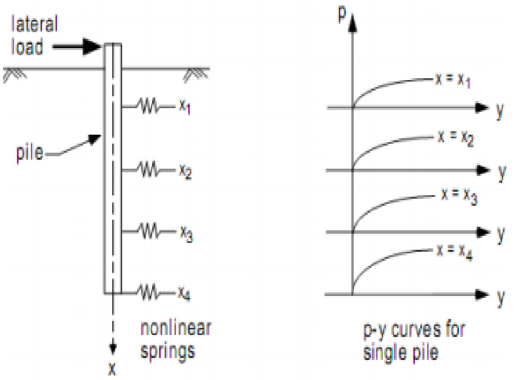

Fig.3.1 P-Y Model For Laterally Loaded Piles

The method outperforms the sub grade reaction approach because it accounts for the nonlinear behaviour of most soils without the numerical limitations inherent in the sub grade reaction approach. However, the method has some limitations; such as the p-y curves are independent of one another. Therefore, the continuous nature of soil along the length of the pile is not explicitly modelled. The acquisition of the appropriate p-y curve is similar to the gain of the appropriate value of Kh; and one must either perform full-scale instrumented lateral load tests or adapt the existing available standard curves for use in untested conditions.- These standard curves are limited to the soil types in which they are developed, but not universal.

Elastic Column Approach:

Poulos (1971 a, b) presented the first systematic approach to analyze the behaviour of laterally loaded piles and pile groups by assuming the soil as a homogeneous elastic continuum. In this analysis, the soil is assumed to be a homogeneous, isotropic, semi-infinite elastic material which is unaffected by presence of pile and also the soil at the back of the pile near the surface adheres to the pile (Poulos et al. 1980). In this model the pile is assumed to be a thin rectangular vertical strip divided into elements, and it is considered that each element is acted upon by uniform horizontal stresses (Fig.3.2) which are related to the element displacements through the integral solution of Mindlin's problem. Finally, the soil pressures over each element are obtained by solving the differential equation of equilibrium of a beam element on a continuous soil with the Finite Difference Method (FDM). After the acquisition of the pressures, the displacements are found.

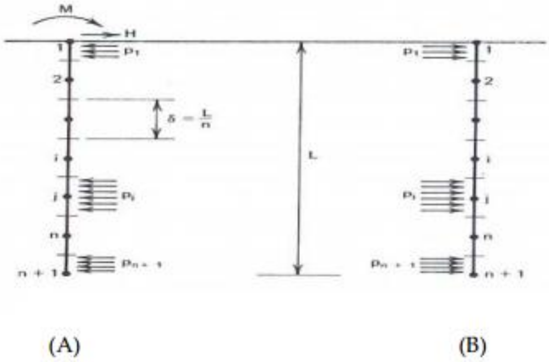

Fig.3.2 Continuum Model For Laterally Loaded Pile Stresses Acting On (A) Pile (B) Soil Adjacent To Pile

As well Novak in 1974 presented an approximate continuum approach to account for soil-pile interaction, in which it is assumed that the homogeneous soil layer is composed of a set of independent horizontal layers of infinitesimal thickness, extending to infinity. As each plane is considered independent, this model may be viewed as a generalized Winkler model. The planes are homogeneous, isotropic, and linearly elastic, and considered to be in a plane strain state. The researcher presented the stiffness constants and constants of equivalent viscous damping for single, vertical piles in the form of tables and charts in which he gave it for two different cases like a constant soil shear modulus and shear modulus varies with depth according to a quadratic parabola.

Elastic continuum approach was used by Madhav and Sarma (1982) to study the behaviour of overhang pile embedded in homogeneous soil mass subjected to both axial and lateral loads. The load displacement behaviour was found to be dependent on magnitude of axial load and also on pile and soil parameters (height of overhang, relative stiffness of pile and soil, undrained shear strength).

The Continuum model has the advantage that it is able to take into account the continuous nature of soil, the semi-infinite dimension of the half-space, and the boundary conditions along the unloaded ground surface. Although yielding of soil may be introduced by varying the soil elastic modulus, this approach does not permit to consider local yielding and layered soil. One of the biggest limitations of the method (in addition to computational complexities) is the difficulty in determining an appropriate soil modulus, Kh.

Finite Element Method:

The finite element method is a numerical approach based on elastic continuum theory that can be used to model pile-soil-pile interaction by considering the soil as a three-dimensional, quasi-elastic continuum. Finite element techniques have been used to analyse complicated loading conditions in which the soil is modelled as a continuum.- Pile displacements and stresses are evaluated by solving the classic beam bending equation using one of the standard numerical methods such as Galerkin, Collocation, or Rayleigh-Ritz. Various types of elements are used to represent the different structural components. Interface elements are often used to model the soil-pile interface.- These elements provide for frictional behaviour when there is contact between pile and soil, and do not allow transmittal of forces across the interface when the pile is separated from the soil (Brown and Shie 1991). Salient features of this powerful method include the ability to apply any combination of axial, torsion, and lateral loads; the capability of considering the nonlinear behaviour of structure and soil; and the potential to model pile-soil-pile- structure interactions. Time dependent results can be obtained and more intricate conditions such as battered piles, slopes, excavations, tie-backs, and construction sequencing can be modelled.- The method can be used with a variety of soil stress-strain relationships, and is suitable to analyze pile group behaviour, as described in next Section. The implementation of three-dimensional finite element analyses requires considerable engineering time to generate input and interpret results. For this reason, the finite element method has predominately been used for research on pile group behaviour, rarely for design.

Modelling of RCC frame with soil layers:

The analytical models of the frame include all components that influence the mass, strength, stiffness and deformability of structure. The structure system frame consists of beams, columns and foundation. All beams and columns are modelled in STAAD.PRO. Isolated and Pile foundation and soil are modelled with the help of PLAXIS 2D. Brief descriptions about the elements used for modelling are discussed below.

RCC Frame*:*

In this project we are consider the G+5 building with 4-bay spacing of each is 3m along X and Z direction. Fig.3.1 Shows the plan of the building, which is modelled on the STAAD.Pro. loads considered on the building are given below.

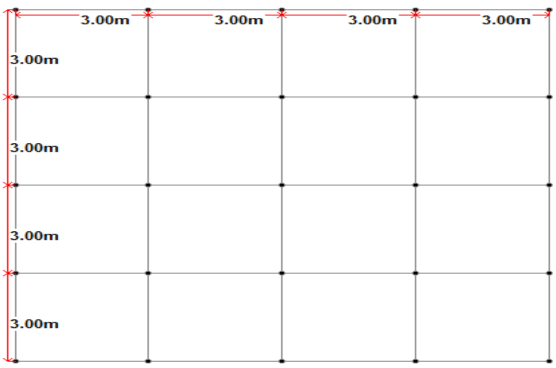

Fig. 3.3 Plan of the RCC frame

Dead Loads*:*

All permanent constructions of the structure form the dead loads. The dead load comprises of the weights of walls, partitions floor finishes, false ceilings, false floors and the other permanent constructions in the buildings. The dead load loads may be calculated from the dimensions of various members and their unit weights. the unit weights of plain concrete and reinforced concrete made with sand and gravel or crushed natural stone aggregate may be taken as 24 kN/m^3 and 25 kN/m^3 respectively.

Imposed Loads:

Imposed load is produced by the intended use or occupancy of a building including the weight of movable partitions, distributed and concentrated loads, load due to impact and vibration and dust loads. Imposed loads do not include loads due to wind, seismic activity, snow, and loads imposed due to temperature changes to which the structure will be subjected to, creep and shrinkage of the structure, the differential settlements to which the structure may undergo.

S.No	Property	Dimentions
1	Plinth Beam	230 x 300 mm
2	Floor Beam	230 x 500 mm
3	Column	230 x 450 mm
4	Slab	150 mm

Tabel 3.1 Details of RCC frame Model

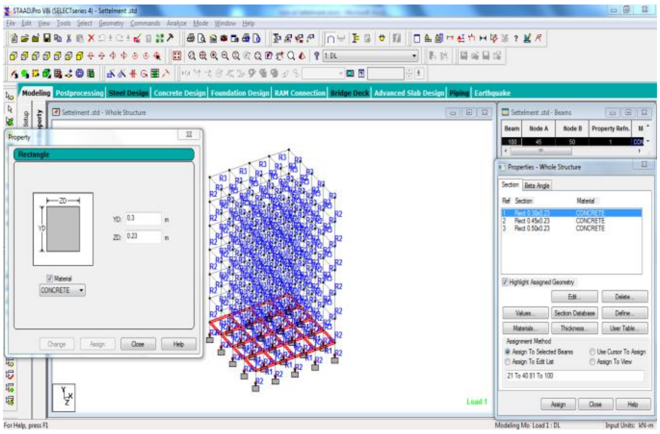

Fig.3.4 Assigning of Section Properties

S.No	Type	Load
1	External Wall	12 kN/m
2	Internal Wall	6 kN/m
3	Slab Dead Load	4.75 kN/m^2
4	Slab Live Load	2 kN/m^2

Tabel 3.2 Applied Dead and Live loads on RCC frame

Parameter	C	Φ	E kN/m^2	γ_{unsat} kN/m^3	γ_{sat} kN/m^3	ν
Clay	2	25	2000	15.5	18	0.35
Sand	1	35	20000	17	20	0.3

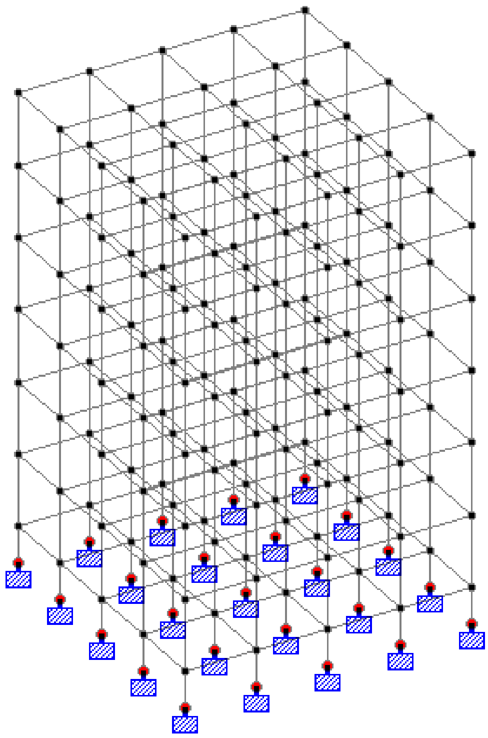

Fig.3.5 Support for the RCC frame building

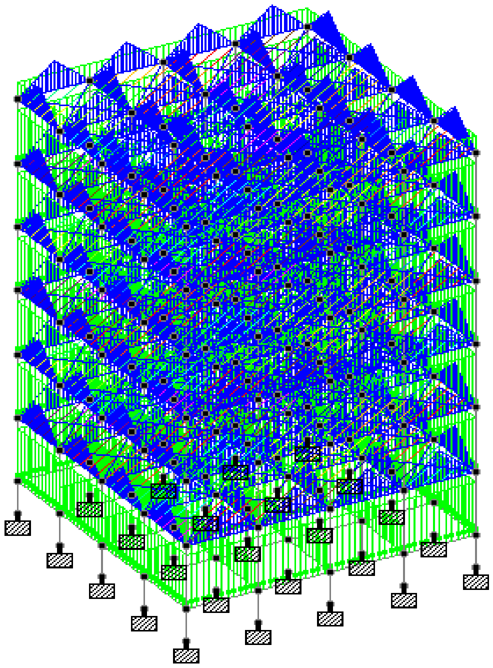

Fig.3.6 Dead and Live Loads on the RCC frame

Modelling of Soil Layers and Foundation:

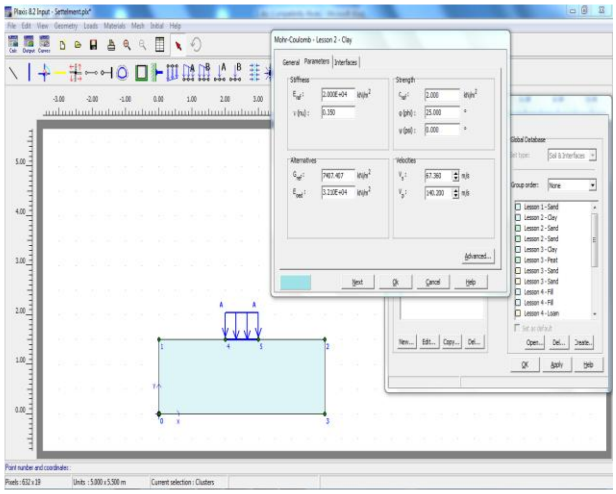

Fig.3.7 Assign Of Clay Property

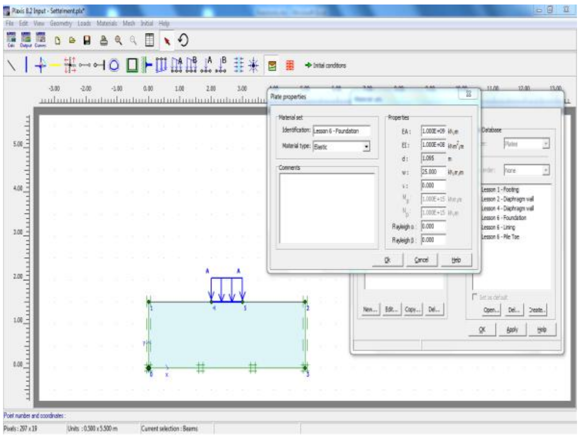

Fig.3.8 Assign Of Isolated Foundation Property

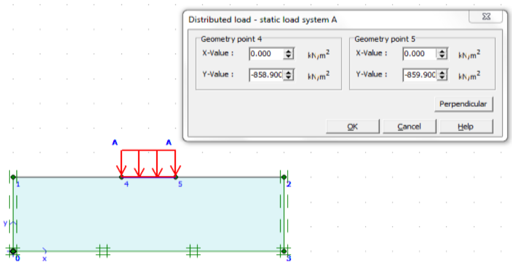

Fig.3.9 Assign of foundation laod

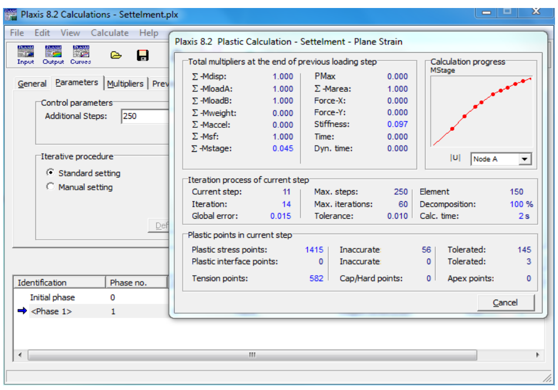

Fig.3.10. Analysis of Clayey Soil

V.ANALYSIS RESULTS

Soil Type	Foundation	Vertical Displacement (mm)	Stresses kN/m^2
Clayey	Isolated	33.02	33.93
	Pile	32.46	34
Sandyey	Isolated	2.5	25.87
	Pile	2.52	26.05

RCC Frame Results From STADD Pro:

From the staad we are taking the support reaction of the framed building which is used for the foundation load in PLAXIS 2D model. Tabel 4.1 shows the support reaction which is acting along the Y-Direction

Soil Behaviour Results From PLAXIS 2D:

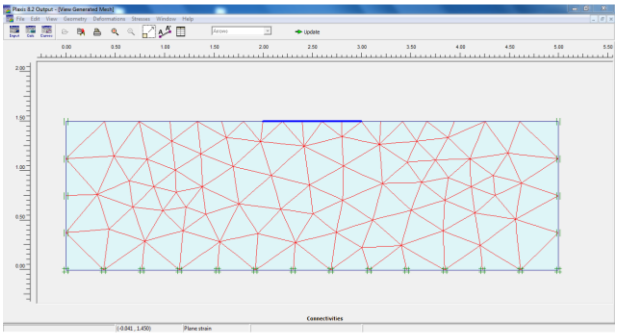

Fig.4.1. Meshing of Clayey Soil

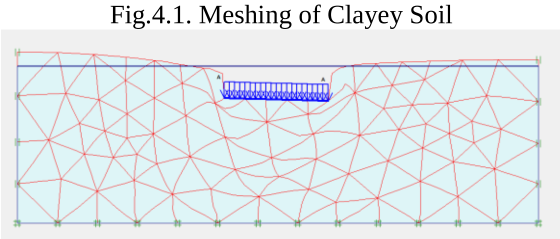

Fig.4.2 Deformation of Mesh

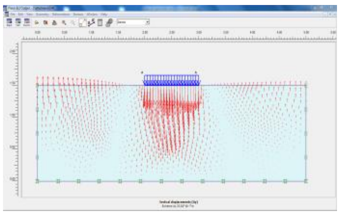

Fig. 4.3 Vertical Displacement For Clayey Soil

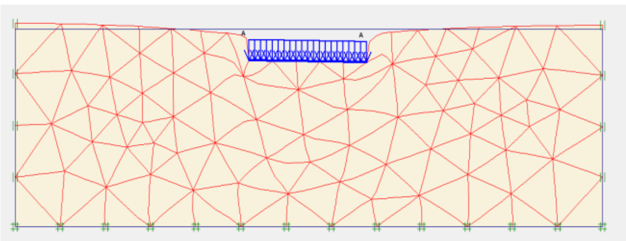

Fig.4.4 Mesh Deformation of Sand Soil

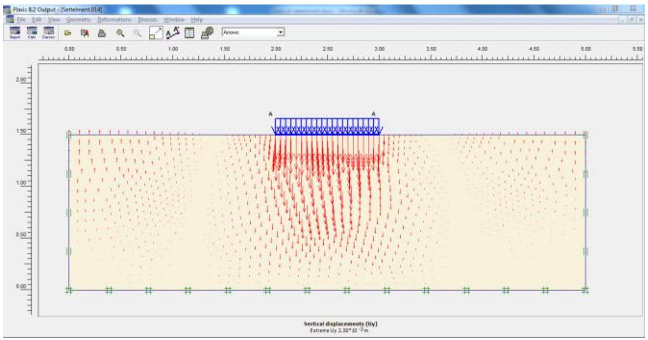

Fig. 4.5 Vertical Displacement For Sandy Soil

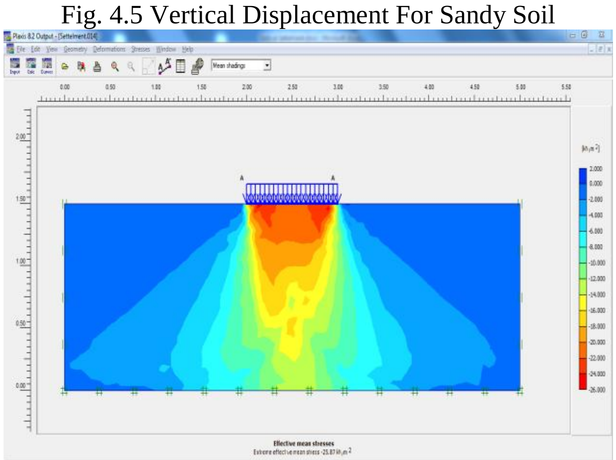

Fig. 4.6 Mean Stress For Sandy Soils

Tabel 4.3 Total Vertical Displacement of Foundation with clayey and Sandy Soils

VI.CONCLUSION

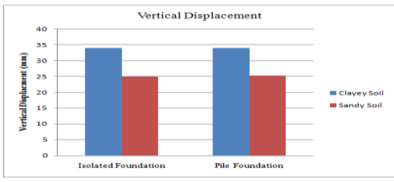

Fig.5.1 Vertical Displacement of Clayey And sandy Soils

- From the above results it is concluded that the load on foundation is consider from the maximum support reaction which we get from the staad.
- The effective stresses of clayey with isolated foundation is 30% more than the Sandy Soil.
- The effective stress of clayey soil with pile foundation is 23% more that the sandy soils.
- Both isolated and pile foundation get the max vertical settlement (33 mm) occur for clayey soil.
- Compared to sandy soils vertical settlement reduces very low.

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