A Study on Piled Raft Foundation: a complete Reviewing

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Abstract- *With increasing in urbanisation in last three decades all over the world led to rapid increase in number and height of buildings even on problematic subsoil conditions. Piled raft system proves to be more effective on such problematic subsoil conditions. It takes the high vertical load and used to bring the settlement, differential settlement and tilting of structure within the permissible limit. Piled raft system proves to be cost effective than the conventional pile foundation system. Piled raft foundation accounts for complex soil-structure interaction, which needs interaction between structure engineer and geotechnical engineer for giving most economical and safe design of the system. This paper reveals the performance of piled raft foundation in sandy soil, clayey soil and, layered soil carried.*

Key words: Pile raft, Differential settlement, Overall settlement, Load- settlement, Settlement Ratio, Finite element method, Soil-Structure interaction (SSI)

1. INTRODUCTION

A combined piled raft foundation serves as an efficient foundation for medium rise buildings for circumstances where the capacity of raft alone does not satisfy the design requirements. The applied load is transferred by means of a load sharing mechanism between pile and raft, which is generated through a process of interaction between the pile, soil and the raft. Unlike the conventional pile foundation design in which the piles are designed to carry the majority of the load, the design of a piled-raft foundation utilizes the load carrying capacity of both raft and piles. For most piled raft foundations, piles are provided to act as settlement reducers. In that case, raft may be designed to withstand the major loads and piles may be designed for the additional loads which cause excessive settlement. Raft foundations are generally provided where the soils stratum at shallow depth is weak and high stress is applied by superstructures to soil. Due to large dimension, the raft is able to withstand high pressure of superstructure. The settlement of raft can be brought within permissible limits if it is supported by group of piles of various configurations. The major advantages of using a piled raft foundation are the reduction in uniform and differential settlements, increase in overall stability of foundation, reduction in number of piles compared to conventional pile foundation and reduction in bending stress for the raft. It is also suitable in stiff as well as soft clays. All the previous model studies were conducted either a sandy soil or in clayey soil. Limited results are available on model studies done in layered soils. As the actual soils available as foundation medium are layered ones, in this paper an attempt is made to conduct model foundation study in a layered soil profile.

2. LITERATURE REVIEW ON COMBINED PILE RAFT FOUNDATION (CPRF)

Nitin Nandwani, Prof P.J.Salunke, Prof N.G.Gore et. al.[1] reported that the use of piled raft foundations has become more popular in recent years, as the combined action of the raft and the piles can increase the bearing capacity, reduce settlement, and the piles can be arranged so as to reduce differential deflection in the raft. Piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. A piled raft foundation is economical compared to the pile foundation. Because piles do not have to penetrate the full depth of clay layer but it can be terminated at higher elevations. Such piled raft foundation undergoes more settlement than the pile foundation and less settlement than the raft foundation. In this paper the study of different parameters like size of the raft, thickness of the raft(500mm, 750mm, 1000mm), diameter of the piles(600mm, 800mm, 1000mm), length of piles(12m), spacing of piles(4D and 5D) etc., which affect the behaviour of piled raft foundation. And its interdependency is also reviewed for G + 20 storey building. This study is useful to decide the various parameters like that maximum settlement of the raft decreases as the diameter of the pile increases, as spacing between the piles increases, settlement increases, the ultimate bearing capacity of Piles will be increased as the Pile diameter increases. To reduce the differential settlement and moment the piles should be place strategically using some trial and error or using parametric study, required in the design of piled raft foundation and suggest the suitable combination of Pile Raft Foundation.

Aleena Tom, Sindhu A R et. al.[2] reported that Combined piled raft foundation is an efficient foundation for medium rise buildings in which the superimposed load is transferred to the soil by the combined action of pile and raft and facilitates settlement reduction. Raft and pile are combined in a view to reduce the overall settlement of the structure. In this paper, 1g model study is conducted on piled raft foundation subjected to vertical axial loading. The foundation medium adopted is a layered soil profile. As a result of experimental model study, load- settlement graphs are plotted for various configurations of piled raft where the arrangement, length and spacing of piles are varied. The thickness of raft is kept constant as it has less influence on the capacity. Numerical modelling is done in PLAXIS 3D software to validate the results. The major parameter used in this study to identify the best piled raft configuration is the settlement ratio. As a result of the study, when the number of piles increases settlement ratio decreases and becomes negligible beyond a 4x4 pile arrangement, where the spacing between the piles is 3.75D, where 'D' is the diameter of the pile. Based on the conducted model tests, following conclusions have been obtained, Comparing the load-settlement response of plain raft and piled raft, it is seen that at any given settlement the load taken by the piled raft is greater than that of plain raft, When the number of piles increases, the settlement ratio decreases gradually from 0.929 and becomes 0.032 when the number of piles is increased from 1 to 16, for L/D of 15cm, When the L/D ratio increases from 15 to 25, Settlement Ratio, SR decreases gradually and becomes zero for R + 16P configuration of length 25cm, It can be concluded that as the spacing between piles beyond a value of 3.75D has no effect in reducing settlement, Maximum percentage reduction in settlement occurs at this spacing. This study focused on study of settlement characteristics of combined pile-raft foundation with various arrangements of pile groups using experimental and numerical models. The work can be extended as follows: This study can be extended by the application of lateral loads instead of axial loads. In this study 'Static Loading' was given. Instead of that 'Dynamic Loading' can be given and its effects can be studied. The study can be extended by using 'Bulb Piles' instead of Circular piles.

Jaymin. D. Patil, Prof. S. A.Vasanvala, Prof. C. H. Solanki et. al.[3] reported that with increasing in urbanisation in last three decades all over the world led to rapid increase in number and height of buildings even on problematic subsoil conditions. Piled raft system proves to be more effective on such problematic subsoil conditions. It takes the high vertical load and used to bring the settlement, differential settlement and tilting of structure within the permissible limit. Piled raft system proves to be cost effective than the conventional pile foundation system. Piled raft foundation accounts for complex soil-structure interaction, which needs interaction between structure engineer and geotechnical engineer for giving most economical and safe design of the system. This paper reveals the performance of piled raft foundation in sandy soil, clayey soil and, layered soil carried through experimental and numerical analysis.

Shukla S.J., Desai A.K., Solanki C.H. et. al.[4] reported that a piled raft foundation is a combination of a shallow foundation and a deep foundation with the best characteristics of each of its components. The piled raft foundation is a composite construction consisting of three bearing elements, piles, raft and subsoil. Unlike the traditional design of foundation where the load is carried either by the raft or by the piles, in the design of a piled raft foundation the load share between the piles and the raft is taken into account. In this foundation the piles usually are not required to ensure the overall stability of the foundation but to reduce the magnitude of settlements, differential settlements and the resulting tilting of the building and guarantee the satisfactory performance of the foundation system. The bearing behaviour of a piled raft foundation is characterized by complex soil-structure interactions (Katzenbach et al. 1998). The modelling of these interactions requires a reliable and powerful analysis tool, such as the Finite Element Method in combination with a realistic constitutive law. Different researches have been realized investigations about the numerical modelling of piled rafts with FE analysis and different constitutive models. The present research combines the 3D modelling with a modern and realistic constitutive model. An increasing number of structures, especially tall buildings are founded on piled rafts (O'Neil et al. 1996; Katzenbach et al. 2000, Poulos 2001). For this reason, it is important to develop a methodology to study the bearing behaviour of piled rafts. In this paper different parameters of piled raft foundation like diameter of the piles, thickness of rafts, are discussed. It is incorporated with computational modelling of piled raft foundation. In this research work the analysis was carried out for 25 storey building with 3 different types of sub soil: - medium dense sand (ϕ-soil), clayey sand(c- ϕ soil) and clayey soil(c-soil). The FEM modelling was carried out with Winkler's approach with different elasto-plastic spring which represents soil elements with different modulus of sub-grade reaction and study was carried out for time history analysis. In area of research work for static gravitational loading, it was observed that for the first 3 modes, c soil gives highest time period and ϕ soil gives lowest time period. As c soil reflects more flexibility and structure behaves with more flexibly. In case of dynamic analysis, three time histories were applied at the base of the footing with different duration and PGA. In which Bhuj time history was with highest time period and highest PGA where as El-centro time history was with lowest duration and lowest PGA.

Shukla S J, Desai A K, and Solanki C H et al. [5]. reported that a piled raft foundation is a combination of a shallow foundation and a deep foundation with the best characteristics of each of its components. The piled raft foundation is a composite construction consisting of three bearing elements, piles, raft and subsoil. Unlike the traditional design of foundation where the load is carried either by the raft or by the piles, in the design of a piled raft foundation the load share between the piles and the raft is taken into account. In this foundation the piles usually are not required to ensure the overall stability of the foundation but to reduce the magnitude of settlements, differential settlements and the resulting tilting of the building and guarantee the satisfactory performance of the foundation system. The bearing behaviour of a piled raft foundation during earthquake is characterized by complex soil-structure interactions (Katzenbach et al. 1998). The modelling of these interactions requires a reliable and powerful analysis tool, such as the Finite Element Method in combination with a realistic constitutive law. As the inclusion of study of soil structure interaction is very important in case of high rise building, in this paper an attempt is made to study the behaviour of 25 storey building resting on different types of subsoil with piled raft foundation system during earthquake. The full scale finite element modelling of a 25 storey building supported with piled raft foundation have shown that effect of sub soil on the behavior of the structure is very significant. It has been observed that building support been observed that cohesion less (dense sand) give minimum acceleration response ted with dense sand gives minimum displacement in x direction for both pile length l = 15 m and l = 30 m. For acceleration response, six numbers of points through the length of the structure have been selected and acceleration response on all the points analysed. It has and time period for all the selected height. Overall it have been concluded that piled raft foundation with dense sand type of subsoil was a very good combination for good bearing behaviour of the structure.

A. **Kumar, D. Choudhury, R. Katzenbach et al.** [6] reported that the effect of pile head connection condition on the behaviour of Combined Pile-Raft Foundation (CPRF) by using finite element based geotechnical program PLAXIS3D is investigated. The finite element model is first validated with experimental results from available literature. Thereafter, the responses of CPRF in terms of settlements, normalized bending moments ($M/Mmax$) and normalized lateral displacements (u/D) under available input earthquake loadings, like 2001 Bhuj, 1989 Loma Prieta and 1995 Kobe are studied. Results show that connection condition has little influence on settlement under vertical load alone whereas load sharing by raft varies from 30% for hinged connection to 54% for rigidly connected CPRF model. Under the application of lateral load including various earthquake loads, raft mobilizes ultimate resistance at faster rate compared to pile irrespective of connection rigidity. Connection rigidity played an important role in bending moment variations, lateral displacements and rotations. In the present study, series of modelling and analyses of raft foundation alone, CPRF-H and CPRF-R were carried out by using PLAXIS 3D. The numerically obtained results simulated the experimental results both quantitatively and qualitatively which validates the present numerical model. It was observed that pile head connection condition had little influence on vertical settlement under application of vertical load alone. However, it was noted that connection condition played an important role in load sharing between foundation components where raft shared 30% to 54% of total load depending on connection rigidity. Load sharing by raft decreased with increase in horizontal load and corresponding displacement, it became nearly constant at higher load because of faster mobilization of raft resistance to its ultimate value. This phenomenon was observed irrespective of connection rigidity which is unlike the case of bending moment variations. It was also observed that piles in CPRF-H experience more lateral displacement when compared with piles in CPRF-R. CPRF-R undergoes more inclination as compared to CPRF-H case and varies in proportion to the lateral displacement. This may be due to flexibility of the connection condition in reducing rotation.

Nirmal John Joy, Hashifa Hassan et. al. [7] reported that the Combined pile raft foundations provide an economical foundation option for circumstances where the raft foundation can satisfy the bearing capacity requirement but fails to keep differential as well as maximum settlement below the maximum allowable limit. It had been established that augmenting features like thickness of raft, length of piles etc has decreased the settlement of raft and on other hand: decreasing 'spacing/depth' of piles has increased settlement of raft. In this paper permuted arrangement of piles were adopted rather than a uniform arrangements; such that an improved performance of CPRF system can be envisioned. In this paper CPRF is analysed using Finite Element Software PLAXIS 3D with permuted arrangement of piles. Three different Pile diameters and its combinations were modelled and analysed. For the study a 10 storey building founded on Medium Dense Sand was analysed in STAAD.Pro Software to determine the loads to be transferred, after fixing dimensions of raft and settlement analysis of raft PLAXIS 3D work programme was composed. Piled Rafts with various combinations of piles were modelled and analyzed. From the comparison of results, it has been found out that; installing high capacity piles at region with maximum load concentration and reinforcing the rest of the raft with medium capacity piles have the most important effect on significantly reducing maximum settlement and the differential settlement. A few general trends in the behaviour of piled rafts have been studied during this investigation. Thus, from our study on settlement characteristics of combined pile raft foundation founded on sand with various arrangements of piles using Plaxis-3D following points can be concluded, from the results obtained, it is advisable to provide piles with different diameter than with equal diameter irrespective of soil type, from all the possible diameters, it is best to provide larger diameter piles in the interior region to reduce the maximum settlement and the differential settlement. The piles configurations in raft have the most important effect on significantly reducing maximum settlement and the differential settlement, particularly by concentrating the piles in the centre of raft.

Therefore by carefully combining these factors maximum economy can be achieved; save for the choice should be done such that maximum economy can be achieved. That is based on availability of materials, labour cost, time, amount of settlement reduction required etc. Those cases are subjective to the engineering judgment of the designer which includes the knowledge of geotechnical and structural aspects of Combined Pile Raft Foundation. Thus we can say that Combined Pile Raft Foundation has a better scope for both research and applications in the field. This paper will give an idea for designers and practitioners about benefits of using different combination of piles in raft.

Dinachandra Thoidingjam, Dr.D S V Prasad , Dr. K.Rambha Devi et. al. [8] reported that In the valley area of IMPHAL in Manipur, organic clay are often encountered in the substrata of the soil which often creates problem in construction. These soils are characterized by low bearing capacity and high compressibility. A pile-raft foundation can be used to reduce the settlements caused by concentrated building loads. This study is mainly aimed to study the influence of spacing of piles and raft width on the behaviour of the pile raft foundation in organic clay. Tests were conducted on rafts of size 100x100mm and 200x200mm of thickness 2mm. The numbers of piles were varied at 1, 4 and 9 and from the test results the ultimate bearing capacity of Piles will be increased and the settlement of Pile is reduced as the diameter of Pile increases. It is obtained that the settlement in the pile group standing alone are fast in settling in the beginning and reduced after some loading, but in case of raft alone slow settlement is observed. It has been observed that piled raft foundation concept has significant advantages in comparison to conventional foundation for some soft clay. The ultimate bearing capacity of Piles will be increased and the settlement of Pile is reduced as the diameter of Pile increases. It is obtained that the settlement in the pile group standing alone are fast in settling in the beginning and reduced after some loading, but in case of raft alone slow settlement is observed. The piles take a major portion of total load at the initial stage of loading, but after yielding, a considerable portion of total load is transferred by the raft. The settlement of raft depends on raft thickness; increasing the thickness of the raft the settlement reduction can be noticed. The settlement reduction ratio (immediate) of a piled raft decreases with increase in pile to raft area ratio as well as pile slenderness ratio. This analysis may be useful in design of piled raft in soft consolidating, organic, clayey soil. The settlement reduces when the slenderness ratio s/d reduces. The increase in number of piles in a piled raft foundation results in increase in ultimate bearing capacity and decrease in settlement.

Jaymin D Patil, Sandeep A Vasanwala, Chandresh H Solanki et. al. [9] reported that an experimental program in laboratory is conducted on model piled rafts in sand soil. The aim of the experimental program is to study the behaviour of piled raft foundation system subjected to vertical load. The experimental program includes the model test on un-piled raft, raft supported by single pile, (2x2) and (3x3) pile groups. The model piles used in this test are non displacement piles. In the laboratory test, model mild steel piles of diameter 10mm and length 200mm were used, represents slenderness ratio, L/D of 20. The raft was made of mild steel plate with plan dimensions of 160mm x 160mm with different thicknesses of 5mm, 10mm and 15mm. The refinement in the bearing capacity is represented by load improvement ratio and the reduction in settlement is represented by settlement reduction ratio. The influence of number of piles and raft thickness on load improvement ratio and settlement reduction ratio are presented and discussed. The results of the tests show that as the number of piles underneath the raft increases, load improvement ratio and settlement reduction ratio increase and percentage of load carried by the raft decreases. Also, there is a negligible effect on load improvement ratio and settlement reduction ratio with increase in raft thickness, while raft thickness has a minimal effect on the load carried by the raft. This paper has presented experimental results of small scale laboratory model test on sand, to investigate the load-settlement behaviour and load sharing between the piles and raft. From the results of this study, the following conclusions can be drawn: 1) The load bearing capacity of piled raft increases as the number of piles beneath the raft increases, 2) Load improvement ratio increases at 10mm and 20mm settlement, as the number of pile increases, 3) The raft thickness has insignificant effect on the settlement and the loading sharing between piles and raft, 4) The efficiency of piled raft foundation system in reducing settlement is minimal beyond a certain number of piles.

S.J. Shukla, Dr.A.K.Desai, Dr. C.H.Solanki et. al.[10] reported that the use of piled raft foundations has become more popular in recent years, as the combined action of the raft and the piles can increase the bearing capacity, reduce settlement, and the piles can be arranged so as to reduce differential deflection in the raft. Piled raft foundation is a new concept in which the total load coming from the superstructure is partly shared by the raft through contact with soil and the remaining load is shared by piles through skin friction. A piled raft foundation is economical compared to the pile foundation. Because piles do not have to penetrate the full depth of clay layer but it can be terminated at higher elevations. Such piled raft foundation undergoes more settlement than the pile foundation and less settlement than the raft foundation. In this paper the author has study different parameters like size of the raft, thickness of the raft, diameter of the piles, length of piles, configuration of piles stiffness of raft and piles etc., which affect the behaviour of piled raft foundation. And its interdependency is also reviewed. This study is useful to decide the various parameters required in the design of piled raft foundation. From the literature review it has been studied that In comparison to shallow (raft) foundations, piled rafts reduce effectively the settlements, the differential settlements and the bending moment proportionally in tall buildings. To reduce the differential settlement and moment the piles should be place strategically using some trial and error or using parametric study. In more the soil structure interaction of piled raft foundation also play a vital role in the behaviour of tall building resting on piled raft foundation . The problem can be analysed by use of the finite element method where appropriate shell elements can be used for modelling the raft. Beam elements can be used for modelling piles. The soil around the piled raft system can be conveniently modelled as spring elements.

R.Radhika, S.P.Jeyapriya and P.Soundrapandiyan et. al.[11] reported that the design and construction of foundations on soft ground have posed various problems to geotechnical engineers, such as excessive settlement and bearing capacity failure. Though raft and pile foundations on such soils are found to be a solution to these problems, the combinations of raft and piles are adopted in the recent years, which are termed as piled rafts. This study is aimed at to investigate the performance of piled raft in soft clay by varying length of piles with three different configurations and to study the load – settlement behaviour of un-piled raft and piled raft. In the present work, laboratory model tests were conducted on both un-piled and piled raft on soft clay. The model tests include the use of un-piled raft and piled raft of three configurations namely 1x1, 2x2 and 3x3 with varying Slenderness Ratio of 23, 27 and 30. The results proved that ultimate load has increased and the settlement has reduced which is expressed by Load Improvement Ratio (LIR) and Settlement Ratio (SR). Parametric study showed that reduction in settlement takes place due to increase in pile length as well as with increase in number of piles. Among the tested footing models, the maximum length of pile of 180mm with piled raft of 3x3 group showed 67% increase in ultimate load and 83% reduction in settlement compared to that of same pile configuration with pile length of 140mm. The observed settlement values from experimental study was compared with numerical modelling using PLAXIS 2D and found that the results are in good agreement.

The study has been undertaken to investigate the behaviour of raft and piled raft model footing placed on soft clay. Based on the results, the following conclusions are drawn. The ultimate load for un-piled raft was found to be 355N and increased to 436N, 571N, and 685N respectively for piled raft with single pile of length 140mm, 160mm and 180mm. The addition of small number of piles beneath the raft increases the ultimate load of piled raft, and this enhancement effect increases with increase in number of piles as well as with increase in l/d ratio. Settlement reduces with increase in length and number of piles. The percentage reduction in settlement was found to be significant when the number of piles increased from 1 to 9 in each piled raft configuration. Parametric study reported that with increase in length and number of piles, Load Improvement Ratio (LIR) increases and Settlement Ratio (SR) reduces. Numerical simulation using PLAXIS 2D reported settlement values which are very close to the experimental results.

Reza ZIAIE_MOAYED , Meysam SAFAVIAN et. al.[12] reported that Piled-raft foundations for important high-rise buildings have proved to be a valuable alternative to conventional pile foundations or mat foundations. In pile raft foundation when we don't calculate the contact effect of raft we say that conventional pile raft foundation. The concept of using piled raft foundation is that the combined foundation is able to support the applied axial loading with an appropriate factor of safety and that the settlement of the combined foundation at working load is tolerable. Pile raft foundation behaviour is evaluated with many researches and the effect of pile length; pile distance, pile arrangement and cap thickness are determined under vertical or horizontal static and dynamic loading. In the present paper the behaviour of pile raft foundation with different pile diameters are evaluated under unequal vertical loading. The obtained results showed that the total and differential settlements of pile raft foundation could be reduced with using piles with different diameters. This paper presents the results of finite element analysis of piled raft foundation system on gravely soil in the four following cases:
1) Raft only, 2) Pile raft with the same pile diameter, 3) Pile raft with different diameter of piles, 4) Conventional piled-raft system
The investigation results are concluded as follows: The total and differential vertical settlement of piled raft foundation is less than that of the conventional raft foundation and it is less than individual raft foundation. For the same number of piles use of the pile raft system with different diameter of piles increases the load carrying capacity and decreases the vertical settlement. The piled raft foundation with different pile diameter may be considered as a suitable option to reduce total and differential settlement when the applied loads are different. In conventional pile raft foundation only piles carrying the applied loads and the raft hasn't effect in carrying loads. Thus in this system, vertical settlement is more than piled raft foundation

Rahul Solanki, Sagar Sorte et al.[13] reported that it was found out that connected pile raft foundation (CPRF) helps in reducing differential settlement and to some extent overall settlement by locating piles strategically beneath the raft. Unconnected pile raft foundation (UCPRF) as described by Al Ataa et al [2] is also reviewed. He observed that cushion helped in distribution of load beneath the raft. Favourable conditions for UCPRF are similar to that of CPRF. But UCPRF was found relatively less effective (depending on different conditions) foundation system. Author proposes a future scope of combination of CPRF and UCPRF as effective and economical foundation system. Further analysis may be carried out to investigate whether a combination of UCPRF and CPRF proves to be economical. By providing connected pile system at a critical location (critical location is to be identified through modelling or other appropriate method), the differential settlement can be reduced. To reduce overall settlement, cushion of higher thickness with relatively higher modulus of elasticity shall be provided. But if we opt for higher elastic modular cushion the section tends to be uneconomical. So combination of two or more different materials (thus different elastic modulus) shall be used. Geo-foam instead of soil can be used and should be investigated for economy. Figure 5 depicts hypothetical general case of how combination of CPRF and UCPRF. In the figure 5 only central portion is considered as a critical portion.

Er.Nilay BNaik, Dr Atul K Desai et al.[14] reported that the last two years have seen the start of many mega construction projects in India, which include several skyscrapers having more than 40 floors and several more than 150m tall. Their foundation types may be very much different depending on the structural loading and subsurface conditions. In recent years, there have been an increasing number of structures using piled rafts as the foundation to reduce the overall and differential settlements. For cases where a piled raft is subjected to a non-uniform loading, the use of combined pile-raft can improve the performance of the foundation. Computer aided finite element coding is done by sap2000 v14 for analysis of different foundation system with inclusion of varying soil parameters with respect to different soil layers. For piled rafts embedded in layered soil, the modulus of each layer of soil is used in the computation and accurate solutions are obtained without the use of an averaging technique. Considering Soil-Structure interaction (SSI) makes a structure more flexible and thus, increasing the natural period of the structure compared to the corresponding rigidly supported structure. This effect is also repeated in Time History analysis in which calculated acceleration at 0.5h and 1h (top of the structure) is less compared to rigidly supported structure. Thus considering the SSI reduces the acceleration. Acceleration at top portion of the structure is more compared to lower portion of structure in both SSI and NON-SSI. While comparing piled raft foundation with conventional raft foundation for static load case, settlement ranges from 13.5mm to 19.5mm in raft foundation and 0.3mm to 0.4mm in piled raft foundation. Differential settlement is found to be 4mm in raft foundation while Piled raft foundation shows no sign of differential settlement. Calculated values suggested that there is a tilting of foundation in raft foundation for lateral static load case while for same load case no tilting of foundation is observed in piled raft foundation. For dynamic load case, Uplift is observed in raft foundation though the amount of uplift is very small. There is no uplift observed in piled raft foundation. Horizontal deflection at top of the super structure is more in raft foundation than the piled raft foundation for dynamic case. Thus piled raft foundation controls the top detection more efficiently than raft foundation.

3. DISCUSSIONS

This review paper on piled raft foundation postulates that considerable research, either experimentally or theoretically has been conducted on the behaviour of piled raft foundation. Significant contributions have been made to learn the different aspects of piled raft foundation. Most of these models reckon on arduous analytical and numerical methods. The plate on spring, 2D finite element analyses and hybrid approach are incompetent of analyzing the torsion behaviour and material alteration in third axis. Therefore 3D finite element method is the most competent to replicate the complex behaviour of piled raft foundation.

It was found from literature review that finite research has been committed to evolve simple analysis models and design methods. A number of 3D numerical models have been developed but no effort is found to evolve analytical method based on numerical methods. Analytical methods were stated only to access the settlement of the piled raft foundation but the forecasting of differential settlement and ultimate bearing capacity is yet to be done. Therefore further studies are required to evolve simple analysis and design methods. Prediction of load sharing between piles and raft in piled raft system are required at preliminary design stage. The need for developing simple analysis and design models for piled raft foundations has been recognized by many workers in this field.

4. CONCLUSIONS

On looking into the above research papers on piled raft foundation postulates that considerable research, either experimentally or theoretically has been conducted on the behaviour of piled raft foundation. Significant contributions have been made to learn the different aspects of piled raft foundation. Most of these models reckon on arduous analytical and numerical methods. The plate on spring, 2D finite element analyses and hybrid approach are incompetent of analyzing the torsion behaviour and material alteration in third axis. Therefore 3D finite element method is the most competent to replicate the complex behaviour of piled raft foundation. It was found from literature review that finite research has been committed to evolve simple analysis models and design methods. A number of 3D numerical models have been developed but no effort is found to evolve analytical method based on numerical methods. Analytical methods were stated only to access the settlement of the piled raft foundation but the forecasting of differential settlement and ultimate bearing capacity is yet to be done. Therefore further studies are required to evolve simple analysis and design methods. Prediction of load sharing between piles and raft in piled raft system are required at preliminary design stage. The need for developing simple analysis and design models for piled raft foundations has been recognized by many workers in this field. Piles of different diameter with different sizes are considerably used in order to reduce the total and differential settlement.

5. Future Scope

Piles of different diameter with different sizes are considerably used in order to reduce the total and differential settlement. Different arrangements of piles along with raft can be used in order to get the best combination of less pile with high bearing capacity and ultimately reduces the costing of piling. By providing connected pile system at a critical location (critical location is to be identified through modelling or other appropriate method), the differential settlement can be reduced. To reduce overall settlement, cushion of higher thickness with relatively higher modulus of elasticity shall be provided. But if we opt for higher elastic modular cushion the section tends to be uneconomical. So combination of two or more different materials (thus different elastic modulus) shall be used. Geo-foam instead of soil can be used and should be investigated for economy. Fig 5 depicts hypothetical general case of how combination of CPRF and UCPRF. In the figure only central portion is considered as a critical portion.

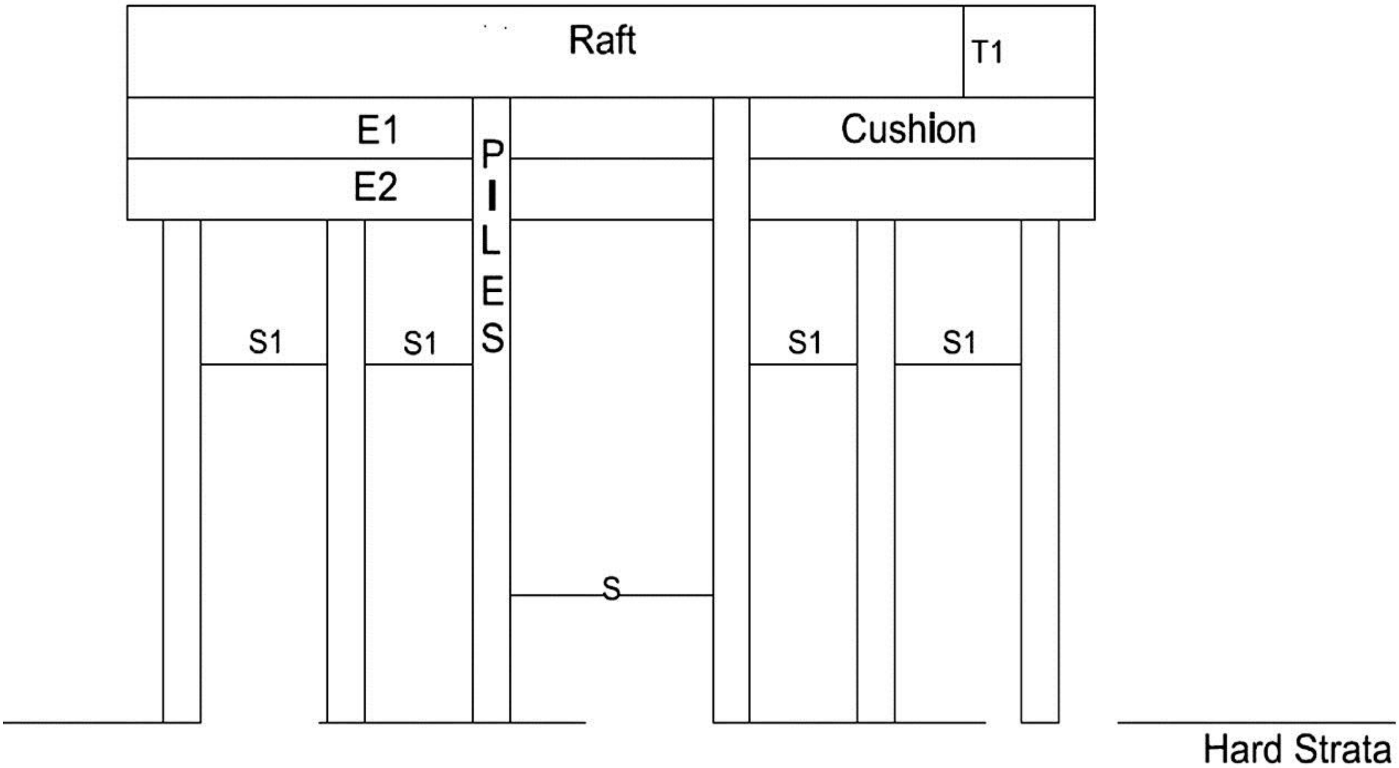

Fig-1: Suggested system of combine CPRF

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