Comparative Study on RCC Raft Foundation and Prestressed Concrete Raft Foundation for Multistory Building

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***Abstract*—The use of raft foundations has increased in recent years as they are considered suitable and economical for multistory and high-rise structures constructed on soils with low bearing capacity. In a mat foundation, loads transferred from the superstructure are uniformly distributed over the soil surface, making it effective for weak soil conditions. Such foundations are capable of carrying heavy vertical loads and help in controlling total settlement, differential settlement, and overturning of structures within permissible limits. The raft/ mat foundations are generally constructed as reinforced concrete slabs that support and transfer structural loads safely to the underlying soil while reducing differential settlement. In addition, the application of post-tensioning techniques has been increasing due to their structural advantages. The use of post-tensioning enables achievement of required structural performance with reduced member size, making it an economical alternative without compromising structural stability. In developing countries such as India, the advantages of prestressing, particularly post-tensioning, are yet to be fully recognized. Considering the significant benefits of post-tensioned systems compared to conventional reinforced concrete structures, the present study attempts to compare the structural behavior and efficiency of post-tensioned raft (mat) foundations with reinforced concrete raft foundations. Both systems are analyzed using SAFE and ETABS software based on the design methodologies. The study aims to evaluate the performance and economic feasibility of both foundation systems for multistorey building applications under similar loading and soil conditions.**

***Index Terms*—Post-tensioned (PT), Reinforced Concrete (RCC), Raft (Mat) Foundation, Multistorey Buildings, Structural Performance, SAFE Software, ETAB Software, Foundation Design, Settlement, Soil Bearing Capacity.**

I. INTRODUCTION

Rapid urbanization and the increasing demand for multistorey and high-rise buildings have led to the construction of structures on sites possessing low to moderate soil bearing capacity. In such conditions, raft foundations are widely used as they distribute structural loads uniformly over a large area, thereby reducing excessive settlement. Conventionally, the RCC raft foundations are extensively used due to their simplicity in design and construction. However, RCC systems often result in increased structural self-weight with larger member thickness, higher reinforcement requirements, and greater material consumption, especially in heavily loaded multistorey buildings. These limitations lead to higher construction costs and increased foundation stresses transmitted to the supporting soil. Whereas, prestressing techniques, particularly post-tensioning (PT), have gained significant attention in modern structural engineering. Post-tensioning introduces compressive stresses into concrete members, which counteract tensile stresses induced by external loads. This mechanism enhances load-carrying capacity, controls cracking, reduces deflections, and allows reduction in member size and thickness without compromising structural safety. Consequently, PT systems contribute to improved structural efficiency, reduced material usage, and overall cost optimization. While post-tensioning has been widely implemented in floor systems and bridge structures, its application in foundation systems remains comparatively limited, particularly in developing countries such as India. Incorporating prestressing benefits into raft foundations has the potential to reduce foundation thickness, minimize reinforcement demand, and improve overall structural performance under service and ultimate loading conditions. The present study focuses on implementing prestressing concepts in raft foundation systems by adopting post-tensioned raft foundations and comparing their structural behavior with conventional RCC raft foundations. Analytical modeling and design are carried out using ETABS and SAFE software to evaluate parameters such as bending moments, settlements, uplift deflection characteristics, and reinforcement requirements. The study aims to assess the feasibility and structural effectiveness of post-tensioned raft foundations as an efficient alternative for multistorey building construction.

II. REVIEW OF LITERATURE

Several researchers have performed comparative investigations between post-tensioned (PT) and reinforced concrete (RCC) structural systems focusing on structural efficiency and economic performance. Post-tensioned (PT) systems have been widely investigated as an alternative to conventional reinforced concrete (RCC) construction for improving structural efficiency and economy in multistorey buildings. Omar Ahmad (2022) [1] carried out a financial comparison between PT and RCC flat slabs using M30 and M25 concrete grades respectively and reported that reduction in slab thickness from 32 cm to 26 cm made PT slabs more economical. Soubhagya Ranjan Rath et al. (2019) [2] performed modelling using ETABS and SAFE and observed reduction in concrete quantity and nearly 60% lower slab forces in PT systems, although slightly higher storey drift occurred due to flexibility. Similarly, P.V.L. Narasinga Rao et al. (2018) [3] showed that PT slabs achieved about 47.8% reduction in depth and nearly 15% cost savings compared to conventional two-way slabs. Jnanesh Reddy R.K. et al. (2017) [6] also reported considerable reduction in concrete and steel quantities in PT flat slab construction, resulting in economical multistorey commercial buildings. Further, Thayapraba M. (2014) [20] concluded through SAP-based analysis that PT floor systems require less concrete and remain cost-effective for increasing panel spans.

Performance of PT systems under service and seismic loading conditions has also been extensively studied. Osama Khalid Abdelaziz et al. (2021) [4] analysed G+12 buildings resting on raft foundations under seismic Zone III conditions and observed lower deflection and 25–37% reduction in construction duration for PT systems with spans exceeding 6 m. Shubham Nighot et al. (2020) [8] modeled a G+7 structure using ETABS and found that reduced slab thickness decreases beam and column requirements, thereby lowering material consumption. Ila Vamsikrishna et al. (2021) [5] reported reduction in bending moments between 58–66% along with decreased displacement and shear forces in PT slabs. Likewise, Vanteddu Satwika et al. (2021) [17] highlighted improved punching shear resistance and reduced support reactions due to dead-load reduction achieved through tendon balancing.

Studies focusing on material optimization and structural behaviour of PT systems indicate improved serviceability performance. Nyome Tin (2019) [16] compared PT and RC buildings and reported nearly 16% reduction in steel quantity, though overall project cost slightly increased due to prestressing operations. Maulik G. Kakadiya et al. (2016) [11] demonstrated through ADAPT-PT and ETABS analysis that PT slabs become more economical for panel sizes beyond 7 m with reduced reinforcement demand. Shubham R. Nikam et al. (2021) [18] evaluated RCC, flat slab, and PT systems under seismic zones III–V and observed higher displacement in PT structures but satisfactory performance within seismic limits.

Raft foundation behaviour and design have been investigated by several researchers using finite element analysis tools. Suman M. Sharma et al. (2014) [7] compared conventional raft and beam-slab raft foundations and concluded that beam-slab raft systems provide economical solutions while maintaining safety. Zia-abe Deen S. Punekar et al. (2017) [9] performed response spectrum analysis using ETABS and SAFE and confirmed raft safety against punching shear with permissible deflection limits. Nezar Hassan Mohamed et al. (2018) [19] verified through SAFE modelling that punching shear stresses remain within allowable resistance limits. Similarly, Joshna Manjareakar et al. (2018) [13] observed that reinforcement demand increases under dynamic loading, although displacement remains minimal.

Advanced foundation configurations have also been explored to improve settlement behaviour. Sunesra Shakira et al. (2020) [10] analysed raft and piled-raft systems and concluded that piled-raft foundations effectively reduce total and differential settlement. Amit Dhage et al. (2023) [14] further demonstrated that load sharing between piles and raft improves stiffness and reduces settlement, making piled-raft systems more economical than isolated raft or pile foundations.

Influence of soil properties on raft foundation performance was examined by Devesh Ojha et al. (2021) [12], who reported variation in bending moment and pressure distribution with changes in soil stiffness, while settlements remained within allowable limits. Nabanita Sharma et al. (2015) [15] emphasized the importance of geotechnical considerations in raft foundation design and highlighted soil shear behavior as a governing factor.

Performance-based raft foundation analyses were conducted by Harpreet Singh et al. (2023) [21], who evaluated uplift pressure, settlement, and long-term deflection using ETABS and SAFE and recommended adequate raft thickness to control creep effects. Harshil Vaghani et al. (2025) [22] confirmed acceptable settlement and soil pressure behaviour for raft foundations resting on soft soil conditions. Similarly, Aniket Patale et al. (2025) [23] analysed raft performance under seismic Zones II and V and observed settlements between 10–17 mm, remaining within permissible limits prescribed by IS codes.

Overall, existing literature demonstrates that post-tensioned systems significantly reduce the structural member size, self-weight, and material consumption, without compromising the structural stability while raft foundations effectively control settlement in multistorey buildings. However, limited research has focused on incorporating prestressing principles directly into raft foundations and evaluating their structural behaviour and performance under in comparison with conventional reinforced concrete (RCC) raft systems, which constitutes the objective of the present study.

III. OBJECTIVES OF THE STUDY

1. To analyze and design conventional Reinforced Concrete (RCC) raft foundation and Prestressed Concrete raft foundation for multistorey building under identical loading and soil conditions using SAFE software.
2. To evaluate and compare the structural behavior of RCC and prestressed raft foundations in terms of bending moments, shear forces, and stress distribution.
3. To study the variation in deflection and settlement characteristics between RCC raft and prestressed raft foundation.
4. To examine the effectiveness of prestressing in reducing foundation thickness.
5. To compare reinforcement demand and for both foundation systems.
6. To investigate punching shear performance and stability of RCC and prestressed raft foundations.
7. To assess soil pressure distribution and check uplift and tension conditions for both foundations.
8. To evaluate the material consumption of PT raft foundation with respect to conventional RCC raft foundation.
9. To determine the feasibility of prestressed raft foundation as an efficient alternative to RCC raft foundation for multistory structures.

IV. METHOD OF ANALYSIS

1. Selection of Structural Model

A suitable building plan will be selected and modelled using ETABS with identical loading conditions and base reaction exported to SAFE.

2. Soil Parameter Evaluation

Soil properties such as safe bearing capacity, modulus of subgrade reaction, and settlement characteristics will be assumed.

3. Analysis & Design of RCC and PT Raft

Both rafts will be analyzed and designed using SAFE software to determine structural behavior.

4. Settlement and Uplift Analysis

Settlement and uplift check will be done for similar loading and soil conditions.

5. Performance Comparison

Results obtained from analysis will be compared based on structural design and serviceability parameters.

6. Material Demand Analysis

Quantity of concrete and reinforcement steel, along with prestressing tendons will be compared for economic comparison.

V. STRUCTURAL MODELLING

A. Modelling of Super-Structure

Two plans have been selected for modelling multi-storey building in ETABS, non-symmetric as shown in Fig.1 and symmetric as shown in Fig.2.

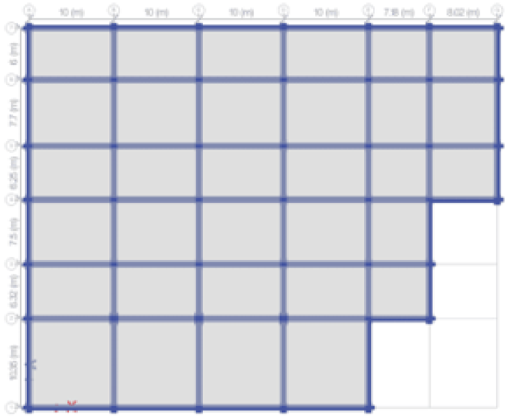

Fig. 1 Non-Symmetric Plan

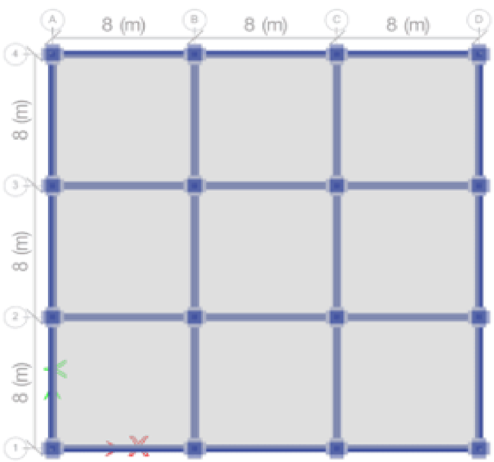

Fig. 2 Symmetric Plan

Both the structures have been modelled in ETABS as shown in fig.3, with similar material as well as loading considerations as per the following data,

Plan Type	Story	Concrete	Steel
Non-Symmetric	15	M-40	Fe-500
Symmetric	15	M-40	Fe-500

Post modelling and analysis, the base reactions have been exported to the SAFE. F2k file for proceeding with the foundation analysis and design for both types of structures.

B. Modelling of Sub-Structure

The substructure modelling in CSI SAFE focuses on

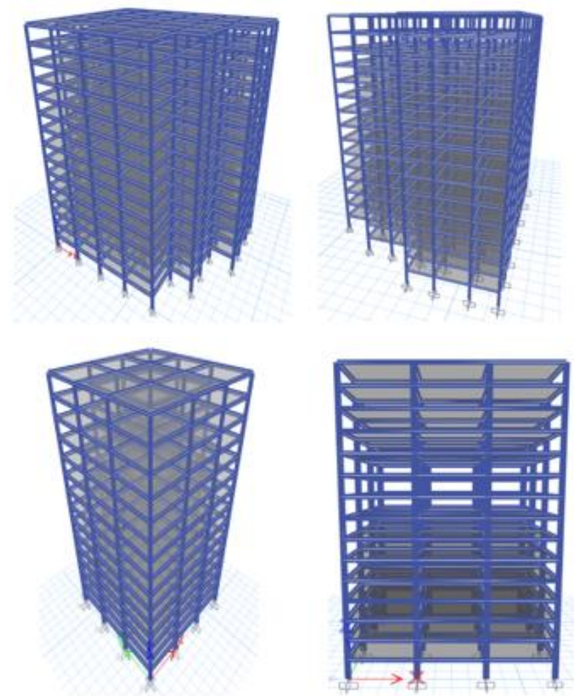

Fig. 3 ETABS 3-D Models of Non-Symmetric and Symmetric Super-Structures

accurate analysis and strip-based design of RCC and PT raft foundations for multi-storey buildings.

The soil properties adopted for analysis of both the raft foundations using SAFE are as per Table 1.

Table 1. Soil properties for raft analysis

Property	RCC Raft	PT Raft
SBC	40 T/m^2	40 T/m^2
Allow. Settlement	50 mm	50 mm
Subgrade Modulus	8000 kN/m^3	8000 kN/m^3

Modelling of RCC Raft Foundation –

Base reactions are imported from ETABS in SAFE software in F.2K text format. Geometry is defined by drawing raft slab matching building footprint. The modelling properties as well as material specifications are adopted as per Table 2.

Table 2. Properties of the RCC raft

Characteristics	Non-Symmetric	Symmetric
Thickness	1600 mm	1200 mm
Concrete	M50	M50
Steel	Fe500	Fe500

Loading considerations are auto generated through imported F.2k file of ETABS. Further the design strips are drawn and assigned in X direction as Layer-A and Y direction as Layer-B with program calculated strip width.

The soil properties are assigned to base mat as per details mentioned in Table 1. Analysis and design command has been initiated to obtain results.

Modelling of PT Raft Foundation –
Similar process of modelling is followed as discussed above for RCC raft. But the properties considered in case of PT raft are as per Table 3.

Table 3. Properties of the PT raft

Characteristics	Non-Symmetric	Symmetric
Thickness	1500 mm	1000 mm
Concrete	M50	M50
Steel	Fe500	Fe500
Tendon Fy	1670 Mpa	1670 Mpa
Tendon Size	12.7mm strand wire with strand area of $99mm^2$	

However, the tendons are drawn in the column line adopting parabolic profile such that the tendon is lowered at column junction and raised up for the other part of raft. Additionally, tendons are considered to be fixed at one end and stressing is done at another end followed by analysis and design command.

The above analysis primarily emphasizes strip-based design procedures within CSI SAFE for RCC and post-tensioned raft foundations, incorporating loads transferred from ETABS superstructure models to precisely understand foundation behavior across similar loading and soil considerations. This study allows assessment of factors like soil pressure variations, total and differential settlements, two-way shear resistance, and reinforcement requirements according to IS 456:2000 and IS 1343 standards.

VI. RESULTS AND DISCUSSION

The results present the investigation of structural behavior and performance comparison between Reinforced Concrete (RCC) raft foundation and Prestressed Concrete (PT) raft foundation subjected to identical loading and soil conditions with symmetric as well as non-symmetric layout of raft.

1. Punching Shear

The punching shear behaviour of the raft foundation was evaluated to examine the critical stress concentration around column locations. The comparison between RCC and Prestressed Concrete raft foundations for symmetric as well as indicates the variation in shear resistance and structural capacity under applied loading conditions.

For non-symmetric RCC raft, the thickness of mat required is 1600 mm ass shown in Fig 4, whereas thickness required for PT raft is 1500mm as per Fig 5.

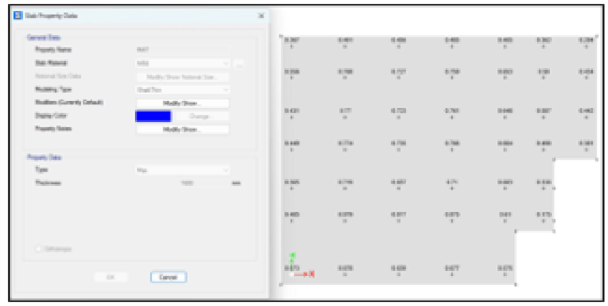

Fig. 4: Punching shear for non-symmetric RC raft

Also, as per Fig. 6, for symmetric layout, RCC raft

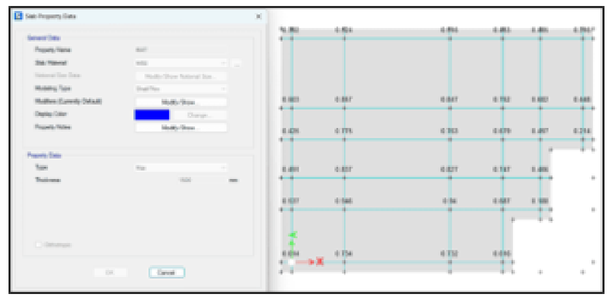

Fig. 5: Punching shear for non-symmetric PT raft

requires 1200mm thickness. But PT raft is comfortable with 1000mm of thickness as shown in Fig. 7

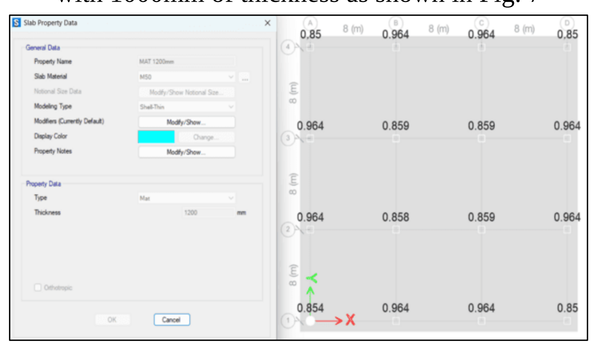

Fig. 6: Punching shear for symmetric RCC raft

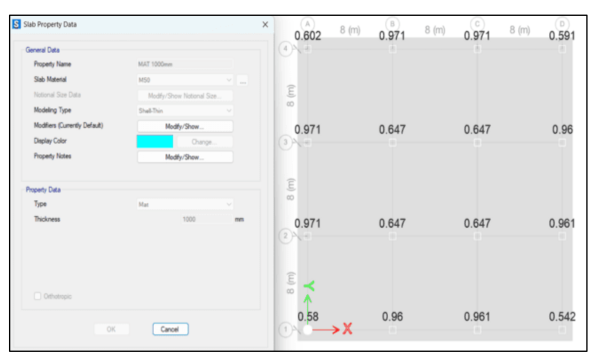

Fig. 7: Punching shear for symmetric PT raft

2. Settlement of Raft

Settlement analysis was carried out to study total and differential settlement characteristics of the raft foundation. The comparative results illustrate the influence of prestressing on reducing deformation and improving uniform load distribution over the supporting soil. Settlement in case of non-symmetric RCC raft is 33.3mm as shown in Fig8, whereas in non-symmetric PT 27.5mm is observed as per Fig 9.

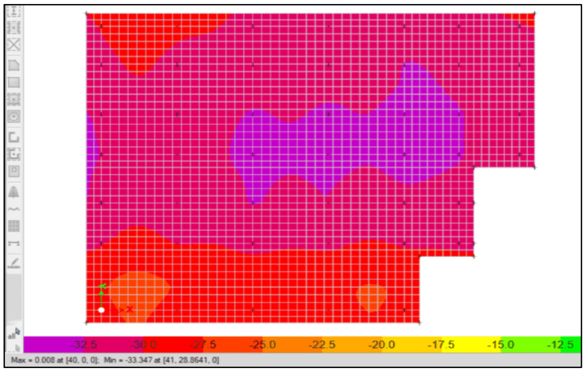

Fig. 8: Settlement for non-symmetric RCC raft

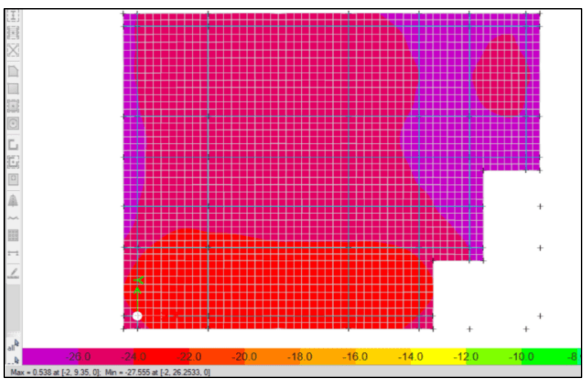

Fig. 9: Settlement for non-symmetric PT raft

Similarly for symmetric layout, the settlement of RCC raft is 23.35mm (Fig 10) which is more than the settlement observed in case of PT raft of 17.4mm only (Fig 11).

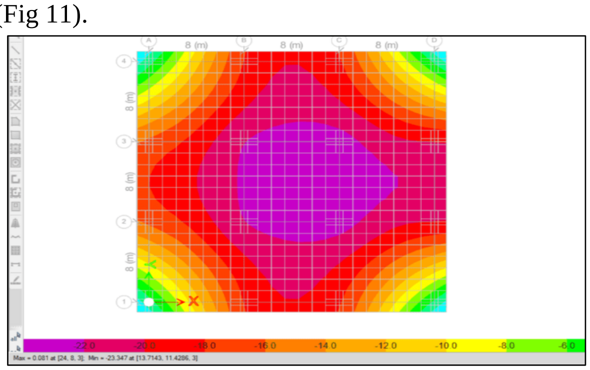

Fig. 10 Settlement for symmetric RCC raft

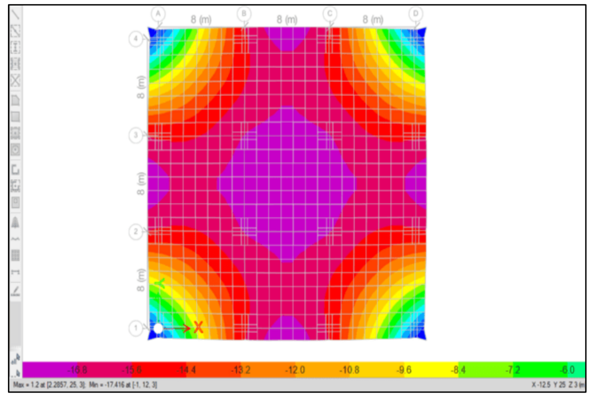

Fig. 11 Settlement for symmetric PT raft

3. Uplift on Raft

Uplift response of the foundation system was analyzed to assess stability against upward soil pressure. The results demonstrate the effectiveness of both systems in maintaining compressive contact pressure within permissible limits. The uplift in RCC raft for non-symmetric layout is negligible (Fig 12) whereas for PT raft, it is 0.5mm (Fig 13).

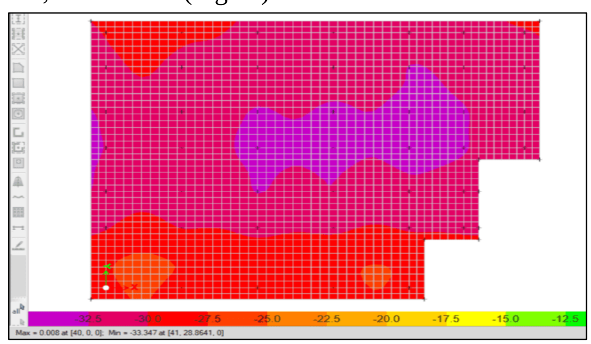

Fig. 12: Uplift for non-symmetric RCC raft

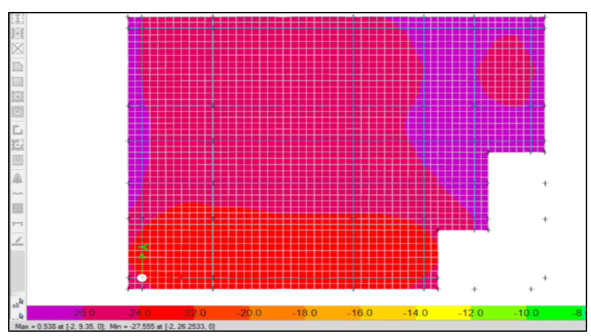

Fig. 13: Uplift for non-symmetric PT raft

Similarly, for symmetric layout in case of RCC, as per Fig. 14, uplift is again negligible and for symmetric PT raft, uplift of 1.2mm is observed as shown in Fig 15.

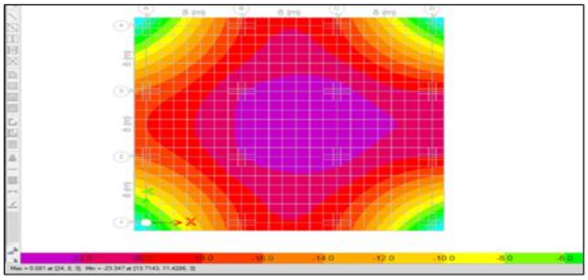

Fig. 14: Uplift for symmetric RCC raft

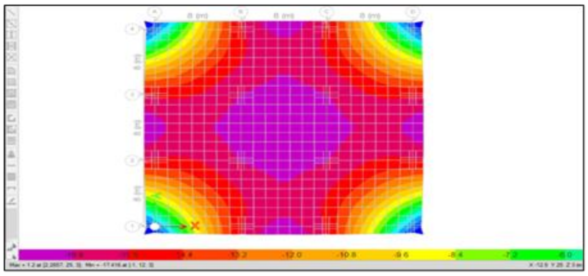

Fig. 15: Uplift for symmetric PT raft

4. Strip Forces

The strip forces comparison was performed to evaluate the distribution bending moments and shear forces along critical directions of the raft foundation. The comparison between RCC and Prestressed Concrete raft systems highlights that maximum strip forces are observed in case of RCC raft as compared to PT raft. The prestressing cables are withstanding the moments and shear which results in lower strip forces.

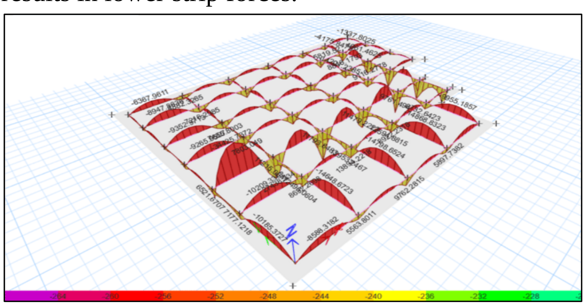

Fig. 16: Strip moments of non-symmetric RCC raft

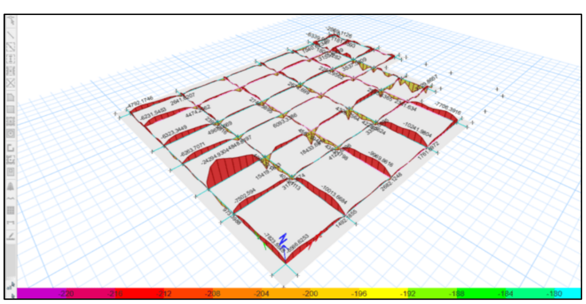

Fig. 17: Strip moments of non-symmetric PT raft

The strip bending moments for non-symmetric layout in case of RCC raft as shown in Fig.16 are on the higher side compared to PT raft bending moments as shown in Fig. 17.

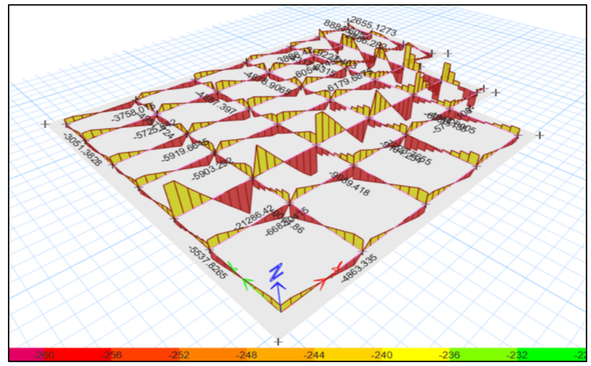

Fig. 18: Strip shear forces of non-symmetric RCC raft

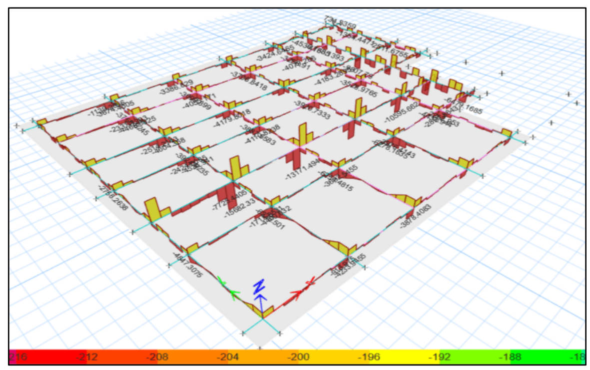

Fig. 19: Strip shear forces of non-symmetric PT raft

Similarly, the strip shear forces for non-symmetric layout in case of RCC raft as shown in Fig.18 are on the higher side compared to PT raft shear forces as per Fig. 19.

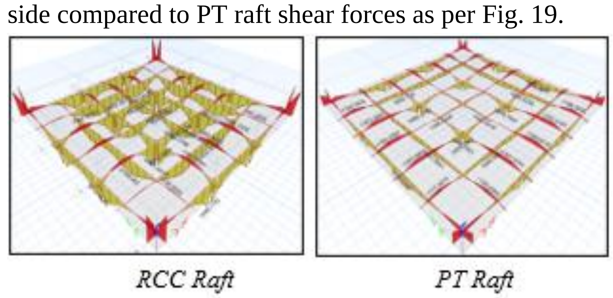

Fig. 20: Strip Bending Moments of symmetric plan

The strip bending moments in case of symmetric RCC raft are higher than those of PT for the areas below and near column faces as shown in Fig. 20. However, slight negative moment is observed in case of PT raft only in the midspan peripheral area which is due to load balancing action of prestressing tendons, that reduces moments in column regions through induced compressive forces. Consequently, redistribution of internal forces occurs, leading to slightly higher moments at midspan locations.

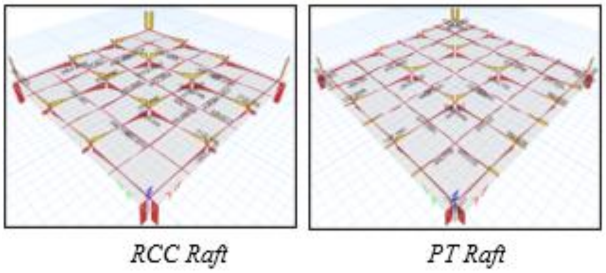

Fig. 21: Strip Bending Moments of symmetric plan

Similarly, the strip shear forces for RCC raft are on the greater side compared to PT raft shear forces as per Fig. 21, for symmetric geometry of foundation.

5. Soil Pressure

The results obtained from SAFE analysis present the distribution of contact soil pressure developed beneath the raft foundation for both RCC and prestressed concrete raft systems under applied loading conditions. The evaluated soil pressure contours indicate that the pressure distribution remains predominantly compressive throughout the raft area, thereby satisfying the no-tension criteria.

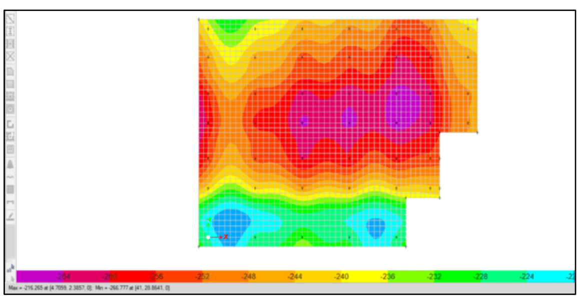

Fig. 22: Soil pressure for non-symmetric RCC raft

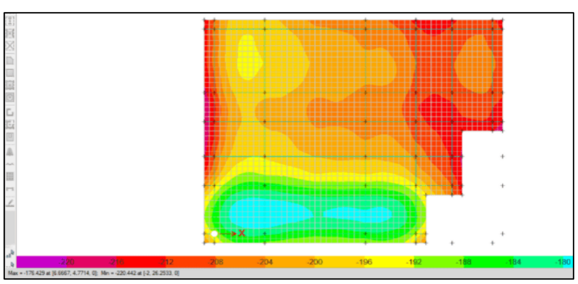

Fig. 23: Soil pressure for non-symmetric PT raft

The RCC raft exhibits comparatively high maximum soil pressure values as shown on Fig. 22 and Fig.24, due to greater self-weight and stiffness concentration, resulting in increased stress transfer to the soil. Whereas, the PT raft as per Fig. 23 and Fig. 25, shows relatively uniform soil pressure distribution owing to reduction in dead load and improved load balancing achieved through prestressing action.

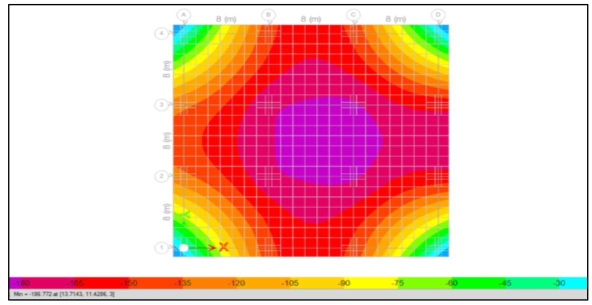

Fig. 24: Soil pressure for symmetric RCC raft

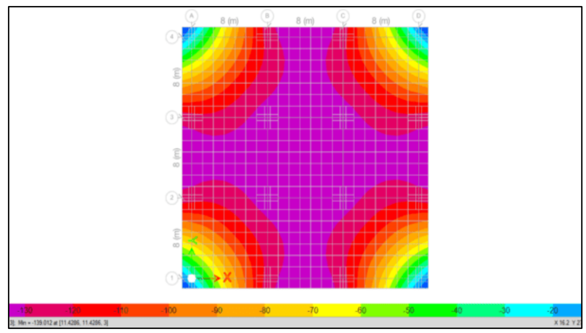

Fig. 25: Soil pressure for symmetric PT raft

Furthermore, the maximum and minimum soil pressure values in both symmetric and non-symmetric layouts remain within the permissible Safe Bearing Capacity (SBC) limits, confirming the adequacy and safety of the foundation system against bearing failure.

The improved pressure uniformity in the prestressed raft contributes to reduced differential settlement and enhances the overall foundation performance.

6. Reinforcement Demand

Reinforcement demand was assessed based on the design forces obtained from SAFE analysis for both foundation systems. The results indicate the influence of prestressing in reducing tensile stresses, thereby optimizing reinforcement requirements. From the Fig. 26 and Fig. 28, it is observed that reinforcement demand of RCC raft in both the layouts is much higher than that of PT raft foundation as shown in Fig. 27 and Fig. 29, for both symmetric as well as non-symmetric configurations.

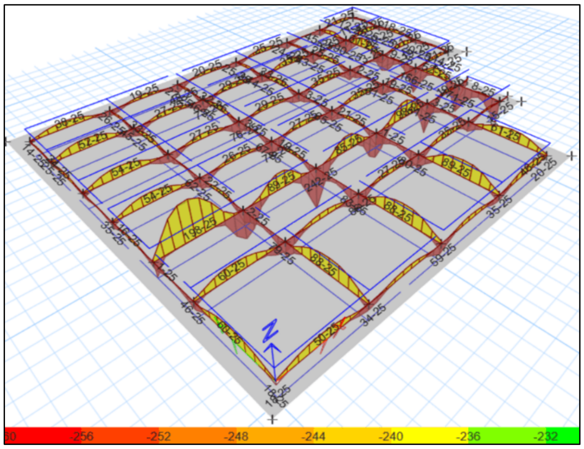

Fig. 26: Reinforcement demand for non- symmetric RCC raft

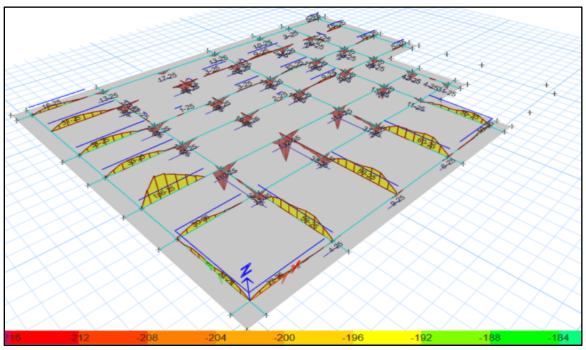

Fig. 27: Reinforcement demand for non- symmetric PT raft

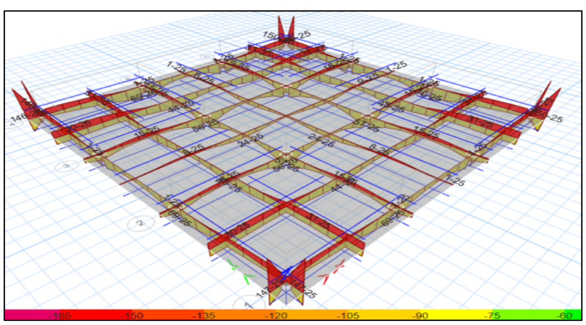

Fig. 28: Reinforcement demand for symmetric RC raft

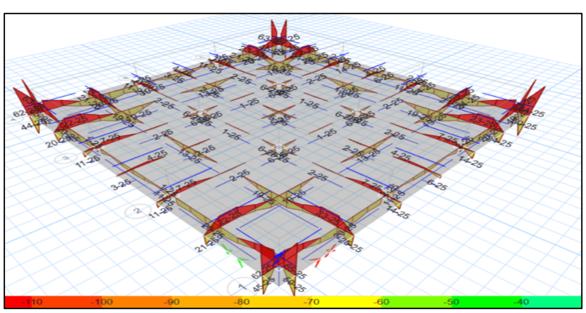

Fig. 29: Reinforcement demand for symmetric PT raft

VII. CONCLUSION

From the present studies following broad conclusions are drawn:

- The non-symmetric raft layout, RCC raft foundation demands thickness of 1600 mm, whereas the Prestressed Concrete (PT) raft satisfies punching shear requirements with a reduced thickness of 1500 mm. Similarly, in the symmetric layout, RCC raft requires 1200 mm thickness, while the PT raft performs adequately with only 1000 mm, indicating improved structural efficiency due to prestressing action.
- The uplift observed in the PT raft foundation for the non-symmetric layout is approximately 0.5 mm, while uplift in the RCC raft remains negligible. In the symmetric configuration, PT raft shows an uplift of 1.2 mm, whereas RCC raft again exhibits negligible uplift. However, the observed uplift values remain within permissible serviceability limits.
- Settlement Performance - For the non-symmetric layout, settlement in RCC raft foundation is 33.3 mm, whereas the PT raft shows reduced settlement of 27.5 mm. In the symmetric layout, RCC raft undergoes settlement of 23.35 mm, compared to settlement of only 17.4 mm in PT raft, demonstrating improved stiffness capability in prestressed concrete foundations.
- Strip Forces - RCC raft foundation experiences comparatively higher strip shear forces and bending moments due to conventional load-resisting behavior near column junction. Whereas, PT raft exhibits reduced internal forces as prestressing tendons effectively counterbalance applied loads and bending effects. However, a slightly high negative moment was observed in case of PT raft at midspan peripheral areas. This behavior can be attributed to the load balancing action introduced by prestressing tendons, which effectively reduce bending moments in column areas through induced compressive forces. Consequently, redistribution of internal forces occurs, leading to relatively higher negative moments at midspan locations. Additionally, the reduced thickness adopted in PT raft results in comparatively lower flexural stiffness, resulting in increased midspan moment response.

- The RCC raft foundation develops comparatively higher maximum negative soil pressure due to increased self-weight and stiffness concentration, leading to greater stress transfer to the supporting soil. Additionally, no significant positive soil pressure is observed in either system, satisfying the no-tension criteria for both raft configurations. The PT raft exhibits a more uniform soil pressure distribution as a result of reduced dead load and effective load balancing provided by prestressing action. Hence, the maximum and minimum soil pressure values for both symmetric and non-symmetric layouts remain within the permissible Safe bearing capacity (SBC) limits, confirming the safety of foundation against bearing failure.
- The RCC raft foundation requires significantly higher reinforcement in both symmetric and non-symmetric configurations to resist tensile stresses and bending actions. The PT raft system demands comparatively lesser reinforcement owing to induced compressive stresses, resulting in the reduction of overall steel demand.

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