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Engineering Significance of Annular Raft Foundations over Solid Raft Foundations

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***Abstract:** Raft foundations play a pivotal role in distributing structural loads to the underlying soil, thereby ensuring the stability and integrity of various civil engineering structures. The choice between different types of raft foundations, such as solid and annular rafts, significantly impacts the overall performance and durability of a structure. This paper explores the engineering significance of annular raft foundations in comparison to solid raft foundations. The traditional solid raft foundation offers uniform load distribution and settlement control; however, it often encounters challenges when dealing with non-uniform soil profiles, differential settlements, and expansive soils. Annular raft foundations, a relatively innovative approach, address these challenges by featuring a central void within the raft. This void introduces a controlled differential settlement mechanism, enabling the foundation to accommodate non-uniform soil conditions effectively. Moreover, annular rafts offer improved structural performance in regions prone to ground movements, as the central void allows the foundation to adjust to soil displacements more flexibly than a solid raft. The engineering significance of annular rafts extends to their enhanced load-bearing capacity and reduction in material usage compared to solid rafts. The design of annular rafts takes advantage of the arching effect within the void, which enables the foundation to support heavier loads while minimizing the amount of concrete and reinforcement required. This not only contributes to cost savings but also aligns with sustainable construction practices by reducing the environmental impact associated with excessive material consumption.*
***Keywords:** Solid Raft, Annular Raft, Settlement Influence Factor, Raft, Settlement of Raft*

I. INTRODUCTION

The selection of an appropriate foundation system is a critical decision in civil engineering, as it directly influences the overall performance and longevity of structures. Raft foundations, known for their ability to distribute loads uniformly and minimize differential settlements, have been a preferred choice for various types of structures [1-2]. However, the challenges posed by non-uniform soil conditions, expansive soils, and ground movements have led to the exploration of innovative foundation solutions that can better accommodate these complexities. One such solution is the annular raft foundation, which introduces a central void within the traditional solid raft configuration. This void alters the load distribution and settlement behaviour, offering distinct advantages in challenging soil environments and regions susceptible to ground movements [3-7]. In this manuscript, the engineering significance of annular raft foundations is compared to traditional solid rafts. By examining their differential settlement mechanisms, load-bearing capacity, and material efficiency, it is aimed to provide a comprehensive understanding of annular rafts address engineering challenges and contribute to more sustainable and effective foundation design [8]. Through a synthesis of theoretical insights, case studies, and numerical analyses, this manuscript sheds light on the promising potential of annular raft foundations and encourages their broader application in the field of civil engineering.

The performance of an annular raft foundation is influenced by several key features that distinguish it from traditional solid raft foundations [9]. These features contribute to its ability to address challenges posed by non-uniform soil conditions, differential settlements, and ground movements [10-12]. Here are the key features of annular rafts that significantly impact their performance:

1) *Central Void:* The central void is the defining feature of an annular raft foundation. It creates a ring-like or doughnut-shaped configuration within the foundation. This void allows controlled differential settlements to occur, enabling the foundation to adjust to varying soil stiffness and settlement rates across its footprint. The central void plays a pivotal role in minimizing differential settlements and mitigating potential structural damage that could result from non-uniform soil conditions [13-14].
2) *Load Distribution Mechanism:* Unlike solid raft foundations that distribute loads uniformly across their entire area, annular rafts distribute loads in a modified manner due to the presence of the central void. The load-bearing capacity of the annular raft is enhanced through the arching effect created within the void, allowing it to efficiently transfer loads to the surrounding soil while supporting heavier loads with less material [15].

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3) *Settlement Control:* The annular configuration of the foundation offers an innovative solution for controlling settlements [16]. The controlled differential settlement mechanism allows the foundation to settle differentially based on the soil's stiffness and settlement characteristics, reducing the risk of uneven settlement-induced structural distress.
4) *Adaptability to Soil Movement:* Annular rafts demonstrate superior adaptability to ground movements, such as those caused by soil subsidence, swelling, or seismic activity [17]. The central void enables the foundation to adjust to soil displacements more flexibly compared to a solid raft, thereby reducing the likelihood of structural damage.
5) *Stress Redistribution:* The presence of the central void changes stress distribution patterns within the foundation. This redistribution can lead to reduced stress concentrations, enhancing the foundation's resistance to bearing capacity failure and potentially improving its performance in dynamic loading conditions [18-19].
6) *Material Efficiency:* Annular rafts often require less concrete and reinforcement compared to solid rafts of the same load-bearing capacity. The arching effect within the void allows for optimization of material usage while maintaining structural integrity, contributing to cost savings and sustainable construction practices [20].
7) *Geometric Variations:* The geometry of the central void can vary based on design considerations, such as the size of the void relative to the overall foundation area and the specific soil conditions. This flexibility in design allows for customization based on project requirements [21].

II. METHODOLOGY

In this study, the focus of investigating is on the behaviour of a solid raft with a diameter represented as 'D,' as illustrated in Figure 1. Additionally, Figure 2 provides a visual representation of the annular raft, characterized by an internal diameter ('di') and an outer diameter ('do'). The fundamental soil properties considered for analysis are the modulus of deformation ('Es') and Poisson's ratio ('vs') of the surrounding soft soil.

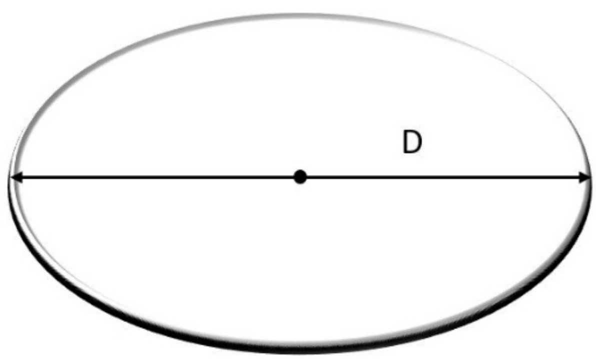

Fig.1 Solid Raft

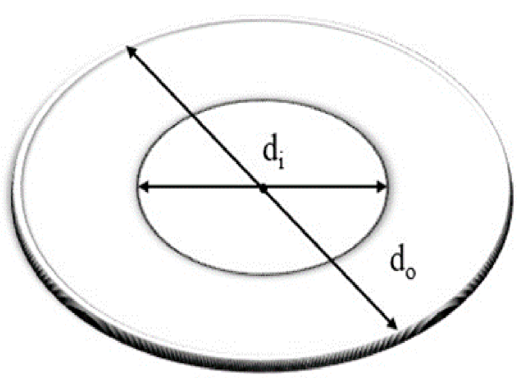

Fig.2 Annular Raft

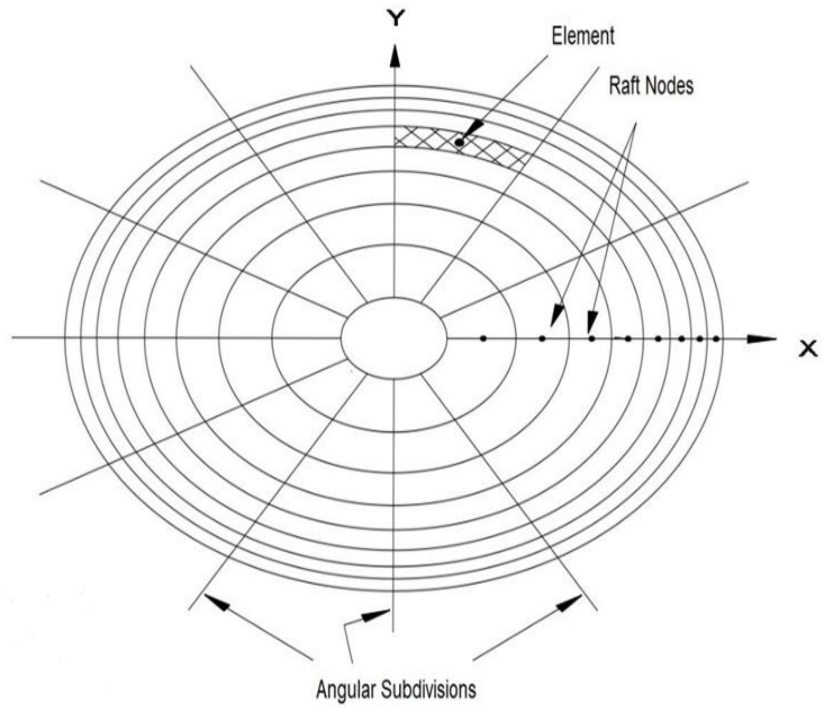

Fig.3 Discretisation of annular raft

For the annular raft configuration, the annular raft is partitioned into 'kr' annular rings of equal area, as outlined in the diagram. Furthermore, the annular raft is subdivided into 'kt' angular segments, as shown in Figure 3. To assess settlement patterns, nodes are selected along the interface between the soil and the raft.

$$S_{raft} = \frac{P}{E_s d_o} I_r \qquad (1) \qquad [19]$$

The SIF of the annular raft are evaluated by using above equation (1) [19]. The settlement influence factor (SIF) is evaluated for the annular raft for the different Dr (di/do). The variation of the SIF with Dr is presented in the Fig. 4. It is observed from the results that the minimum value of SIF is recorded at Dr=0.4 and maximum value is recorded at Dr=0.8. It is showing that as the Dr increases, the SIF increases as the size of the raft increases.

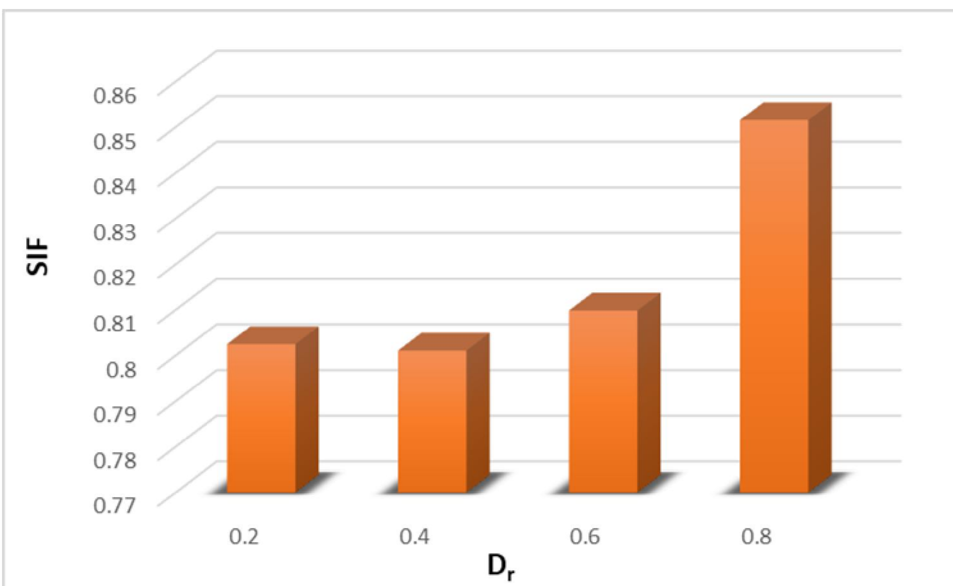

Fig.4 Variation of the SIF with Dr for annular raft

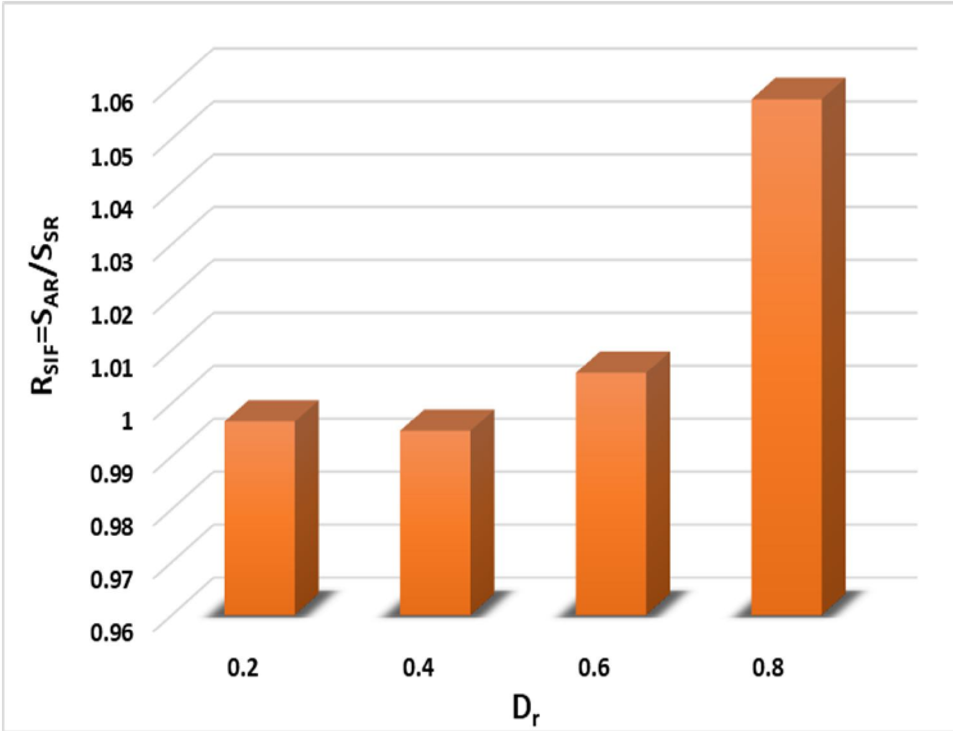

Fig.5 Ratio of SIF of annular raft and solid raft

The variation of the ratio of the SIF of annular raft (RSIF) to solid raft with Dr is depicted in Fig.5. The similar trend is obtained for the RSIF as seen in Fig.4. The minimum value of ratio is obtained at Dr=0.4 and the maximum value is obtained for Dr=0.8. The value of the RSIF is 1 for Dr=0.6. The results show that the annular raft has lower SIF up to the Dr <0.6, that shows the less settlement in comparison to the solid raft. The settlement of annular raft for Dr>0.6 is greater than the solid raft as it behaves like a strip footing.

III. CONCLUSIONS

The current study focused on the engineering significance of the annular raft over the solid raft in terms of SIF. The following conclusion is made from the above study: a noteworthy shift occurs when Dr exceeds 0.6. In this range, annular rafts exhibit greater settlement, behaving more like strip footings.

These findings emphasize the importance of selecting the appropriate Dr to suit the specific structural and soil conditions, as it can significantly influence settlement behavior and ultimately impact the stability and performance of the foundation. Further research and engineering considerations are warranted to optimize annular raft designs based on these insightful observations. Annular rafts demonstrate superior performance in terms of settlement control, particularly for Dr values below 0.6, where they exhibit reduced settlement compared to solid rafts.

This characteristic can be advantageous in projects where stringent settlement criteria must be met to ensure the long-term stability and functionality of structures. However, it is equally important to acknowledge that as Dr exceeds 0.6, annular rafts may behave more like strip footings and experience increased settlement. This knowledge empowers engineers to make informed decisions when selecting the appropriate foundation type, taking into account the specific Dr range that aligns with project objectives and soil conditions. Ultimately, the engineering significance of annular rafts lies in their versatility and the ability to fine-tune settlement characteristics to suit the demands of a wide range of construction projects, promoting structural integrity and performance while optimizing foundation design.

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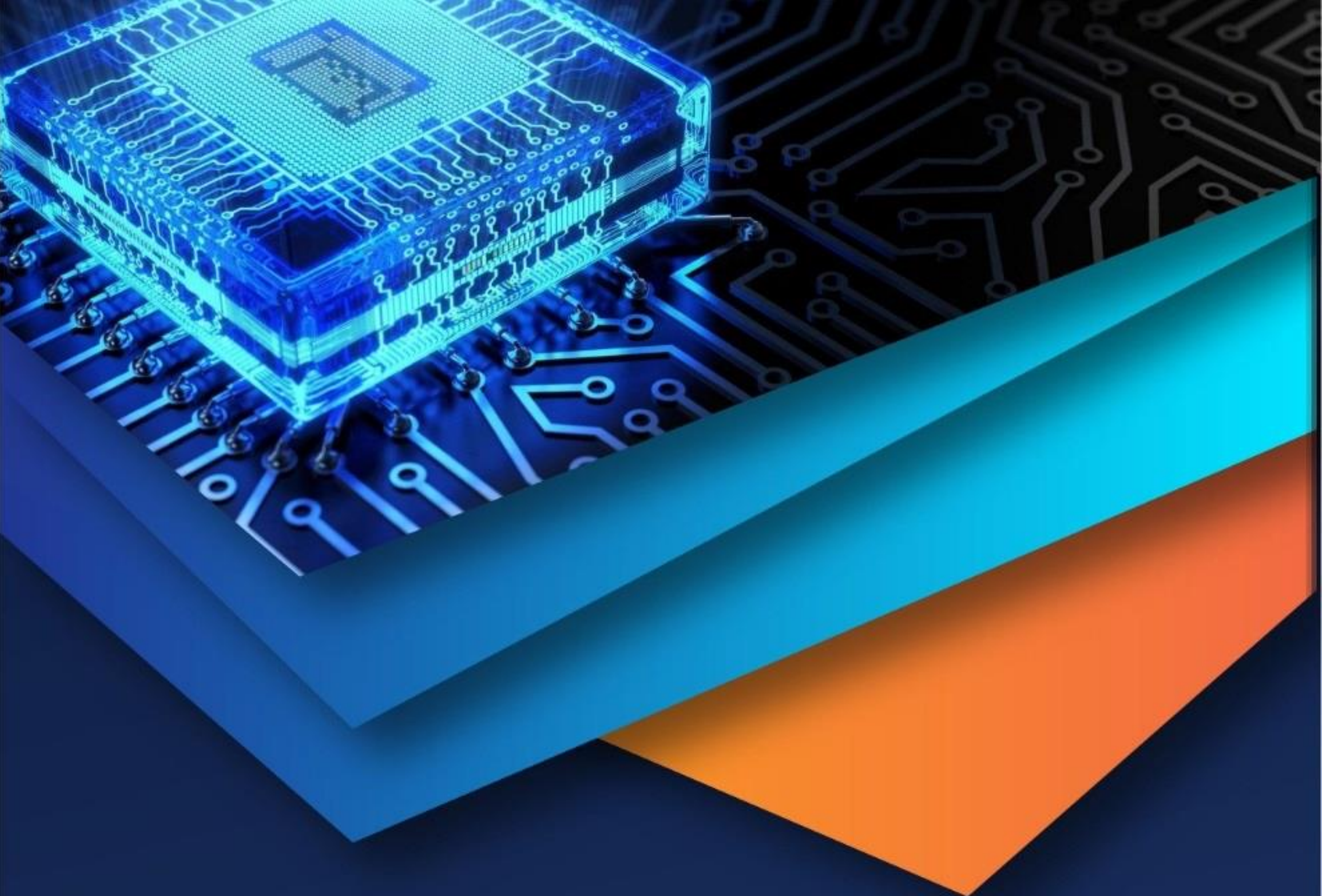

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