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Disconnected Piled Raft Foundations Systems

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الملخص العربي:

هذا البحث يتضمن عرض شامل عن نظام جديد للأساسات العميقة وهو الحصيره المرتكزة على خوازيق منفصلة عن الحصيرةالخرسانية وباستخدام الوسادة بين الحصيرة والخوازيق ، وهو مسلك هندسي جديد للتخفيف من مشكلات الهبوط في المباني المقامةعلى التربة اللينة. من خلال فصل الخوازيق الخرسانية عن الحصيرة) الأساسات(باستخدام وسادة تتكون من ركام ناعم/خشن، في هذا النظام يتم توزيع الأحمال بشكل فعال، مما يقلل من الهبوط ويضمن استقرار المنشأ. تقوم الدراسة بتجميع النتائج من المقالات البحثيةالمختلفة، وتسليط الضوء على العوامل الرئيسية التي تؤثر على اداء هذا النظام، تؤكد الدرا سات على الدور الحاسم لطبقة الوسادة،موضحا كيف تؤثر صلابتها وسمكها على توزيع الحمل وتقليل الهبوط وسلوك الأساس العام. بالإضافة إلى ذلك، توكد المقارنات بين أنظمة الخوازيق المتصلة والمنفصلة على المزايا الفريدة لنظام تاسيس موضوع البحث , خاصة في المناطق المعرضة للأنشطةالزلزالية او الأحمال الثقيلة. علاوة على ذلك، تستكشف الدراسة التطبيقات العملية لة مثل الجسور والمباني الشاهقة.يؤكد البحث علىالجدوى الاقتصادية لهذا النظام ويعرض فعاليته من حيث التكلفة وكفاءتة في تقليل مشاكل الهبوط. تستعرض الدراسة سلوك هذا النوعمن الأساسات من خلال دراسة متأنية لخصائص الوسادة وترتيب الخوازيق وجساءة الحصيرة، يمكن للمهندسين تحسين تصميم هذاالنظام مما يضمن أقصى قدرة تحمل مع تقليل التكاليف. يعد هذا البحث دليل قيم للمهندسين الجيوتقنيين ومحترفي البناء، حيث يقدم رؤى حول التطبيق المبتكر لأسا سات الحصيرة المرتكزة على خوازيق غير متصلة بها في مشاريع البنية التحتية.

Abstract:

This research provides a comprehensive analysis of Disconnected Piled Raft (DPR) foundations, a novel engineering approach for mitigating settlement issues in structures built on soft soils. By disconnecting concrete piles from the raft using a cushion layer, DPR foundations distribute loads effectively, reducing settlement and ensuring structural stability. The study synthesizes findings from various research articles, highlighting key parameters influencing DPR performance. The analysis emphasizes the critical role of the cushion layer, demonstrating how its stiffness and thickness impact load distribution, settlement reduction, and overall foundation behavior. Additionally, comparisons between connected and disconnected pile-raft systems underscore the unique advantages of DPR foundations, especially in areas prone to seismic activities or heavy loads. Moreover, the study explores practical implementations of DPR foundations in real-world projects, such as bridges and high-rise buildings. The research underscores the economic viability of DPR systems, showcasing their cost-effectiveness and efficiency in minimizing settlement concerns. The findings reveal that DPR foundations offer significant advantages in reducing settlement and enhancing structural stability. Through careful consideration of cushion properties and pile arrangement, engineers can optimize DPR designs, ensuring maximum load-bearing capacity while minimizing costs. This research serves as a valuable guide for geotechnical engineers and construction professionals, offering insights into the innovative application of DPR foundations in various construction projects.

Key words: disconnected pile raft, settlement, Axial force, Bearing capacity.

Introduction:

The research discussed in the provided text focuses on the analysis and comparison of different foundation systems, particularly the Disconnected Piled Raft (DPR) method, which involves disconnecting piles by introducing a soil cushion to isolate the piles from the raft. The primary objective of the research is to investigate the behavior and performance of the DPR system in contrast to Connected Piled Raft (CPR) systems, especially under various loading conditions and soil characteristics.

The researchers have explored essential factors influencing foundation bearing capacities and settlement behaviors, including pile length, cushion thickness, soil stiffness, and load distribution. They have conducted experimental model tests and utilized advanced numerical simulation techniques to investigate the relationship between applied load and settlement, evaluating the distribution of axial stress along the piles and the bending moments experienced by the raft, and overall efficiency of both CPR and DPR systems.

Through their comprehensive studies, the researchers have provided valuable insights into the load transfer mechanisms, settlement reduction capabilities, and optimal design parameters for Disconnected Piled Raft foundations. Their findings highlight the effectiveness of DPR foundations in minimizing settlements and enhancing structural stability, particularly in soft soil conditions. Additionally, the research emphasizes the significance of parameters such as cushion stiffness, pile length, and their interactions in determining the overall performance of DPR systems. These insights are valuable for practical engineering applications, providing guidance for designing cost-effective and efficient foundation systems, especially for structures subjected to heavy loads or seismic activities.

Researchers Appointment:

According to (Azizkandi et al., 2018) findings suggest that both connected and disconnected piled raft foundations are successful in mitigating ground settlements.

However, there is a notable distinction in their behavior. Connected piled rafts, in particular, exhibit substantially greater lateral stiffness, and the piles in these systems play a notably more efficient role in supporting lateral loads. This results in connected piled rafts having piles that bear increased moments and lateral loads, thereby reducing The enhancement of lateral motions' effectiveness. compared to non-connected piled rafts. Additional assessments for connected piled rafts considering cap weight and superstructure effects highlight the significance of these factors. The introduction of a superstructure increases pile moments and raft inclination, with frequency effects being crucial. Heavier caps lead to greater rotations and induce higher loads on the piles. During lateral cyclic loading, connected piled rafts exhibit smaller displacements, resulting in smaller residual displacement compared to non-connected piled rafts. In dis-connected piled rafts, piles bear smaller moments and lateral forces than in connected cases. In the case of connected piled rafts, the maximum pile moment corresponds to cap rotation rather than cap horizontal displacement. Both connected and non-connected piled rafts reduce soil settlements; however, in the dis-connected case, settlement reduction is highest at the pile heads and decreases with distance from the raft center. Moreover, connected piled rafts demonstrate superior settlement reduction efficiency under lateral seismic loading.

In the study by (Fioravante and Giretti, 2010) it was noted that contact piles serve the purpose of minimizing settlements by distributing the applied load from their heads into extensive soil volumes located deeper underground. Interestingly, the introduction of a flexible barrier that separates a raft from a pile head does not guarantee compatibility in terms of displacement. This is because the pressure exerted by the actual granular material impacts both the pile heads and induces surface-level soil settlements, ultimately resulting in adverse effects such as abrasions caused by upper body skin friction segment of the shaft of piles. On the other hand, nonconnected piles primarily reinforce the soil. In non-contact piled rafts, The inclusion of a flexible layer positioned between the raft and the pile heads permits a downward relative movement, which can take place at different distances from the pile heads. Piles are responsible for supporting loads through their heads, while concurrently experiencing negative skin friction on the upper section of their shafts. This settlement activates triggers positive skin friction along the lower shaft and generates resistance at the base. The effectiveness of This process relies on the level of stiffness and thickness of the intervening layer. If the granular fill lacks stiffness, the pile's bearing capacity isn't fully utilized, potentially resulting in lower efficiency for non-connected piled rafts compared to contact piled rafts in similar conditions.

(Cao et al., 2004) conducted testing studies to validate the efficacy of disconnected piled rafts. They conducted load tests on prototype rafts placed on sand strengthened with piles, aiming to investigate the variations in performance. The introduction of disconnected settlement-reducing piles resulted noticeable decrease in both variations in settlement and moments of bending within the raft models. Within a specific pile group, elongating the piles proved effective in enhancing the pile-raft system's rigidity. The precise arrangement of the limited number of settling reduced piles emerged as a crucial factor. Concentrating these pile reductions in the model raft's center region in both differential settlement and plate bending moments. Interestingly, simply increasing the number of piles did not prove efficient in managing model raft settling and bending moments.

(Biesiadecki et al., 2004) In recent construction projects, a practical strategy involves separating cushions in place atop piles of the raft. This technique ensures a more even distribution of pressure on the raft's base and alleviates constraints in the superstructure, foundation, and soil. Prominent examples include the foundation system of the Rion Antirion Bridge in Greece and the exceptionally long-span Izmit Bay Bridge (see Fig. 1),

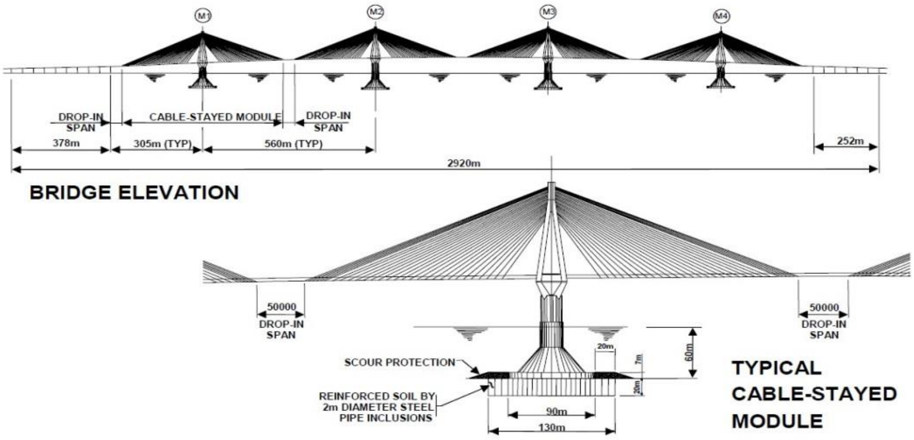

Figure (1) Conceptual Stage Bridge Profile (Biesiadecki et al., 2004)

both incorporations verticals (disconnected piles) to enhance shear resistance in soil foundations and mitigate risks associated with differential settlements. Additionally, gravel is used as a base material to restrict moments and shear forces among the soils of the superstructure and the base.

The Disconnected Piled Raft (DCPR) presents itself as an alternate solution to address the challenges encountered in the linked system. In this particular methodology, the piles are disengaged from the raft structure by the use of a soil cushion. (Liang et al., 2003) reported that indicate that in foundation engineering, short piles are employed to strengthen shallow, the utilization of soft soil, whereas lengthy piles reduce settling. Additionally, the use of A cushion functions to disperse and modify the ratios of stress. between the subsoil and piles fig. (2). This study aims to examine the key parameters that have a significant impact on the bearing capabilities of foundations and their settling behavior, it becomes apparent that the augmentation of lengthy pile length exhibits a more conspicuous effect in mitigating settling compared to enhancing modulus of elasticity for short piles. Economically, there is an optimal balance between elastic modulus and pile length that minimizes settlement while keeping costs in check. Furthermore, cushions facilitate an even distribution of load-sharing among piles and enhance the utilization of bearing capacities in short piles. When comparing foundations with and without a cushion, it is seen that the greatest axial stress undergoes a shift towards a specific depth from the pile head. This enables better utilization of shallow subsoil bearing capacities, especially in regions characterized by a rigid outer layer found in relatively shallow depths. Consequently, the mitigation of stress concentration in long piles and the

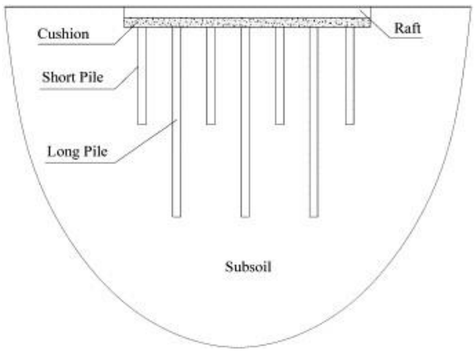

Figure (2) A drawing of a hybrid piled raft base (Liang et al., 2003)

improvement of the load-bearing capacity of short piles can be achieved by decreasing the elastic modulus of the cushion.

Several research studies have been dedicated to examining how the presence of layer of cushion influences the efficiency of disconnected-piled-raft foundations. (Cao et al., 2004, Hor et al., 2016) observed that disconnected piled raft (DPR) foundations are a cost-effective method for structures constructed on soft soils. They are also well-suited for supporting heavy loads and large surface structures. DPR foundations consist of a

raft (a concrete slab) and piles (long, thin concrete cylinders) driven into the ground until they reach a firm layer. The piles help to distribute the weight of the structure over a wider area and reduce settlement. DPR foundations are a popular choice for a variety of projects, including bridges, power plants, factories, and high-rise buildings. They are also relatively easy to construct, making them a time- and cost-efficient option.

In accordance with (Ata et al., 2015) findings in 2015, Proof that the UnconnectedPiled-Raft Foundation (UCPRF) presents a cost-effective alternative to the connected piled-raft foundation when tied to the force on the vertical axis. In the context of an independent structural system, Without reinforcement, basic concrete piles work. Their primary purpose is to enhance the structural stability of the upper section and mitigate settlement. The focus of interest lies in the dis-connected-piled-raft foundation. In the interconnected piled raft system, the maximum axial load is concentrated at the pile head and subsequently gradually lessens as one moves along the pile. Conversely, in the disconnected pile raft system, location the highest axial load shifts downward by a specific distance on the lower part of the pile. The distribution of load between the pile and the cushion is influenced by the thickness of the cushion. An augmentation in cushion thickness results, reduction in axial force experienced at the pile head. Likewise, when the diameter of the piles is increased while maintaining a consistent spacing between disconnected piles, there is a corresponding decrease in overall settlement. This phenomenon can be attributed to the direct relationship between pile stiffness and pile diameter. In comparison to a foundation raft devoid of piles, the connected piled raft exhibits a substantial 77% reduction in maximum settlement, while the dis-connected piled raft demonstrates a slightly lower reduction of 74%. In the connected-piled-raft system, the highest axial load is concentrated at the pile top and subsequently diminishes along the pile's length. Conversely, In the context of a disconnected system, it is seen that the point of greatest axial load undergoes a downward shift to a particular depth below the pile head. In the analyzed model, this shift is estimated to be roughly three meters.

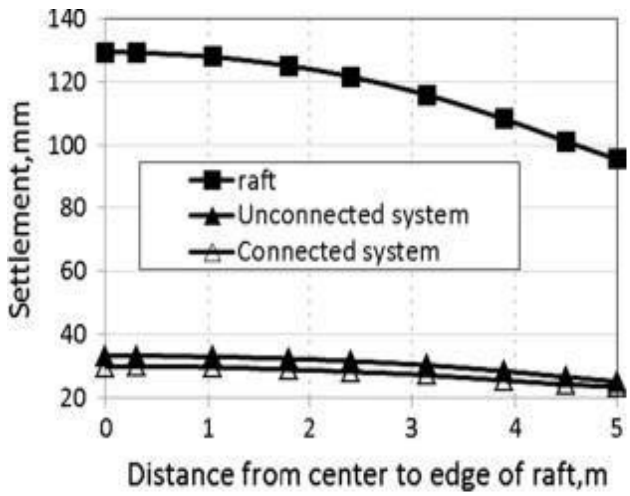

Figure (3) The raft's maximum settlement, UCPRF, and CPRF. (Ata et al., 2015)

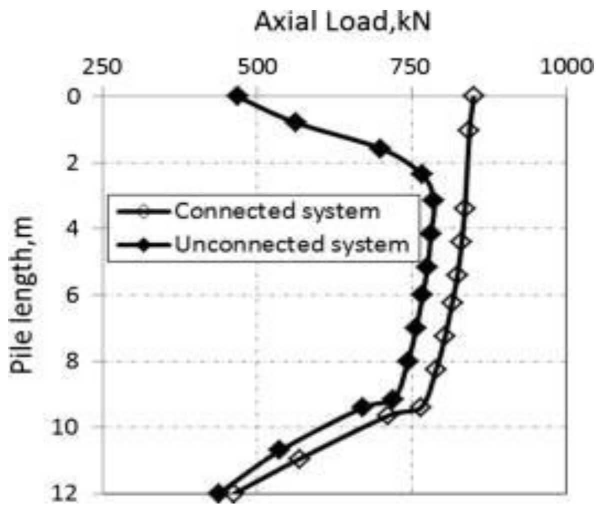

Figure (4) Axial load at the central pile vs the UCPRF and CPRF pile lengths. (Ata et al., 2015)

(Han et al., 2016) reported that in areas with frequent seismic activity, The displacement among the cushion and raft is minimal in the disconnected-piled-raft system, which restricts the cushion's influence due to the earthquake behavior of the super-structure. Therefore, the earthquake absorption effect of the cushion may be neglected. Moreover, the dynamic behavior of the super-structure. is notably affected by the thickness of the cushion. The earthquake absorption effect of the cushion improves as its thickness increases. Typical cushion thicknesses range from 200 mm to 300 mm, which can reduce seismic acceleration by an estimated 10% to 15%, therefore It is important to note that the cushion remains pliable throughout intense seismic events. The elastic modulus of the cushion does not have a major impact in defining its shear stiffness, and therefore, cushions with different elastic moduli exhibit similar seismic absorption effects.

In the study conducted by (Khalifa et al., 2021) it was observed that in unconnected piled systems, A location around two meters below the pile head receives the majority of the axial load. Beyond this uppermost two-meter range, the axial stress within the pile starts diminishing, aligning with the pattern seen in connected systems. Cushion thickness affects how the load is shared between the cushion and the piles fig. (5). As the thickness of the cushion increases, there is a corresponding decrease in the axial stress at the pile top. Comparatively, the overall settling in the interconnected piling system experienced a reduction of 37% when contrasted with conventional pile groups. Remarkably, the unconnected piled system exhibited a greater reduction in total settlement, amounting to 45%. Additionally, in the connected-piled-raft, The axial force first increases at the pile head and thereafter diminishes throughout the length of the pile. Furthermore, the load distribution between the pile and cushion is influenced by the thickness of the cushion; as the cushion thickness increases, the axial stress at the pile head decreases.

In (Saeedi Azizkandi et al., 2019a)'s study, it is highlighted that achieving an optimal design in geotechnical engineering requires careful consideration of three crucial factors: the axial stiffness of dis-connected piled rafts, settling and pile-length stress distribution. The research findings demonstrate that the impact of pile spacing on reducing raft settlement is more pronounced in connected piled rafts compared to nonconnected ones. Additionally, cushion stiffness plays a more significant role in disconnected piled rafts having shorter piles than taller ones. In connected piled rafts, piles bear a higher load than

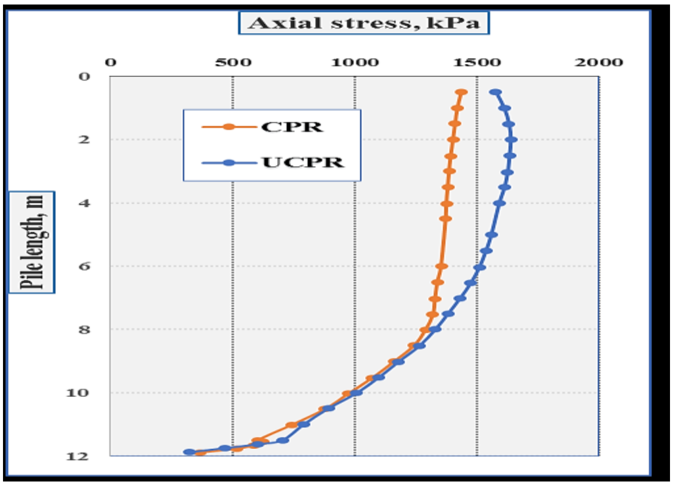

Figure (5) The distribution of axial stress in relation to the interconnected and disconnected central piles exhibits variation. (Khalifa et al., 2021)

in non-connected piled rafts. However, Increased loads are caused by stiffer cushions on dis-connected piles up to a certain threshold. The increase in pile length exhibits a similar rising pattern for both dis-connected and connected piled-rafts. Nevertheless, while longer non-connected piles result in a marginal increase in pile top stress, the stress increment inside the vertical extent of the pile is significantly more notable.

According to (Liang et al., 2003), their study findings have been implemented in coastal cities in China and can serve as a valuable guide for designing composite piled raft foundations, offering significant economic advantages. When considering the effects of elastic modulus and pile length, the influence of extending the length of long piles on lowering foundation settling is more obvious compared to raising the elastic modulus's of short piles. It's worth noting that for economic reasons, there is an optimal combination of elastic modulus and pile length that minimizes settlement while keeping costs in check. Furthermore, when compared to foundations without the maximum axial stress, the displacement of a cushion inside a pile gradually decreases as it moves from the top of the pile to a specific depth. This approach proves particularly advantageous for efficiently utilizing the bearing capacities of shallow subsoil, especially in areas with a firm upper layer in shallow layers. Interestingly, by reducing the elastic modulus of the cushion, it is possible to alleviate stress concentration in long piles and optimize the utilization of the bearing capacity of short piles.

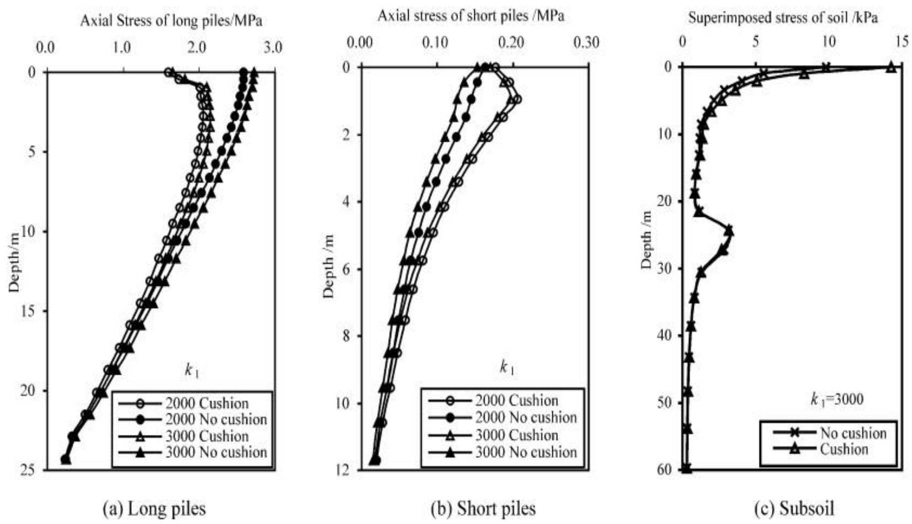

Figure (6) Influence of cushion on the mechanism of load transmission in a composite heaped raft foundation (Liang et al., 2003)

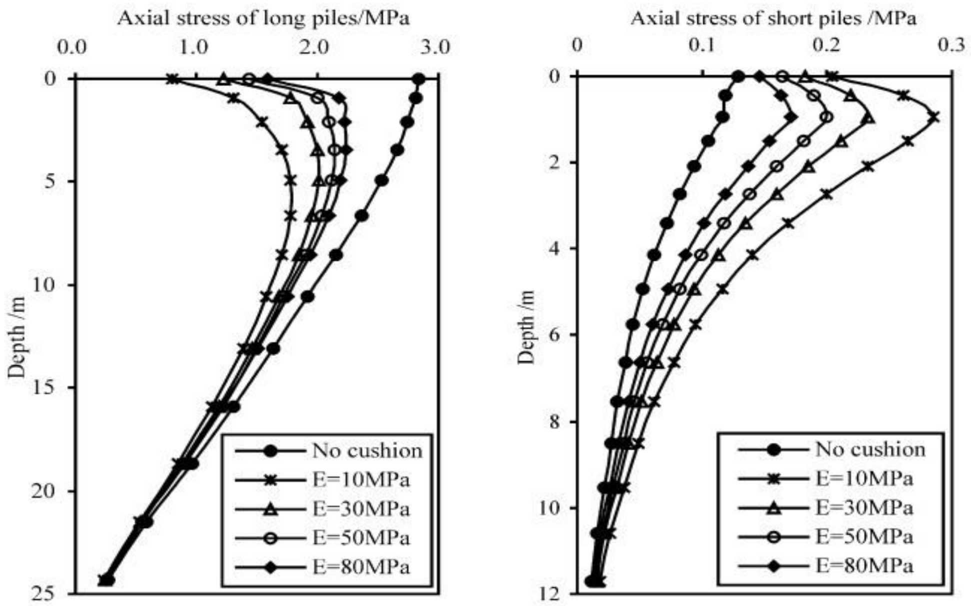

Figure (7) The impact of cushion elastic modulus on the distribution of axial stress in piles. (Liang et al., 2003)

(Melese and Gebregziabher, 2021) found that the behavior of dis-connected piled-raft foundations is primarily influenced by the stiffness and thickness of the interposed layer (cushion). Increasing the cushion rigidity from 24 MPa to 82 MPa reduces the pile loadbearing capacity by 49%. The effect of cushion rigidity on pile load-bearing capacity is more important for dis-connected piled rafts with shorter piles than longer ones. Additionally, Augmenting the thickness (rigidity) of the raft proves to be the key factor in diminishing differential settlement. In contrast, the relative stiffness between the raft and soil (raft thickness) has a minimal influence on the load supported by the disconnected piles.

(Saeedi Azizkandi et al., 2019b) According to the results, the axial stiffness of the detached piled raft foundation system may be greatly improved by improving the grading of the load transform platform.

(Rasouli et al., 2017) The research demonstrated that the length of the piles, cushion thickness and young's modulus play crucial roles in influencing the relative settlement between piles, soil, and raft, the maximum settling of the raft, and the distribution of loads in dis-connect piled-raft foundations. Additionally, increasing the pile length increases the load sharing ratio and reduces the pile-soil-raft relative settlement, especially when the number of piles is increased. In simpler terms, the longer the piles are and the more piles there are, the less the foundation will settle and the better the load will be distributed. Non-contact piled raft foundations are a good option for structures built on soft soils, as they can help to reduce settlement and strengthen the base's bearing ability.

(Halder and Manna, 2022) investigated the mechanism of load transfer in disconnected piled rafts (DPRs) and found that it is significantly different from that in connected piled-rafts (CPRs). In the case of non-contact piled-raft foundations (DPR), it is noteworthy that the point of greatest axial stress appears at a depth equal to ten times the pile diameter below the top of the pile rather than at the pile head. The occurrence of this phenomena can be attributed to the emergence of adverse skin friction in the top section of the pile. This pattern contrasts sharply with connected piled-raft systems (CPR), where the most axial stress is concentrated at the top of the pile. Within the DPR framework, the initial load is primarily sustained by the raft. Subsequently, the proportion of load borne by the piles gradually increases over time. In contrast to the connected piled-raft (CPR) scenario, the dis-connected piled-raft (DPR) exhibits an inverse trend. The axial stress on the piles in DPR decreases with increasing cushion thickness. In CPR configurations, piles primarily serve to decrease raft stiffness. Conversely, in DPR setups aimed at minimizing settlement, the dis-connected-piles primarily function as soil strengthening, augmenting the raft rigidity. The granular cushion layer's compressibility between the raft and piles in a dis-connected piled-raft (DPR) system causes undesirable pile-soil relative movement and negative skin friction in the top pile portion. But at a depth that corresponds to the neutral axis, this negative skin friction changes to positive and stays that way until the pile tip.

(Wong et al., 2000) conducted comparisons between structurally connected and disconnected piles within different raft systems. Surprisingly, disconnecting piles from the raft didn't significantly diminish their effectiveness to lessen the settling and bending moments of rafts. This finding indicates the practical feasibility of such disconnected piles, especially for tall buildings on raft foundations in earthquake or high wind-prone regions. Interestingly, these disconnected settlement-reducing piles primarily function as soil-reinforcing elements, stiffening the base soil rather than directly bearing the load. A fraction of the external force persists in transferring to the piles via the soil between pile heads and the raft, potentially causing an escalation the occurrence of negative skin friction on the top portion of the piles. Nevertheless, the crucial axial stresses in the neutral planes remain comparable, irrespective of whether the piles are attached to the raft or not.

In a study conducted by (El Sawwaf, 2010) The efficacy of use shorter piles, whether connected or dis-connected to the raft, was examined as an alternative to long piles in eccentrically loaded rafts. Various pile arrangements, lengths, and numbers, as well as soil density and load eccentricity, were analyzed to simulate real-world scenarios. The results revealed that incorporating the importance of short piles close to the raft margins enhanced raft bearing pressures and reduced settlements and tilts, resulting in a more cost-effective design. However, The effectiveness of the short piles-raft system was contingent upon the ratio of pressure eccentricity and the arrangement of the piles. Attaching the raft to short piles had a more substantial impact on raft behavior than unconnected piles. Pile arrangement notably influenced raft settling, especially at reduced levels of load, but the optimal pile configuration depended on load and raft geometry. Short piles placed near

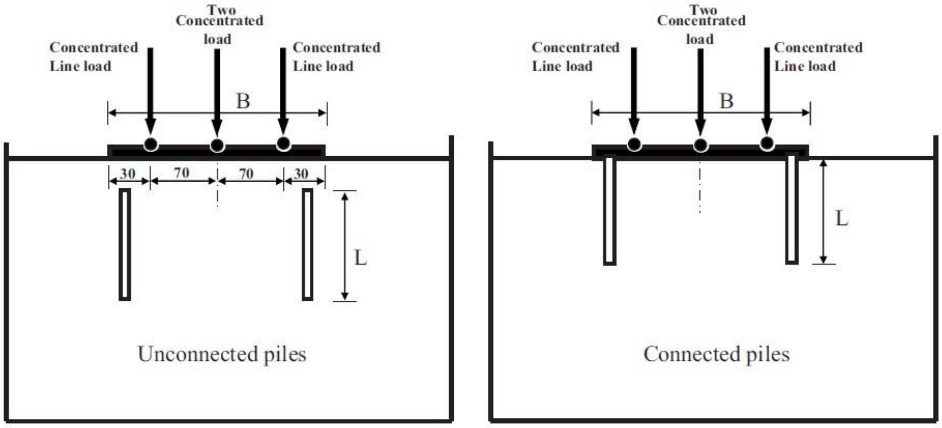

Figure (8) Lab model testing geometric parameters (El Sawwaf, 2010)

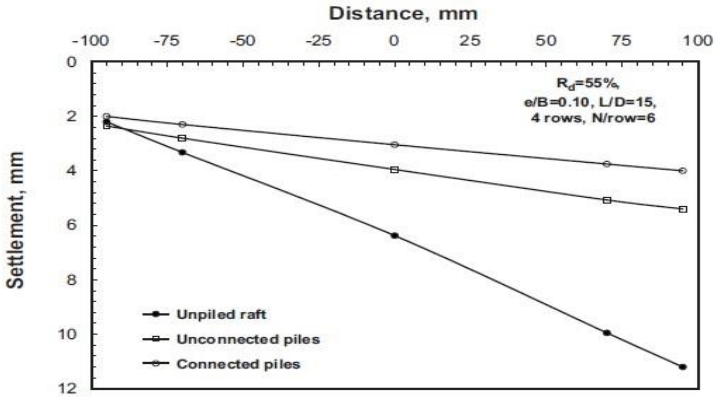

Figure (9) Settlements for unpiled, linked, and disconnected piles to the rafts along section S-S (El Sawwaf, 2010)

the raft edges were identified as a practical and economical solution for addressing eccentric load issues in model rafts supported on sand.

The addition of a granular cushion under a raft foundation can significantly enhance its bearing capacity and reduce settlement, as demonstrated by (Fattah et al., 2014). A 3.0 m thick cushion can increase the raft's load-carrying capacity by an additional 15%. In other words, a granular cushion makes raft base stronger and less prone to settle. This is because the cushion equally distributes structure load and reduces the stress on the soil below. Granular cushions are often used in areas with soft soil, where there is a risk of settlement. They can also be used to support heavy structures.

According to (Hor et al., 2016), the analysis encompasses an investigation into the influence of key parameters, including the area replacement ratio (the percentage of the pile area to the entire area of strengthened soil), pile stiffness and soil, as well as strength and the thickness characteristics of the load transfer platform (LTP). Additionally, the study explores the edge effect arising from the friction at the interface between reinforced and non-reinforced soil. The outcomes of the parametric study have provided valuable insights for design optimization. The Disconnected Piled Raft (DPR) technique exhibits enhanced efficiency. To ensure its effectiveness as a settlement reducer, it is advisable to embed the pile in a relatively firm layer. DPR demonstrates superior performance when applied to structures subject to substantial loads. Furthermore, the analysis of the edge effect suggests that DPR is a suitable choice for extensive surface structures, especially when stringent settlement criteria are not a primary concern. In these cases, it is recommended to construct platform for carrying loads, with a thick layer of strong granular material compacted on top to increase bearing capacity.

In the study conducted by (Alhassani and Aljorany, 2023), The viability of employing disconnected piled raft foundations was investigated through model experimental experiments. The purpose of these experiments was to investigate the load-settlement properties and pile load distribution ratio. in both connected piled raft (CPR) and disconnected piled raft (DCPR) systems. These tests involved varying cushion thicknesses and stiffnesses. Additionally, the finite element analyses was performed using ABAQUS software to assess bending moments along the raft and the distribution of axial stress along the piles. The outcomes demonstrated the effectiveness of DCPR in minimizing settlement in comparison to CPR. The stiffness of the cushion layer played a crucial role in minimizing settlement; however, insufficient stiffness could diminish DCPR's performance compared to CPR. The highest axial stress was observed at the upper section of linked piles and diminishing with depth, whereas the disconnected method transferred the maximum axial stress to the neutral plane. Upon decreasing the elastic modulus, the axial stress at the pile head diminished until reaching a specific depth, after which the impact lessened. The pile load sharing ratio was influenced by both cushion thickness and stiffness, but their increase reached a point of diminishing returns. DCPR demonstrated efficiency in mitigating raft bending moments. When the cushion possessed sufficient stiffness and thickness, the deflected shape approached that of a rigid raft. The aforementioned findings offer significant contributions to the understanding of the behavioral patterns shown by DCPR foundations and have implications for practical engineering applications.

In the study conducted by (A. A. ALSHABA, 2023), an extensive analysis of three distinct foundation systems, namely RAFT, CPR, and DCPR, was carried out to assess their comparative performance in various engineering scenarios. The findings of this research shed light on several crucial aspects related to these foundation types. Effectiveness of Raft Foundations: The study revealed that despite the substantial thickness and inherent stiffness of raft foundations, they exhibited commendable resilience in absorbing wind-induced forces. This characteristic makes them particularly suitable for applications where wind loads are a significant concern. However, it's important to note that raft foundations may not be the most suitable choice when dealing with compressible soils. The settlement observed in such soils was notably higher, ranging from 4.56 to 5.30 times that of connected piled raft system. Settlement Discrepancies: A comparative analysis of settlement among the three different piled raft types—RAFT, CPR, and DCPR—unveiled interesting insights. In this context, it was observed that the settlement of disconnected piled raft (DCPR) systems was approximately 1.21 to 1.24 times greater than that of connected piled-raft (CPR) systems. Factors Influencing Settlement: The study identified two critical parameters that significantly influence settlement in all three piled raft foundation systems: the thickness of the raft (rt) and the length of the piles (L). The correlation between these factors and settlement was found to be substantial. Additionally, the presence of a firm cushion layer proved to be beneficial in reducing settlement compared to situations where such a layer was absent, as evidenced in DCPR systems.

Pile Axial Force: The research indicated that the maximum axial force (Fmax) experienced by the piles is directly proportional to the pile length to diameter ratio (L/D) in all studied piled raft systems fig. (10). However, in the case of CPR and DCPR systems, this force was inversely proportional to the thickness of the raft (rt/rd) fig. (11).

Distribution of Axial Load: Notably, the distribution of axial load within the piles varied between the CPR and DCPR systems. In CPR foundation systems, the maximum axial force (Fmax) was concentrated near the pile head and gradually decreased with depth. In contrast, DCPR systems exhibited a different pattern, with Fmax increasing gradually down to a depth approximately 9 to 10 times the pile diameter, after which it started to decrease with further depth. Influence of Cushion Stiffness: Within the DCPR system, it was observed that increasing the cushion stiffness led to a corresponding increase in the axial load experienced by the piles, up to a certain threshold fig. (12). Moreover, variations in parameters such as cushion thickness (tc) and elastic modulus (E) had distinct effects on the axial load of the piles, with increases in tc resulting in decreased load at the pile head and increases in E leading to the opposite effect.

In conclusion, this research provides valuable insights into the performance characteristics and optimal utilization of different foundation systems in diverse geotechnical and loading conditions. The findings underscore the importance of considering factors such as soil type, cushion layers, and structural parameters when selecting the most appropriate foundation solution for a given engineering application. These insights contribute to the body of knowledge essential for informed decisionmaking in foundation design and construction.

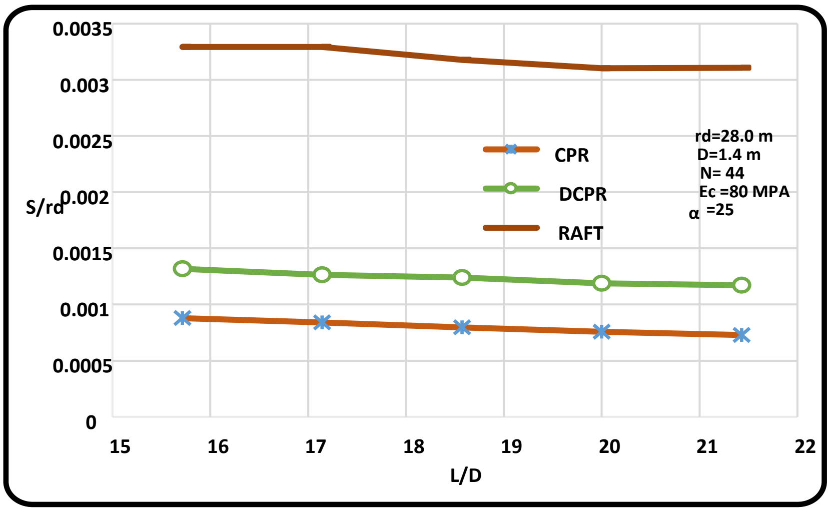

Figure (10) the relationship between settlement and the pile length (L) for different foundations

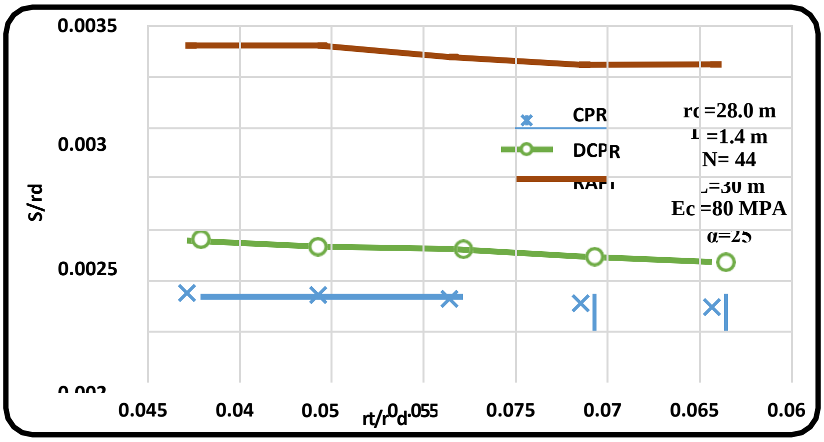

Figure (11) the relationship between settlement and the ratio (rt/rd) for different foundations

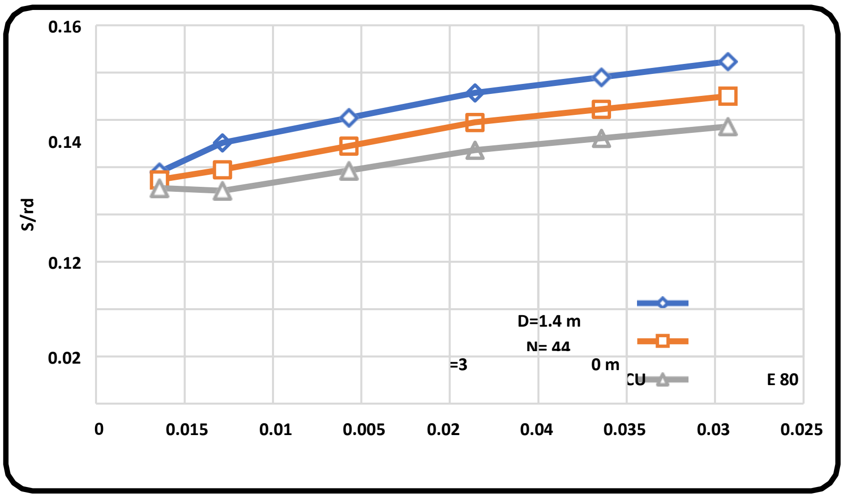

Figure (12) The maximum settlement on Variation of cushion stiffness Ec

Conclusions

Based on the extensive research and findings you've provided regarding disconnected piled raft foundations; several key points and themes emerge:

1. Disconnected Piled-Raft (DPR) vs. Connected Piled-Raft (CPR):
   - Load Distribution: In due to negative skin friction in the upper section of disconnected piled-raft (DCPR) systems, the greatest axial stress on the piles occurs below the pile head. the pile head receives the largest axial load in connected piled-raft (CPR) systems.
   - Load Transfer Mechanism: DPRs transfer load primarily through soil strengthening, enhancing raft stiffness, while CPRs use piles to reduce raft stiffness.
   - Settlement Reduction: Disconnected Piled Raft (DPR) systems demonstrate enhanced settlement reduction capabilities compared to

Connected Piled Raft (CPR) systems, particularly when the design of the cushion layer among the piles and raft is meticulously optimized.

2. The Impact of Cushion Thickness and Stiffness:

- Cushion Thickness: Increasing cushion thickness in DPRs progressively reduces the axial load on the piles. There's an optimal cushion thickness for balancing settlement reduction and load transfer efficiency.
- Cushion Stiffness: The stiffness of the cushion layer has a critical role in minimizing settlement. However, excessive stiffness might not significantly improve DPR performance beyond a certain point.

3. Pile Characteristics:

- Pile Length: Longer piles are more effective in reducing settlement, especially when dealing with soft soils. Increasing pile length also affects stress distribution along the pile depth.
- Pile Diameter: Increasing pile diameter while maintaining consistent spacing between disconnected piles reduces overall settlement. Pile stiffness is directly related to pile diameter.

4. Soil-Structure Interaction:

- Granular Cushion: A granular cushion layer beneath the raft enhances bearing capacity and reduces settlement. It helps distribute the weight of the structure evenly, particularly in soft soils.
- Edge Effects: Consideration of edge effects is important, especially regarding friction at the interface between strengthened and untreated soil.

5. Structural Performance and Efficiency:

- Seismic Performance: DPRs exhibit minimal cushion-raft relative displacement during seismic events, enhancing their seismic performance.
- Economic Considerations: There's an optimal balance between pile length and elastic modulus that minimizes settlement while managing costs effectively.

6. Practical Applications:

- Real-World Projects: DPRs have been successfully implemented in huge constructions like bridges and skyscrapers, where minimizing settlement and ensuring stability are critical.

In summary, disconnected piled raft foundations offer an innovative solution for minimizing settlement and improving the stability of structures, especially in soft soil conditions. Proper design considerations, including cushion thickness, pile length, and diameter, are essential to optimize their performance and ensure cost-effective solutions for geotechnical engineering projects. Additionally, understanding the complex interactions between soil, piles, and rafts through advanced numerical simulations is crucial for safe and effective foundation design

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