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Construction of Secant Pile Wall for Underground Structure

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ABSTRACT

The construction of underground structures or building works is very challenging for engineers, both in the field of design and on-site execution, as they must address various site problems occurred during the design phase of the region. As the soil strata differs from region to region the problem also differs, and hence separate detail design needs to be carried out followed by Geotechnical Investigation to find out the solutions and innovations in the Engineering design. This project synopsis report aims to understand the challenging aspects and the various in situ issues during the construction phase for the design .Based on the geotechnical investigation data and results the GTI (Geotechnical Investigations Report) and the GRF (Geo-factual reports) are to be prepared which shows the approximate profile of the soil strata with respect to depth generally called as “lithological profile”, design of secant pile is carried out taking into all the factors and parameters as obtained in the GFR/GIR. In this study to design the retaining wall as a secant pile wall method, we have examined the soil profile, rock strata, and their properties, which are dynamically changes with increasing depth. Additionally, we have explored the effects of pore water pressure on the side face of the soil and, most importantly, the uplift pressure acting upon the base slab of the structure. The study also includes an analysis of earth retaining techniques, such as secant pile construction and shot Crete concrete.

Keywords:- Underground structures, Geotechnical investigation, Soil strata variation, Retaining wall design, Uplift pressure

Introduction

Cement manufacturing is one of the most energy-intensive industries and a major contributor to environmental degradation, particularly due to its significant carbon dioxide emissions, depletion of natural resources, and high energy consumption. The production of one ton of ordinary Portland cement (OPC) typically releases nearly an equal amount of CO_2, accounting for approximately 7–8% of global greenhouse gas emissions. With the rising demand for infrastructure and urbanization, the pressure on the cement industry to adopt sustainable practices has become more urgent than ever. To mitigate these environmental concerns, researchers and industry experts are increasingly exploring the use of industrial waste materials and alternative binders as partial or complete replacements for cement. Industrial by-products such as fly ash, blast furnace slag, silica fume, rice husk ash, and quarry dust not only reduce the reliance on clinker but also help in the effective disposal of waste that would otherwise pose environmental challenges. Additionally, alternative binders such as geopolymer cement and alkali-activated materials provide a promising pathway toward achieving low-carbon construction materials with superior durability and performance. Incorporating these sustainable solutions not only minimizes the ecological footprint of cement production but also supports the principles of circular economy and resource efficiency. Therefore, the integration of industrial waste and alternative binders in cementations systems represents a crucial step toward environmentally responsible construction practices and the realization of sustainable development goals.

Literature Review

There are several theories that are investigated and published for secant pile wall method in construction in various country. The analysis and the methods are depended upon the property of soil and the strata of region, which plays a vital role in the selection of the type of structure to be built to support the earth fill and provide a safe and dry working space in construction zone. Further based on that the method of execution and purpose to be fulfill the type of retaining wall is going to be proposed and designed win consideration to various codes. Here in this study, we have done the analysis over the B K C region of Maharashtra in India, where this kind of study was not taken before by any of the project publication. In this study we have designed a secant pile wall with retraceable soil anchors which is having its own application and provide supports to the Pile wall and facilitate the reaction against the Active pressure of the soil. This theory and research are completely different from the other practices and earlies theories. The Anchor and water assembly support the pile wall by means of a stressing system of anchors (an assembly of number of Tendon to be prepared as per design specifications – refer fig ##) which will be removed after the completion of the main construction works and the gap between the main construction wall and secant pile wall will be backfilled with suitable soil.

Methodology

The construction of underground structures such as basements, metro stations, tunnels, underpasses, and deep foundations requires careful consideration of earth retention and groundwater control to ensure safety, stability, and durability. Among the various retaining systems available, the Secant Pile Wall (SPW) has emerged as one of the most effective techniques for deep excavations in urban environments and difficult soil conditions. A secant pile wall is a type of continuous retaining wall formed by drilling intersecting reinforced and unreinforced concrete piles, which create a rigid barrier capable of withstanding both lateral earth pressures and groundwater ingress.

The term “secant” refers to the interlocking nature of the piles, where secondary piles (reinforced) are constructed by cutting into or overlapping the primary piles (unreinforced or lightly reinforced), thereby forming a continuous structural wall. This interlocking arrangement offers superior stiffness and strength compared to traditional sheet piles or soldier pile walls, making it suitable for sites with limited working space, high water table conditions, or complex soil profiles.

Secant pile walls are particularly advantageous in densely built-up urban areas, where excavation-induced movements need to be minimized to prevent damage to adjacent buildings, roads, or utility lines. They can serve both as temporary excavation support and as a permanent structural wall, thereby reducing construction time and cost. Depending on project requirements, secant pile walls can be designed as hard–hard (reinforced–reinforced), hard–soft (reinforced–unreinforced), or soft–soft (unreinforced–unreinforced) walls, balancing structural efficiency and economic considerations.

The method involves rotary drilling rigs equipped with casing or polymer slurry, which ensures precise pile alignment and minimal ground disturbance. Reinforcement cages are inserted in the secondary piles to enhance bending resistance, while the concrete used is designed to maintain strength even in groundwater-exposed environments. This construction process allows for flexibility in depth, alignment, and wall thickness, making secant pile walls a reliable solution for deep excavation support.

Result and Discussion

The numerical analyses carried out for the secant pile wall system, as presented in Appendix B, provide a comprehensive assessment of the wall performance under various critical stages of loading and groundwater conditions. The results include the factor of safety, forces mobilized in the secant piles and supporting anchors/bolts, as well as detailed contour plots for shear strain, horizontal and vertical displacements, seepage volume, pore water pressure, and total water head, which collectively illustrate the stability and behavior of the retaining structure. Based on the tender geotechnical data, secant piles have been classified into three types depending on their depth, where each type corresponds to specific soil strata and design requirements to ensure structural adequacy and stability. Shallow-depth secant piles are primarily designed for retaining upper soil layers with lower loads, medium-depth piles provide additional resistance to accommodate intermediate soil conditions and higher lateral pressures, and deep secant piles extend further into the ground to anchor into competent strata, effectively resisting large lateral earth pressures and groundwater loads. This classification ensures that the design remains economical while meeting safety requirements, as the depth of the secant piles directly influences their structural performance, load distribution, and interaction with soil and groundwater pressures.

Conclusion

The construction of secant pile walls for underground structures proves to be an effective and versatile solution in geotechnical and structural engineering, particularly for deep excavations in urban environments where space is limited and soil stability is critical. The technique combines the strength and stiffness of reinforced concrete piles with the water-cutoff properties of overlapping primary and secondary piles, thereby providing both structural support and groundwater control. The execution of secant pile walls requires precise drilling and alignment to ensure overlap between adjacent piles, as even small deviations can compromise wall integrity. When properly designed and constructed, secant pile walls are capable of resisting significant lateral earth pressures, preventing soil collapse, and minimizing ground movements that could affect nearby structures and utilities. Furthermore, this method is adaptable to varying ground conditions, including soft soils, granular deposits, and areas with high groundwater levels, making it highly suitable for basements, tunnels, metro stations, and other below-ground infrastructure. Despite higher costs and the need for specialized equipment and skilled labor, the benefits in terms of safety, durability, reduced leakage, and the ability to accommodate complex excavation geometries outweigh the limitations. In conclusion, secant pile wall construction provides a reliable, safe, and efficient retaining system for underground structures, ensuring stability during excavation and long-term serviceability, while meeting the demands of modern urban development and geotechnical challenges.

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