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The behavior of secant pile wall embedded within soil by numerical analysis

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HIGHLIGHTS

- Lowering water level on the load side reduces wall lateral displacement with constant excavation depth on both sides
- Lowering the water level causes an initial vertical displacement at the ground surface
- Lateral displacement decreases and bending moment increases as pile diameter grows from 0.6 m to 1.1 m in secant walls
- The bending moment in secant pile wall rises as the overlap ratio between the piles increases
- Raising secondary pile strength in secant pile walls results in higher bending moment values

Keywords:
Deep excavation; Secant pile wall; Dewatering; lateral stress; Displacement.

ABSTRACT

Deep excavation projects in areas with high groundwater levels, such as industrial zones with large, heavy structures, present significant challenges. Secant piling techniques offer an effective solution for these conditions. These retaining walls are constructed by overlapping reinforced concrete and plain concrete piles to form a continuous barrier against soil and water ingress. This research investigates the effectiveness of secant pile walls as a deep excavation support system, focusing on the impact of various parameters on ground movement, analyzed using the DeepEX program. The case study centers on the Al Dawoodi/Al Mansur District in Baghdad, Iraq. Key factors examined include excavation depth, water level fluctuations, pile diameter, wall stiffness, soil properties, and the bonding between piles. The results revealed that lowering the groundwater level decreases the total lateral earth pressure while enhancing lateral resistance. For a constant excavation depth of 12.85 m, the total active stress at a depth of 9 m decreases as the water table level drops. When the water table is at -1.8 m, the total active stress is 92.952 kN/m²; at -3.5 m, it decreases to 87.837 kN/m²; and at -5.5 m, it further reduces to 82.016 kN/m². Additionally, deeper excavations result in greater horizontal displacement at the top of the wall. Increasing the pile diameter from 0.6 m to 1.2 m reduces lateral displacement from 0.503 m to 0.467 m but increases the bending moments from 832.56 kN.m/m to 1430.22 kN.m/m within the secant pile wall. Furthermore, the interlock ratio between the piles significantly influences wall performance. As this ratio increases, the bending moment also rises, with moment resistance increasing from 1134.72 kN.m/m to 1209.94 kN.m/m when the overlap distance grows from 5% to 30% of the pile diameter. The analysis also demonstrates that enhancing the strength of the secondary piles within the wall leads to higher bending moments, improving the wall's stability against excavation-induced stresses.

1. Introduction

Due to the limited space available in urban areas and the need to construct skyscrapers, deep excavation is essential. Secant pile walls are a viable substitute for traditional retaining walls such as sheet piling, soldier piling and lagging, soil mix walls, and diaphragm walls. The walls are made of interlocking and overlapping bored concrete piles, including primary (unreinforced) and secondary (reinforced) piles, Figure (1a) shows the types of piles, while Figure (1b) illustrates the types of cast-in-place piles at the Iraq Gate site in Baghdad. At first, primary piles are placed at predetermined intervals along the perimeter. Afterward, more piles are driven or placed on the initial heaps. This construction method entails drilling piles to the specified diameter and depth. Research that has been done in the past, such as that conducted by Liu et al. [1], focused on researching ground movement generated by deep excavation in soft clay material. Only a handful of case studies have been investigated in relation to excavation in sandy soil Zahmatkesh [2] and Ji et al., [3]. In a study conducted by Moormann [4], which analyzed several case studies, it was shown that the average values of the normalized horizontal deflection (δh-max/H%) and the vertical displacement at the ground surface (δv-max/H%) for non-cohesive soil are roughly 0.25% and 0.33%, respectively. Compared to soft clay, where

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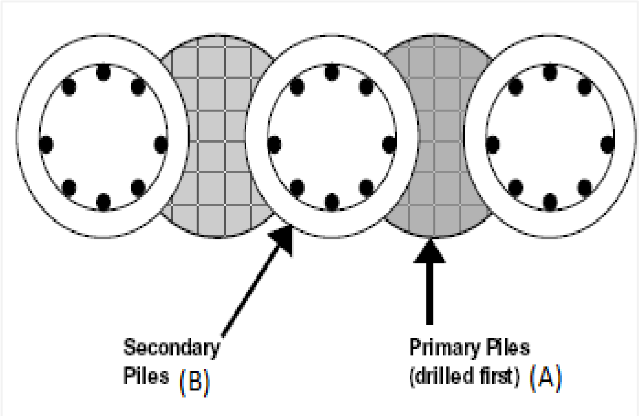
the maximum δh/H% is larger than 1%, and the maximum δv/H% is often equal to 1%, these results are insignificant. The full theoretical pressure is reached in loose sand once a sufficient wall displacement has occurred. Despite this, when working with dense sand, the average soil strength falls below the peak value, which results in the gradual collapse of the soil. It is believed that the soil features and groundwater level are random factors that determine how the soil and structures surrounding the foundation pit would react in the event of unstable seepage conditions. The bentonite slurry material supported both vertical and horizontal movement of diaphragm panel excavation, and they showed that total horizontal movement may occur at $1/3^{rd}$ of the depth of the panel from the ground level Farmer [5].



(a)

(b)

Figure 1: Primary and secondary piles (a) theoretical, (b) actual

The construction sequences of a typical diaphragm wall on clay are simulated using a three-dimensional finite element distinction program. Also, it is reported that the settlement happens at a distance of 0.2D behind the influence zone during the diaphragm wall installation. The influence zone is nothing but 1/3D beneath from the toe and 1/3L from the edge so that the horizontal stress may pile down behind the center of the panel Ng et al., [6]. According to Li and Xie's [7], study the influence of seepage on the envelope of water pressure, earth pressure, and lateral pressure intensifies proportionally with the depth and width of the retaining wall, significantly affecting site conditions. To support excavations in sandy soils, numerical research given by Ramadan and Meguid [8], the analyses of the behavior of cantilever secant pile walls were studied. Using a parametric approach, the study looks at how well cantilever-secant pile walls support excavations in sandy soil. With both horizontal (δh) and vertical (δv) deformations, the primary findings include an inverse relationship between sand density, excavation depth, and wall flexural stiffness (EpIp/Lp). Mahesh [9] presented a comprehensive examination of how the diameter of the secant pile wall affects deep excavation analysis. The bending moment and lateral displacement both increased as the distance between the secant pile walls grew also. Changing the pile diameter from 0.6 to 0.8 m decreased lateral displacement but raised the secant pile wall's bending force amplitude. Ramadan [10] presented a numerical study that examines the behavior of a cantilever secant pile wall that supports excavation in sandy soil, mainly concentrating on issues with ground movement and possible harm to nearby buildings. In order to anticipate wall deflection and choose the right supporting system, the study investigates variables that affect lateral earth pressure and ground movement. This investigation culminates in a thorough parametric study. The study examines the efficacy of cantilever-secant pile walls in providing support for excavations in sandy soil by conducting a parametric analysis. The main discoveries consist of the inverse correlation between sand density (Dr), excavation depth (H), and wall flexural stiffness (EpIp/Lp) with both horizontal (δh) and vertical (δv) deformations. Suggested guidelines involve excavating to a maximum depth of 2 m prior to installing the initial support and using a design approach that estimates deformations using Dr, H, and EpIp for piles that are entirely bonded. The importance of the bonding between piles within the wall is emphasized, affecting deformations.

Cui et al. [11], investigated the "Application of secant piles for Excavation Pit in a Complicated Environment" the project is situated at the junction of Xiangshan South Road and Sanyanjing Street. It consists of two underground levels, which have been designed using finite element analysis. The investigation findings reveal that the foundation pit support system exhibits a total displacement of 13.11 mm, with a maximum horizontal displacement of 11.8 mm and ground settlement reaching 5.7 mm. The measurements satisfy the specified criteria for the foundation excavation. In addition, the settling of adjacent foundations is 1.6 mm, which is well below the permissible threshold of 10 mm. The findings underscore the clear advantages of employing secant piles to stabilize both the foundation pit and its immediate surroundings. This type of study is important as the city of Baghdad is witnessing significant urban development with the implementation of many projects that require deep excavations. Given the high water table level, the lateral support method discussed in this study is considered more suitable for such projects. This study seeks to evaluate how water table levels affect the performance of secant pile walls in sandy soils, with a particular focus on total lateral earth pressure, horizontal displacement at the wall's top, and vertical settlement at the adjacent footing. The objective is to systematically examine various factors to understand better their impact on the structural behavior of secant pile walls.

2. Site description

The scheduled examination for this project will be carried out in the Al Dawoodi/Al Mansur District of Baghdad, Iraq. The designated location for the experiment is a multi-story Building. A depth of 12.85 m is necessary for the deep excavation. According to the findings of the site assessment, the water table is located at a depth ranging from 1.8 to 2.0 m beneath the surface of the earth. As a result, an anchored secant pile wall will be employed to support the excavation activities associated with this project.

3. Soil properties and geotechnical parameters

The nature of the existing ground conditions and their engineering performance as a foundation for the proposed project has been assessed through a geotechnical report conducted by Consulting Engineering Bureau Laboratories (CEBL) College of Engineering - University of Baghdad. Ground condition stratification, along with certain mechanical, physical, and chemical soil qualities, can be inferred from samples. Three boreholes were to be drilled as part of the site activities. Thirty meters was the minimum depth to which each borehole was bored. A rotary auger machine that is powered by electricity was used to conduct the drilling. Three types of samples were collected from the boreholes: undisturbed, disturbed, and split spoon. In order to conduct shear and consolidation experiments on undisturbed specimens, 100 mm diameter Shelby tubes were used.

Figure 2 shows the soil profile obtained from the boring. A comprehensive understanding of the subsurface conditions was achieved by combining an analysis of the test boring data with the outcomes of laboratory testing. Builders are advised to use the soil parameters listed in Table 1 when planning foundations. The soil is categorized as either Cohesive Soil (C.H. or CL and M.H.) or Cohesionless Soil (S.P. or SC-SM) based on the unified method of soil classification.

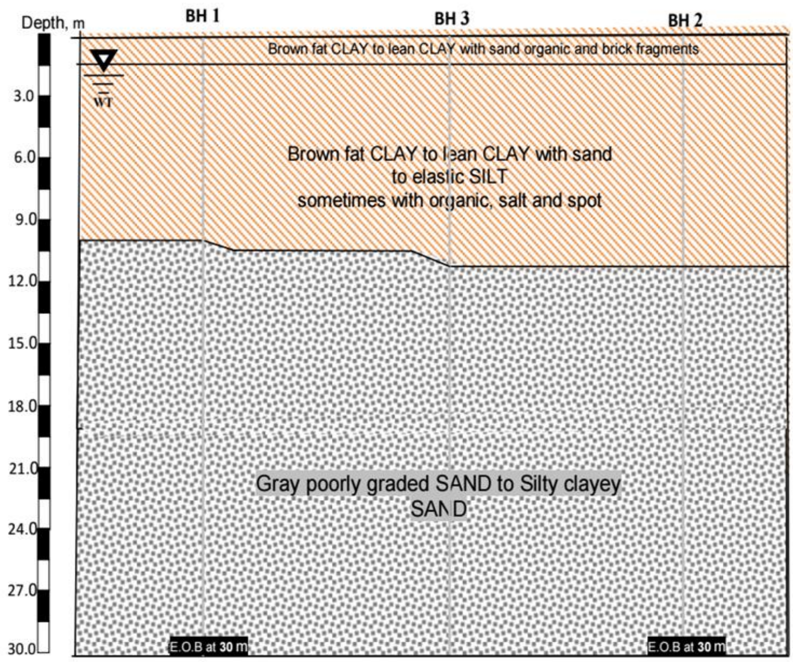


Figure 2: Geological Profile of Soil Layers

Table 1: Recommended average values of soil parameters

Soil parameters	Symbol	Applicable values	Unit	Testing standard
The specific gravity of cohesive soil	G_s	2.71	-	ASTM D854
The specific gravity of cohesionless soil	Gs	2.67	-	ASTM D854
Liquid Limit of cohesive soil	L.L.	55	%	ASTM D4318
Plasticity Index of cohesive soil	P.I.	28	%	ASTM D4318
Bulk Unit weight for cohesive soil	γ_t	20.33	kN/m^3	BS1377:1990
Bulk Unit weight for cohesionless soil	γ_t	17.0 to 19.0	kN/m^3	BS1377:1990
Undrained cohesion for cohesive soil for Shallow foundation	c_u	50	kN/m^2	ASTM D3080
The angle of shearing resistance for Cohesionless soil	ϕ	33-39	degree	ASTM D2166
Compression index	C_c	0.138	-	ASTM D2435
Swelling index	C_s	0.032	-	ASTM D2435
Initial void ratio	e_o	0.678	-	

4. Secant pile wall details

In order to accommodate deep excavations, be close to neighboring buildings, and withstand lateral pressures, the designer relied on the site study report, which included information on the soil, groundwater levels, and adjoining structures, to recommend a secant pile wall as the lateral support system. This choice is in line with engineering standards and scientific investigations, guaranteeing security and stability while reducing harm to the environment. Figure 3 illustrates the site layout.

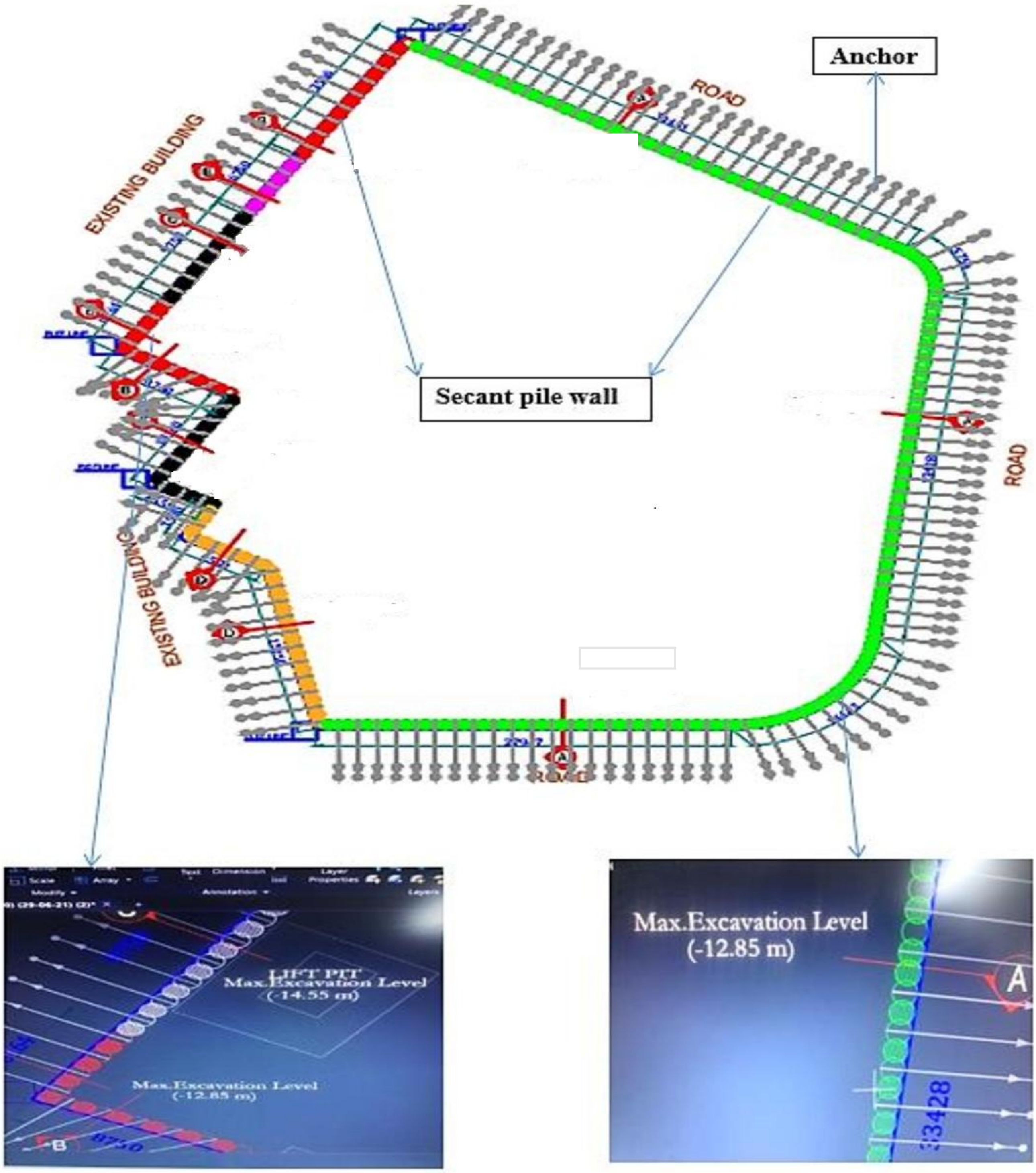


Figure 3: Site layout

The construction plan for the building site's perimeter included using a secant pile wall that was 19 m deep and 206.403 m long. The building's secant pile wall provided the structural backbone. The wall's careful design ensured structural stability and the ability to resist lateral ground stresses. Primary piles and secondary piles were the two main components of the secant pile wall. With a compressive strength of 20 N/mm^2, primary piles were distinguished by their unreinforced concrete composition [12]. Reinforced concrete secondary piles, meanwhile, showed a compressive strength of 40 N/mm^2, which is significantly greater. As depicted in Figure 4, the diameter of the primary and secondary piles was 0.9 m, and an intentional overlap space of 0.15 m was maintained between neighboring piles. This design element strengthened the wall's structure and made sure everything fit together perfectly. The installation of anchors at key points along the wall added even more support. The anchors were set at depths of 3.5 and 9 m, with an inclination angle of 30 degrees from the horizontal plane, and an integral part of the secant pile wall's performance was the resistance to lateral loads provided by these anchors, which measured 18 m in total with a fixed length of 8 m. The anchor installation locations, excavation depth, and secant pile wall depth are depicted in detail in Figure 5.

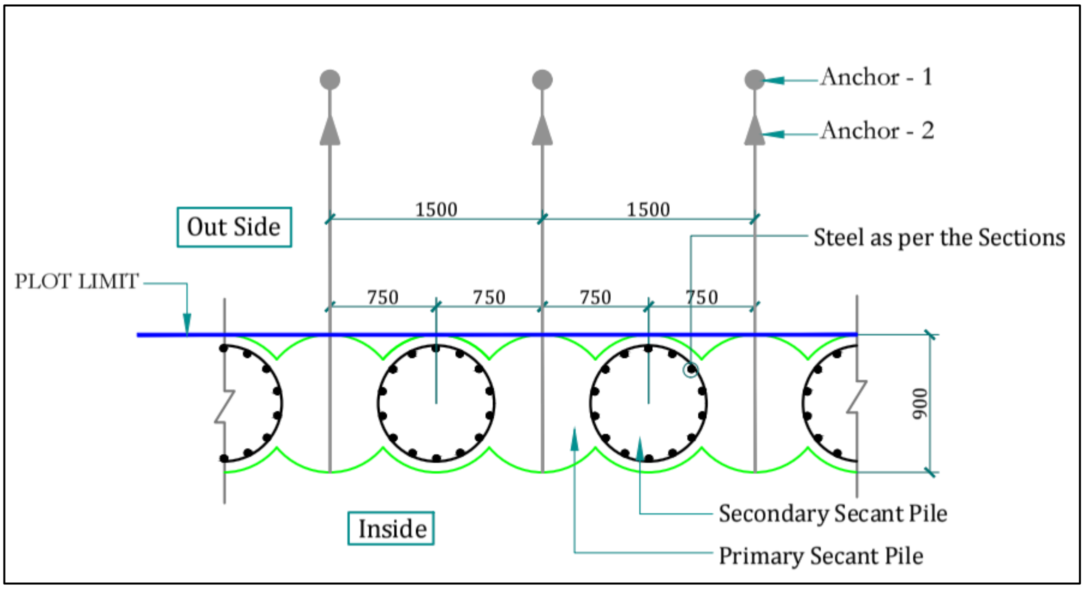


Figure 4: primary and secondary secant pile wall

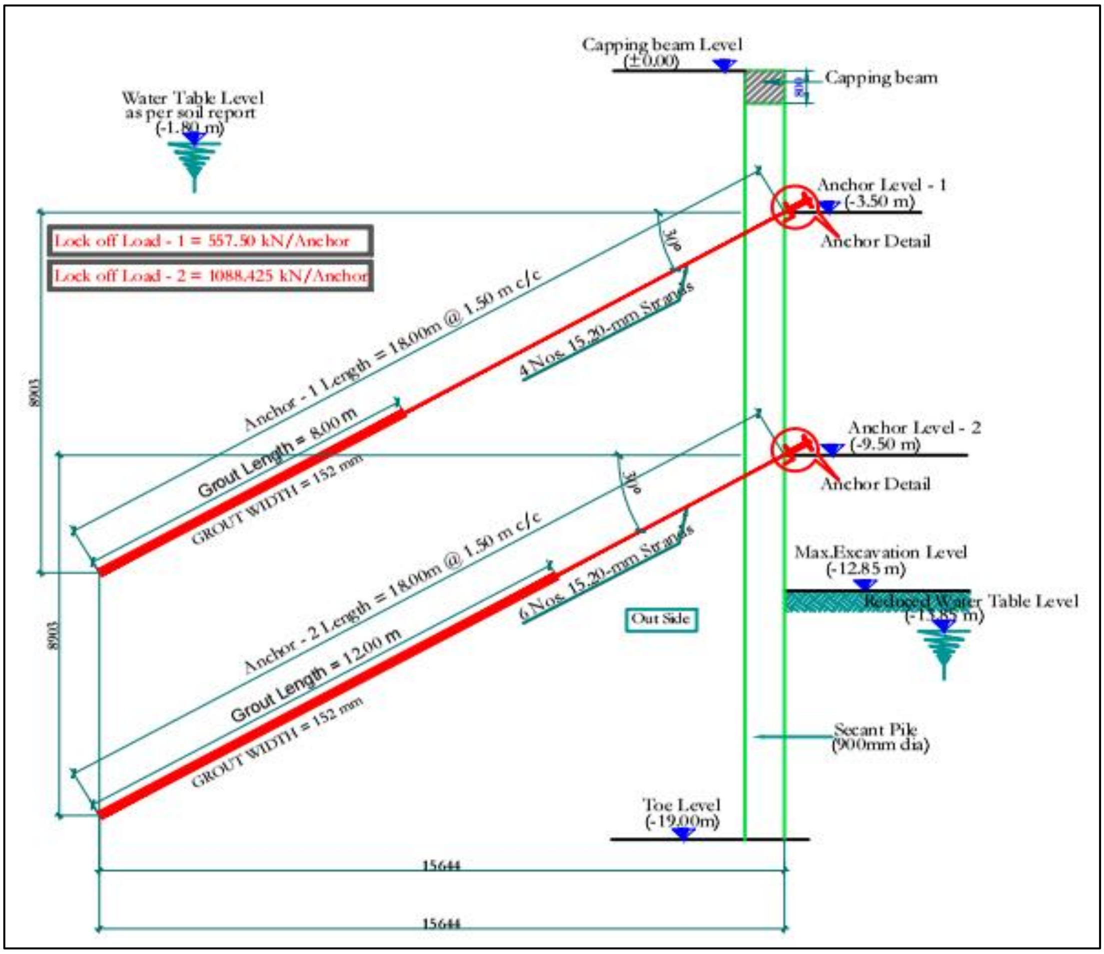


Figure 5: The anchor installation locations

5. Parametric study

In order to gain a thorough understanding of the behavior of the secant pile wall, a study is conducted to investigate the effects of many characteristics by deep Ex. Program. These parameters included factors relating to the wall itself as well as those pertaining to the surrounding soil. For this analysis, the wall located in the Al Dawoodi/Al Mansur District is utilized. We made adjustments to the surcharge load, increasing it to 75 kN/m. It relies on the final site design that is depicted in Figure 6. It is important to note that this wall is situated next to existing buildings.

The variables studied include; effect of excavation stages up to the required depth, Effect of lowering the water level, effect of the diameter of the secant pile wall, effect of overlap between piles, and effect of wall flexural stiffness.

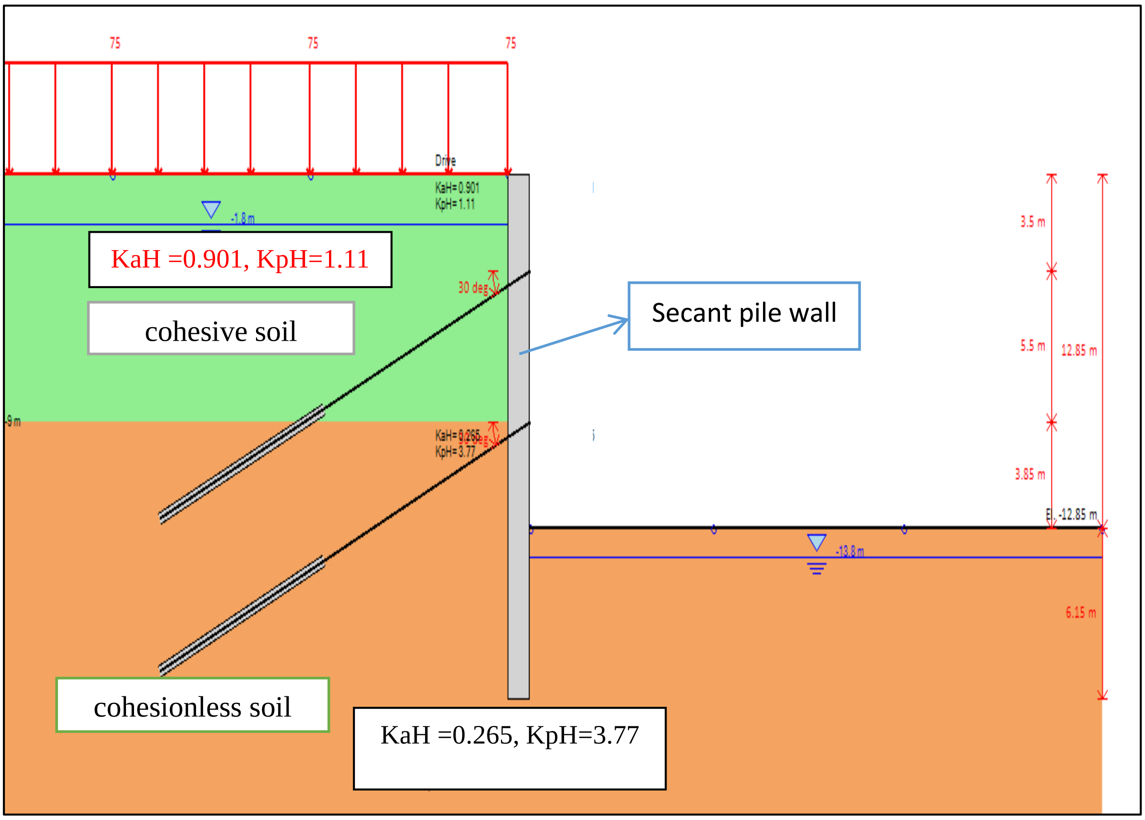


Figure 6: Secant pile wall Al Dawoodi/Al Mansur District

6. Results and discussion

6.1 Effect of excavation stages up to the required depth

Changes in the numbers generated from the analysis conducted using the software we depend on for the design process occur at every stage of the excavation process. An excavation is conducted incrementally until reaching the required depth. Figure 6 illustrates the final design of the excavation process at a depth of -12.85 m, with anchors positioned at two distinct levels (-3.5 m and -9 m) on each side. We employed a range of excavation depths during our inquiry, spanning from -2 m to -12.85 m. At each depth, we documented the records of the lateral wall displacement and the magnitude of the bending moment.

Figures 7 and 8 illustrate the acquired results. Changes in excavation depth led to variations in horizontal displacement and bending moment, as shown by these figures. One crucial observation is that all of the figures display clear displacements at elevations of -4.5 m and -10 m. An excavation was conducted to a depth of -4.5 m without the use of anchors, with the first anchor placed at a depth of -3.5 m. Subsequently, the excavation proceeded till it reached a depth of 10 m before placing the second anchor at a depth of 9 m. Finally, excavation continued until it reached the necessary final depth.

The excavation operation carried out in stages produces outcomes that meet safety criteria. It has been taken into consideration that the wall will be in its final state at an excavation depth of 12.85 m, with two anchor levels at -3.5 m and -9 m. As the excavation depth grows, the horizontal displacement continues to increase, and it remains below the final value attained (0.5933 m) at an excavation depth of -12.85 m (Δh/H=4.617%). A comprehensive set of empirical research was carried out by Moormann [4], further case histories of earth movements of retaining walls were examined. The ground movements occurred due to excavation in soft soil showing undrained shear strength below 75 kPa. It is common for the most significant horizontal wall displacement to be between 0.5%H and 1.0%H, with an average of 0.87%H. This displacement occurs at a depth of z = 0.5H to 1.0H below the earth's surface. According to Ou et al. [13,14], the diaphragm walls and continuous pile walls obtained by the bottom-up approach have an average maximum lateral displacement of 0.4%H. The magnitude of the horizontal displacement found in Taipei case histories is similar to this value. The bending moment value rises with the depth of the excavation up to a maximum of -4.5 m, after which they begin to decrease as the excavation depth increases.

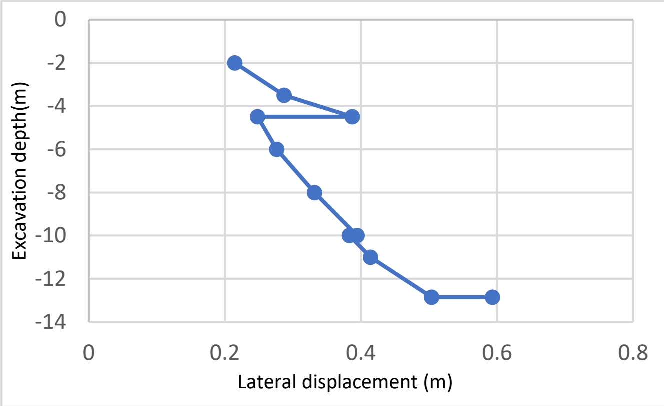


Figure 7: Lateral displacement (m) at different excavation depths

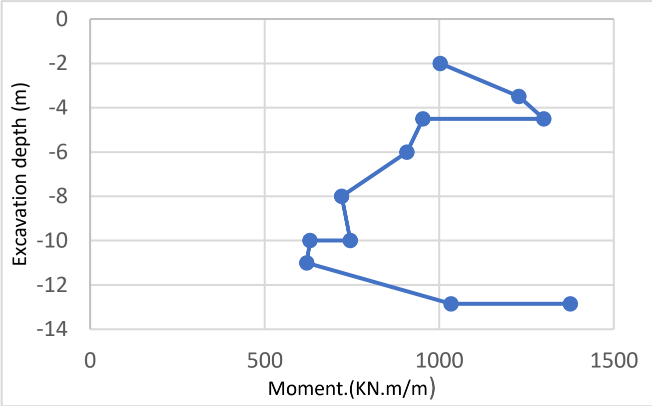


Figure 8: Bending moment (kN.m/m) at different excavation depths

6.2 Effect of water table lowering

The program (Deep Ex.) was utilized to simulate the site conditions and assess various water level reduction scenarios in order to quantify the magnitude of possible changes resulting from this component. Upon successful completion of the analysis, the results shown in Figures (9, 10, and 11) were acquired.

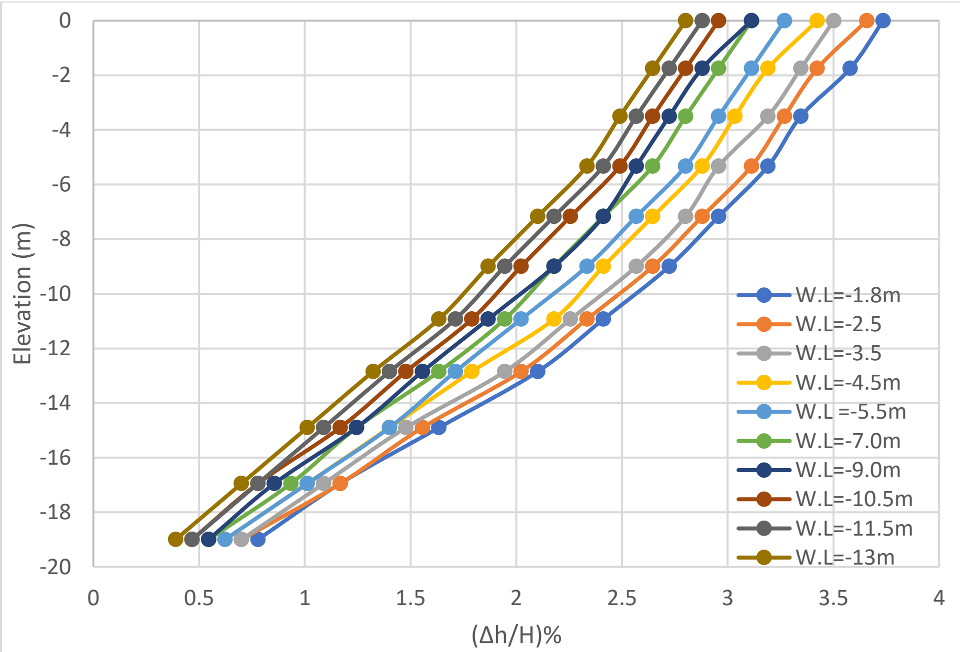


Figure 9: Lateral displacement with the length of the pile at different water levels and excavation depth (-12.85 m)

All of the findings that were obtained, which are depicted in the figures, demonstrate that reducing the water level creates a more favorable and secure environment for the installation of the wall. The horizontal Displacement is shown to be at its greatest near the top of the wall, as shown in Figure 9, and then gradually decreases as one moves deeper inside the wall. The decrease in the water table level in the soil affecting the secant pile wall leads to a reduction in the lateral displacement at the top of the wall. This can be explained by the fact that when the water table is lowered, the pore water pressure in the soil decreases, which increases the effective stress and the soil's shear strength. In this case, the upper layer is clay, which tends to exhibit higher lateral pressure when saturated, while the underlying sandy soil responds more quickly to changes in water content. As the water level drops, the reduction in pore pressure leads to a more stable soil structure and less lateral movement against the wall. As a result of the clayey composition of the soil, the vertical displacement at the soil surface near the wall has decreased slightly, as shown in Figure 10. This can be attributed to the fact that the water level has decreased.

Despite this, such settlement might have a detrimental effect on buildings in the surrounding area. As the water level drops, the values of the bending moment decrease, as shown in Figure 11, due to the fact that we have proved that a lower water level results in lowered stress values on the wall; this is something that is to be anticipated.

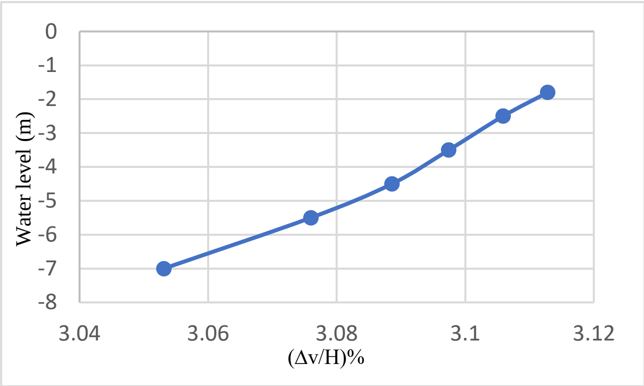


Figure 10: Vertical displacement in the soil surface at different water levels and excavation depth (-12.85 m)

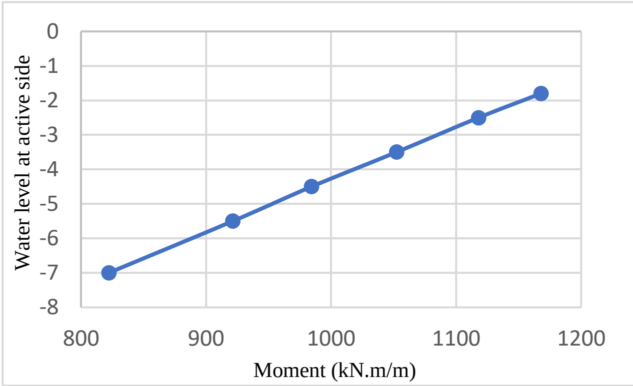
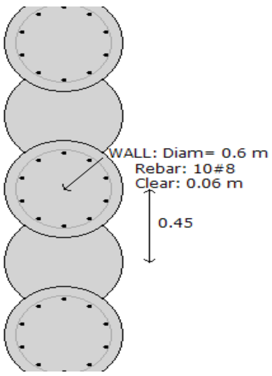


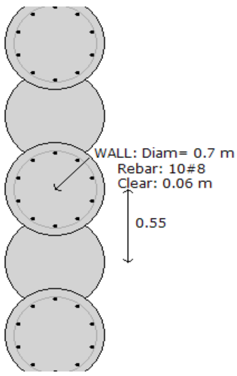
Figure 11: Moment (kN.m/m) at different water levels and excavation depth (-12.85 m)

6.3 Effect of the diameter of the secant pile wall

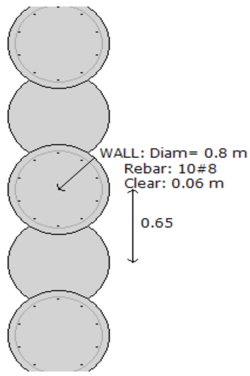
When employing a secant pile wall, it is crucial to assess the diameter of the piles, which is one of the most important factors. Using the same diameter for both primary and secondary piles is a viable option. However, it is also feasible to use different diameters for each type of pile, depending on unique execution conditions and economic factors. In this study, we used the same diameter for both types of piles in the wall. As shown in Figure 12, we employed a range of diameters in this study, including (0.6, 0.7, 0.8, 0.9, 1.0, 1.1, and 1.2) m, with a constant interlock distance of 0.15 m.



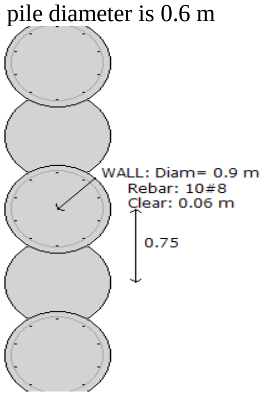
(a) The pile diameter is 0.6 m



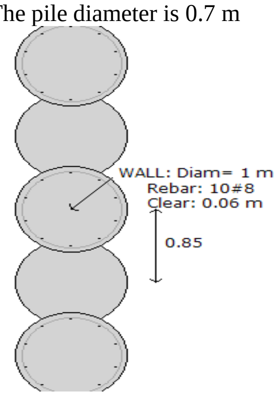
(b) The pile diameter is 0.7 m



(c) The pile diameter is 0.8 m



(d) The pile diameter is 0.9 m



(e) The pile diameter is 1.0 m

Figure 12: Secant Pile Wall Based on Varying Diameters

The aim was to ascertain the impact of the diameter of the piles on the behavior of the wall. We conducted the research via specialized software to determine the influence of alterations in diameter on horizontal displacement, shear force, and bending moment. Figure 13 demonstrates that the maximum lateral movement at the secant pile wall is affected by the pile's diameter; the lateral displacement decreases with the increased diameter of the pile. Figure 14 depicts the correlation between bending moment and changes in diameter. This figure illustrates that an augmentation in diameter leads to an elevation in bending moment, frequently surpassing initial expectations. The study conducted by Mahesh [9] found that expanding the diameter of the pile from 0.6 m to 0.8 m led to a reduction in lateral displacement and an increase in the amplitude of the bending moment in the secondary pile wall.

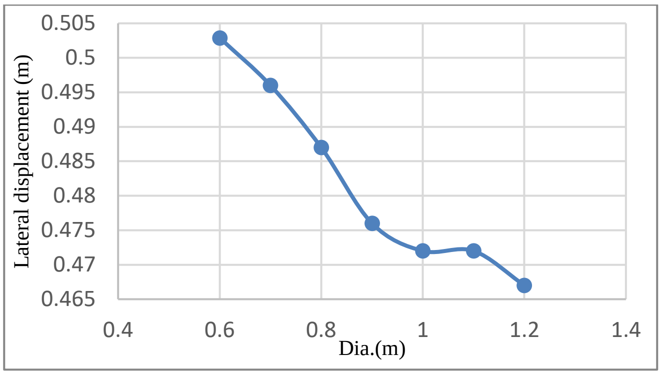


Figure 13: Maximum lateral displacement with diameter of pile

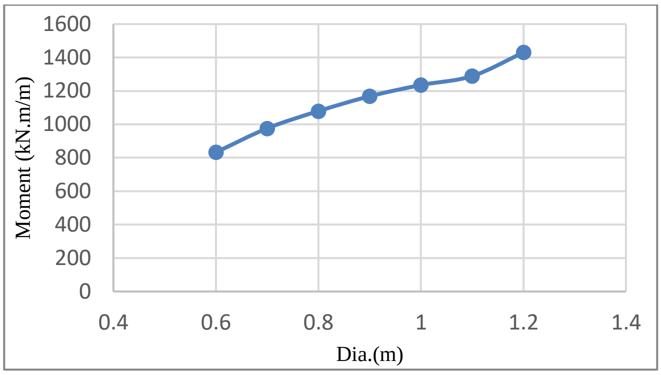


Figure 14: Maximum moment with diameter of pile

6.4 Effect of interlock between piles

For a secant pile wall to effectively prevent water seepage and maintain its structural integrity, the interlock between the primary and secondary piles must be executed precisely. We looked at how the wall performed when the interlock distance was varied as a percentage of the pile diameter (5%, 10%, 15%, 20%, 25%, 30%, and 35%). Table 2 shows that there were no significant changes in lateral displacement as a function of differences in interlock distance. However, we found that the bending moment values went up as the overlap distance went up when we looked at them. The moment resistance increased from 1134.72 kN.m/m to 1209.94 kN.m/m when the overlap distance was increased from 5% to 30% of the pile diameter, as shown in Figure 15.

Table 2: The lateral displacement (m) along the depth of the wall for various overlap values

Elevation (m)	Lateral displacement (m)						
	5% f(Dia.)	**10% (Dia.)**	**15% (Dia.)**	**20% (Dia.)**	**25% (Dia.)**	**30% (Dia.)**	**35% (Dia.)**
0	0.48	0.48	0.48	0.48	0.48	0.48	0.49
-1.75	0.46	0.46	0.46	0.46	0.46	0.46	0.46
-3.5	0.43	0.43	0.43	0.43	0.44	0.44	0.44
-5.33	0.41	0.41	0.41	0.41	0.41	0.41	0.41
-7.17	0.39	0.38	0.38	0.38	0.38	0.38	0.38
-9	0.35	0.35	0.35	0.35	0.35	0.35	0.35
-10.93	0.32	0.31	0.31	0.31	0.31	0.31	0.31
-12.85	0.27	0.27	0.27	0.27	0.26	0.26	0.26
-14.9	0.22	0.21	0.21	0.21	0.21	0.21	0.21
-16.95	0.16	0.16	0.16	0.15	0.15	0.15	0.15
-19	0.09	0.1	0.1	0.1	0.1	0.1	0.1

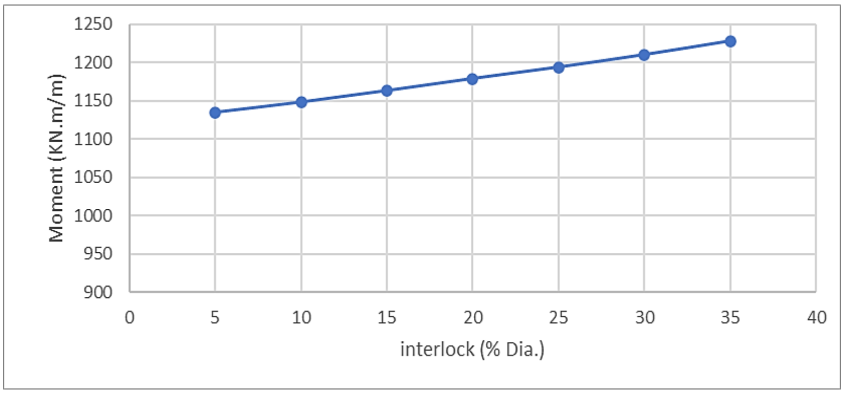


Figure 15: Moment (kN.m/m) with overlap distance

The secondary piles are capable of withstanding greater forces without failure due to the higher compressive strength of the concrete used in them, which enhances the moment resistance. This leads to a stiffening of the wall, making it more resistant to bending moments. The increased moment resistance can be partially attributed to the concrete's ability to endure higher compressive stresses, thereby improving its capacity to resist external loads. Secant pile walls are commonly used to retain soil and resist excavation-induced lateral stresses; in these cases, the main structural load is usually carried by the secondary piles. The wall's resistance to bending and flexural deformation under lateral loads is enhanced by the increased compressive strength of these piles, which in turn raises the wall's total stiffness. Because of the height of the retained soil and the stresses applied by groundwater or surcharge loads, bending moments can be large in deep excavations, making this a particularly essential consideration. The increased overlap did not affect horizontal displacement. Soil characteristics and lateral stresses, in addition to pile bonding strength, are additional variables that impact horizontal displacement.

6.5 Effect of wall flexural stiffness

Table 3 details the main pile's attributes and shows how they differ from those of the secondary pile. The objective of this part is to learn how the features of the secondary pile affect the wall's performance as a whole. Table 4 shows the lateral displacement results from the program, which show that the values of lateral displacement are unaffected by modifications to the secondary pile's properties. Figure 16 shows how the secondary pile's stiffness is improved with respect to the bending moment.

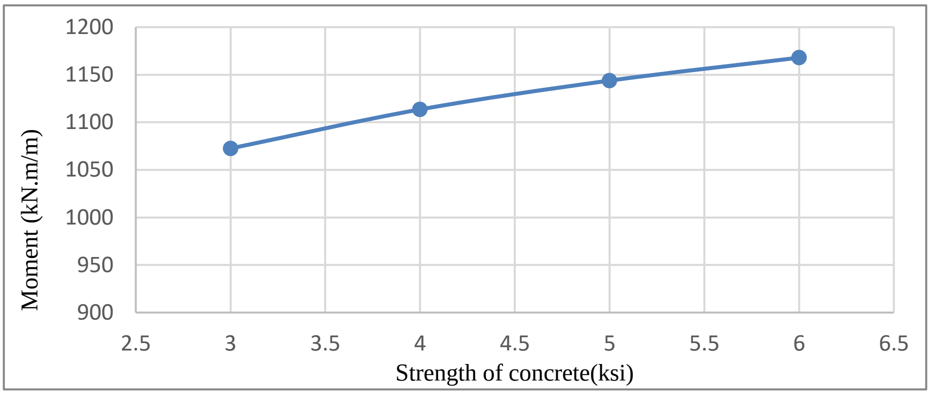


Figure 16: Moment (kN.m/m) with the strength of the secondary pile

Table 3: Properties of concrete used in secant pile wall

Strength (fc−) ksi	Strength (fc−) (N/mm^2)	Elastic (E) (N/mm^2)	Density (kN/m^3)	Tension strength (N/mm^2)	Poisson (υ)
3	20.7	21541.8	23.573	10% (fc−)	0.2
4	27.6	24874.5	23.573	10% (fc−)	0.2
5	34.5	27813.9	23.573	10% (fc−)	0.2
6	41.4	30463.5	23.573	10% (fc−)	0.2

Table 4: The lateral displacement (m) along the depth of the wall for various strengths of secondary pile values

Elevation (m)	Lateral displacement (m)			
	Strength(3ksi)	*Strength(4ksi)*	*Strength(5ksi)*	*Strength(6ksi)*
0	0.47	0.48	0.48	0.48
-1.75	0.45	0.46	0.46	0.46
-3.5	0.43	0.43	0.43	0.43
-5.33	0.41	0.41	0.41	0.41
-7.17	0.39	0.39	0.38	0.38
-9	0.36	0.36	0.35	0.35
-10.93	0.32	0.32	0.31	0.31
-12.85	0.28	0.27	0.27	0.27
-14.9	0.22	0.22	0.21	0.21
-16.95	0.16	0.16	0.16	0.15
-19	0.09	0.09	0.1	0.1

Increasing the compressive strength of the concrete in the secondary piles significantly enhances the moment resistance of the secant pile wall. Specifically, the moment resistance increases from 1072.53kN.m/m to 1167.91kN.m/m as the compressive strength rises from 3 ksi to 6 ksi. The secondary piles, which support most of the wall's weight, help keep it rigid. The wall's resistance to bending and flexural deformation under lateral loads is directly proportional to its compressive strength. With the retained soil at such a high height and the forces from groundwater or surcharge loads being so great, bending moments in deep excavations can be enormous, making this resistance all the more important.

7. Conclusion

The following conclusions have been drawn from the deep excavation analysis using a secant pile wall:

1) As the excavation depth increases, the safety factor against rotation grows smaller, and the lateral displacement at the top of the wall grows larger. To lessen displacement and maximize safety, it is recommended to finish installing anchors. To meet safety criteria during excavation activities, it is essential to incorporate and carefully examine the building approach during the design process.
2) When clay soil is on top of sandy soil, one way to reduce lateral displacement at the wall is to lower the water level on the load side while keeping the excavation depth and water level on the resistant soil side constant. When the water level

is lowered, there is an initial vertical displacement at the ground surface. As the water level drops further, tiny adjustments stabilize the displacement. Moment values and the safety factor against rotation are both reduced as a result of this operation.

3) The lateral displacement reduced, and the magnitude of the bending moment rose in the secant pile wall as the pile diameter expanded from 0.6 m to 1.1 m.
4) The bending moment value of a secant pile wall increases as the overlap ratio between the piles increases.
5) For secant pile walls, raising the secondary pile strength results in a higher bending moment value.

Author contributions

Conceptualization, **A.** Hussein, **M. Mahmood** and **M. Aswad**; data curation, **A. Hussein**, **M. Mahmood** and **M. Aswad**; formal analysis, **A. Hussein** and **M. Mahmood**; investigation, **A. Hussein**, **M. Mahmood** and **M. Aswad**; methodology, **A. Hussein**, **M. Mahmood** and **M. Aswad**; project administration, **A. Hussein**, **M. Mahmood** and **M. Aswad**; resources, **A. Hussein**, **M. Mahmood** and **M. Aswad**; software, **A. Hussein**, **M. Mahmood** and **M. Aswad**; supervision, **A. Hussein**, **M. Mahmood** and **M. Aswad**; validation, **A. Hussein**, **M. Mahmood** and **M. Aswad**; visualization, **A. Hussein**, **M. Mahmood** and **M. Aswad**; writing—original draft preparation, A. Hussein, M. Mahmood and M. Aswad; writing—review and editing, **A. Hussein**, **M. Mahmood** and **M. Aswad**. All authors have read and agreed to the published version of the manuscript.

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Data availability statement

The data that support the findings of this study are available on request from the corresponding author.

Conflicts of interest

The authors declare that there is no conflict of interest.

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