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# EVALUATION OF DESIGN PARAMETER OF DIAPHRAGM WALL FOR COHESIVE & COHESIONLESS- SOIL

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***Abstract:*** - Recent upsurge in infrastructural development and expansion in urban area necessitates productive utilization of underground space. To address this, it is appropriate to adopt diaphragm wall retaining structures. The design and construction of diaphragm walls require greater care and expertise. Unsatisfactory implementation of such structures will adversely affect the performance and cost-effectiveness of entire project. Not many standards are available at present that regulate the specific requirements of diaphragm walls. In this research, different parameter of diaphragm wall is evaluated. As both structural and geotechnical considerations are to be met for deep embedded structures, specifications more than those provided in structural codes should be counted. Based on the research, it is recommended to develop specific analysis and design procedures considering all the requirements of diaphragm walls.

***Index Terms*** **- Diaphragm Wall, Anchor Length, Deep Excavation, Anchor Diameter, Cohesive and Cohesionless soil**

## I. INTRODUCTION

Diaphragm walls are typically constructed in reinforced concrete to provide the required structural capacity, but they may also be designed as unreinforced plastic cut offs. These are watertight structures it can extend to great distances both horizontally and vertically. The construction of the walls minimizes noise and vibration compared to construction of sheet pile walls. Diaphragm walls are typically 20m to 50m deep, but may extend to considerably greater depth. There are two types of diaphragm walls. Temporary and permanent diaphragm walls based on their usage. Temporary diaphragm walls are used only as retaining walls during construction of other permanent structures. The permanent diaphragm wall on the other hand serves both as a retaining wall and as a part of a permanent load bearing structure. Temporary diaphragm walls often require more space on the construction site than the permanent ones. This is because the final structure needs to be built on the inside of the temporary walls, usually few meters from the walls on each side. Therefore, the combination of retaining wall and the final structure with a permanent diaphragm walls become more advantageous in urban areas.

**Fig -1: Anchor Diaphragm Wall**

### 1.1 Concept of Anchor

A prestressed grouted anchor is structural element installed in soil or rock that is used transmit an applied tensile load into ground. Grouted anchors are also referred to as “tiebacks”. The basic components of anchor include: (1) anchorage (2) unbonded length and (3) bond length. The anchorage is the combined system of anchor head, bearing plate, and trumpet that is capable of transmitting the prestressing force from the prestressing steel to ground surface or the supported structure.

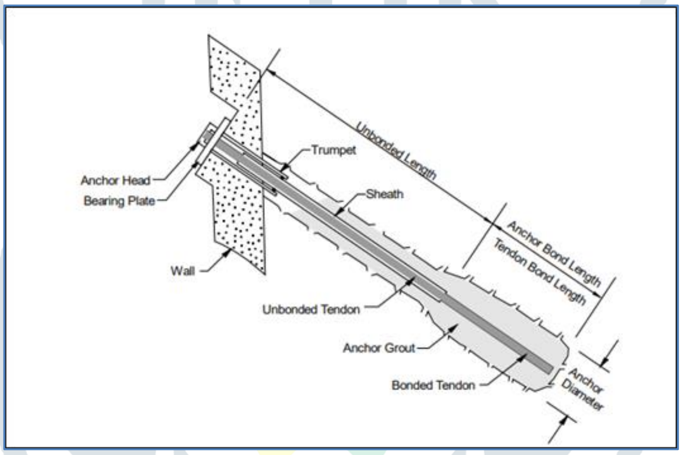


**Fig -2: Component of anchor**

## II. LITERATURE REVIEW

[1] James, A., & Kurian, B. (2020). Design Specifications for Diaphragm Wall: State of the Art. Indian Geotechnical Journal, 50(5), 838–847.

In this research, different structural design codes are evaluated for their application specific for diaphragm walls. The standard consideration for the analysis and design of diaphragm walls includes EN 1997-1, AS 4678, BS 8002, BS 8004, Canadian foundation engineering manual, IS 9556, ACI 318, IS 456, BS 8110, BS EN 1538, CSA A23.3, EN 1992-1-1. Since both geotechnical and structural design criteria are to be considered, uncertainties arise regarding the application of load and resistance factors. The foundation and structural codes of each combination and safety coefficients for lateral pressure, dead loads and live loads. It is advisable to specify a unique design norm to standardize the design and detailing of reinforced concrete diaphragm wall.

[2] Mini, M.., Kurian, D. B., & James, A. (2008). A Theoretical Study on the Analysis of Diaphragm Wall. International Research Journal of Engineering and Technology, 9001(May), 4089.

Diaphragm walls are typically constructed in RCC to provide the required structural capacity. Typical wall thickness varies between 0.6 to 1.1m. Panel width varies from 2.5m to 6m. Diaphragm walls mainly classified into three categories-strutted diaphragm wall, cantilever diaphragm wall, anchored diaphragm wall.

Earth pressure and water pressure have great importance in diaphragm wall design. From the study of Indian standards, there are some uncertainties in field of analysis. Diaphragm wall have greater influence on the adjacent building. There is particular amount of settlement when the building is exposed near to diaphragm wall.

[3] Yajnheswaran, Ranjan, H. S., & Rao, S. (2015). Analysis of the Effect of Anchor Rod on the Behavior of Diaphragm Wall Using Plaxis 3d. Aquatic Procedia, 4(Icwrcoe), 240–247.

Anchor rods may be provided in order to strengthen the structure and to resist the lateral loads and reduce the deflection to a large extent. In this paper the deep draft berth of new Mangalore port provided with diaphragm wall and anchor rods is analyzed using finite element software PLAXIS 3D. The displacement, shear force and bending moment are found out for diaphragm wall for the cases of with and without anchor. The comparison is made on depth V/s bending moment, depth V/s shear force and depth V/s deflection of the diaphragm wall.

The percentage reduction in the displacement of the diaphragm wall due to the presence of anchor rod at 2.5 m is 93.56%, shear force is 18.53% and bending moment is 63.06%. The displacement of the diaphragm wall can be considerably reduced by providing an anchor rod. The provision of an anchor rod at the optimum location will increase the stability of the berthing structure

[4] Helidon Kokona, & Enkeleda Kokona. (2016). Design Concept for an Anchored Diaphragm Wall in the Central Part of Budva, Montenegro. Journal of Civil Engineering and Architecture, 10(7), 806–814.

The concept of an anchored wall system is to create an internally stable mass of soil that will resist external failure modes at an adequate level of safety. The structure is intended for use in the construction of three underground levels of a residential building. The anchored wall will consist of non-gravity cantilevered walls with three levels of ground anchors.

Diaphragm walls with anchored have ability to withstand horizontal pressures without significant increase in wall cross section. It also protection of the excavation base from ground water, uplift pressures and bottom swelling. Anchored continuous diaphragm walls provide minimum noise and vibration levels, which make construction suitable in urban areas.

[5] A.K. Choudhary1, J.N. Jha2, and K. S. G. (2010). Copyright ASCE 2010 GeoShanghai 2010 International Conference GEOTECHNICAL SPECIAL PUBLICATION NO. 205 Copyright ASCE 2010 GeoShanghai 2010 International Conference. ASCE, (204), 34–41.

Shanghai tower have cylinder shaped diaphragm with outer diameter 123.4m, 1.2m thick and 50m in height and excavation depth is 31.1m. The cylinder-shaped diaphragm, by fully utilizing the benefit of high compressive capacity of concrete and cylindrical effect, by transferring the lateral load from underground soil and water will be transferred into lateral centripetal forces. Therefore, no lateral supporting strut is required to be installed during excavation.

Application of larger diameter cylindrical shaped diaphragm wall without lateral supporting strut is not only for economy, but more workable and safer in construction. Analysis of the super-columns were based on the stiffness calculated from the transformed composite section of structural steel and reinforced concrete. Certain Reduction on soil pressure to the cylindrical diaphragm wall can be achieved due to the arching effect, also certain reduction in embedment length of diaphragm wall can be reached, as the stability of soil improved due to cylindrical space effect.

## III. PROBLEM DESCRIPTION

Basically, there are two types of soil are considered for analysis and design- Cohesionless soil and Cohesive soil. For analysis and design of diaphragm wall GEO 5 software is used.

For cohesionless soil silty sand is considered. For cohesive soil sandy silt is considered.

### 3.1 Data input for cohesionless soil:

**Table -1: Soil Parameter for Cohesionless soil**

| Sr. No. | Soil Parameter | Value | Unit |
|---|---|---|---|
| 1 | Unit Weight (ϒ) | 18 | $kN/m^3$ |
| 2 | Angle of internal friction($\Theta_{ef}$) | 29 | Degree |
| 3 | Cohesion of Soil ($C_{ef}$) | 5 | kPa |
| 4 | Angle of friction structure soil | 0 | Degree |
| 5 | Saturated unit weight | 18 | $kN/m^3$ |
| 6 | Saturation | 50 | % |

### 3.2 Data input for cohesive soil:

**Table -2: Soil Parameter for Cohesive soil**

| Sr. No. | Soil Parameter | Value | Unit |
|---|---|---|---|
| 1 | Unit Weight (ϒ) | 18 | $kN/m^3$ |
| 2 | Angle of internal friction($\Theta_{ef}$) | 26.5 | Degree |
| 3 | Cohesion of Soil ($C_{ef}$) | 12 | kPa |
| 4 | Angle of friction structure soil | 0 | Degree |
| 5 | Saturated unit weight | 18 | $kN/m^3$ |
| 6 | Saturation | 50 | % |

### 3.3 Excavation Depth:

For this study following depths are considered:

3m,5 m,7 m,9 m,11 m,13 m,15 m.

## IV. RESULT INTERPRETATION

### 3.1 Result of Cohesion less soil:

**Table -3: Depth in soil, Bending Moment, Shear force and Ast**

| Excavation depth(m) | Thickness of Diaphragm Wall(m) | Depth in soil(m) | Max. Moment (kN-m) | Max. Shear force(kN) | Reinforcement ($mm^2$) |
|---|---|---|---|---|---|
| 3 | 0.5 | 2.13 | 29.85 | 68.13 | 773.5 |
| 5 | 0.5 | 4.21 | 183.86 | 225.62 | 974.2 |
| 7 | 0.5 | 3.17 | 51.25 | 85.70 | 773.5 |
| 9 | 0.5 | 4.91 | 161.39 | 199.94 | 850.2 |
| 11 | 0.5 | 6.11 | 284.63 | 301.85 | 1558.1 |
| 13 | 0.5 | 5.89 | 241.25 | 256.06 | 1304.1 |
| 15 | 0.5 | 7.04 | 374.63 | 363.39 | 2118.7 |

**Table -4: Required Parameter for Anchor**

| Excavation depth(m) | Depth of Anchor (m) | Anchor Force Required (kN) | Free length(m) | Root length(m) | Angle of Anchor (Degree) | Spacing of Anchor (m) |
|---|---|---|---|---|---|---|
| 3 | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - |
| 7 | 3.5 | 231.9 | 5 | 7 | 20 | 2.5 |
| 9 | 3.5 | 342.27 | 5 | 7 | 20 | 2.5 |
| 11 | 4.5 | 548.24 | 6 | 10 | 20 | 2.5 |
| 13 | 4 | 166.09 | 6 | 12 | 20 | 2.5 |
| | 8 | 854.71 | 4 | 12 | 20 | 2.5 |
| 15 | 4.5 | 187.05 | 8 | 12 | 20 | 2.5 |
| | 9 | 1182.15 | 6 | 12 | 20 | 2.5 |

### 3.2 Result of Cohesive soil:

**Table -5: Depth in soil, Bending Moment, Shear force and Ast**

| Excavation depth(m) | Thickness of Diaphragm Wall(m) | Depth in soil(m) | Max. Moment (kN-m) | Max. Shear force(kN) | Reinforcement (($mm^2$) |
|---|---|---|---|---|---|
| 3 | 0.5 | 1.48 | 19.64 | 53.85 | 771.8 |
| 5 | 0.5 | 3.29 | 122.05 | 168.80 | 771.8 |
| 7 | 0.5 | 2.93 | 52.81 | 97.46 | 771.8 |
| 9 | 0.5 | 4.41 | 168.77 | 174.12 | 890.7 |
| 11 | 0.5 | 5.75 | 285.33 | 274.47 | 1562.3 |
| 13 | 0.5 | 5.65 | 204.06 | 246.54 | 1087.0 |
| 15 | 0.5 | 6.89 | 422.4 | 337.63 | 2426.3 |

**Table -6: Required Parameter for Anchor**

| Excavation depth(m) | Depth of Anchor (m) | Anchor Force Required (kN) | Free length(m) | Root length(m) | Angle of Anchor (Degree) | Spacing of Anchor (m) |
|---|---|---|---|---|---|---|
| 3 | - | - | - | - | - | - |
| 5 | - | - | - | - | - | - |
| 7 | 3.5 | 180.82 | 5 | 7 | 20 | 2.5 |
| 9 | 3.5 | 280.96 | 5 | 7 | 20 | 2.5 |
| 11 | 4.5 | 475.79 | 6 | 10 | 20 | 2.5 |
| 13 | 4 | 150.34 | 6 | 12 | 20 | 2.5 |
| | 8 | 782.89 | 4 | 12 | 20 | 2.5 |
| 15 | 4.5 | 165.29 | 8 | 12 | 20 | 2.5 |
| | 9 | 1128.72 | 6 | 12 | 20 | 2.5 |

## V. CONCLUSION

- Depth of d-wall required in soil is less in cohesive soil compared to cohesion less soil.
- Anchor force required in cohesive soil is less compared to cohesion less soil. So, Diaphragm wall provide more resistance in case of cohesive soil compared to cohesion less soil.
- Maximum area of steel required is 16.64% more in cohesion less soil compared to cohesive soil.
- Maximum value of bending moment is 15.35% more in cohesion less soil compared to cohesive soil.
- Maximum value of shear force is 25.18% more in cohesion less soil compared to cohesive soil.
- Maximum change in depth in soil is 30.5% more in cohesion less soil compared to cohesive soil.
- Maximum change observed in anchor force is 22.02% more in cohesion less soil compared to cohesive soil.

## REFERENCES


[1] Yajnheswaran, Ranjan, H. S., & Rao, S. (2015). Analysis of the Effect of Anchor Rod on the Behavior of Diaphragm Wall Using Plaxis 3d. Aquatic Procedia, 4(Icwrcoe), 240–247.

[2] Mini, M.., Kurian, D. B., & James, A. (2008). A Theoretical Study on the Analysis of Diaphragm Wall. International Research Journal of Engineering and Technology, 9001(May), 4089.

[3] James, A., & Kurian, B. (2020). Design Specifications for Diaphragm Wall: State of the Art. Indian Geotechnical Journal, 50(5), 838–847.

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[5] Helidon Kokona, & Enkeleda Kokona. (2016). Design Concept for an Anchored Diaphragm Wall in the Central Part of Budva, Montenegro. Journal of Civil Engineering and Architecture, 10(7), 806–814.

[6] IS 9556.Code of Practice for Design and Construction of Diaphragm Walls. New Delhi: Indian Standards Institution; 1980

[7] IS 456. Code of Practice for Plain and Reinforced Concrete. New Delhi: Indian Standards Institution; 2000.