iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 4 **Issue:** XII **Month of publication:** December 2016

DOI:

Volume 4 Issue XII, December 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Section Optimization of Diaphragm Wall

Ashok V M[1], Dr. Babu Kurian[2], Merin Mathews[3], Anu James[4]
[1]M.Tech student CE, [2] Principal, [3]Asst Professor CE, Ph.D. Scholar
[1 3 4]M.A College of Engineering, Kothamangalam [2]Holy Kings College of Engineering and Technology
MG University, Kerala

***Abstract*— Diaphragm wall is common type of earth retention system. Diaphragm walls are generally used in deep basement of building, congested urban spaces, riverfront structures and marine structures. The stability is provided through an embedment of the wall on the ground, working as a cantilever structure and may be with a system of anchors, so the wall is subject to shear stresses and bending moments.**

Study aims to find an optimal section for a diaphragm wall considering variations in many of its design parameters to suit the soil conditions and depth of excavation. The effects of variations of these design parameters will be compared to get an optimized section. The parameters which are selected for the study are panel shape, panel thickness, and maximum panel length and panel width and soil conditions. Comparison has to be done with the bending moment and head displacement for different diaphragm wall shapes, panel width and panel thickness using SAP2000 software. 1st studied the effect of diaphragm wall by changing panel length as 2.5m, 3.5m, 4.5m and 5.5m and panel thickness as 0.6m, 0.8m and 1.1m for both rectangular section and T section. 2nd study is about the effects while changing the depth of the web in the T section.

***Keywords*—diaphragm wall, soil pressures**

I. INTRODUCTION

Diaphragm wall is a very a very common type of earth retention system in deep excavation/foundation, weak/poor soil condition or congested site condition. They are generally used in deep basement of building, congested urban spaces, underground structures of metro trains, riverfront structures and marine structures. The stability of diaphragm wall is provided through an embedment of the wall on the ground working as a cantilever structure and a system of anchors. It is generally a reinforced concrete wall which can be used to transfer lateral loads like earth pressure, hydrostatic pressure, earthquake loads etc.

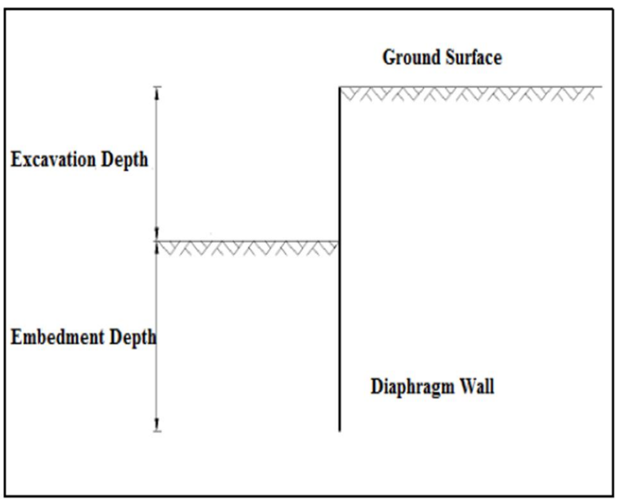


Fig 1 Diaphragm wall

Diaphragm wall provide structural support and water tightness. These reinforced concrete diaphragm walls are also called Slurry trench walls due to the construction technique where excavation is made possible by filling and keeping the wall cavity full with bentonite-water mixture during excavation to prevent collapse of vertical excavated surfaces. These are also used as a permanent basement wall. Typical wall thickness varies between 0.6 to 1.1m. The wall is constructed panel by panel in full depth. Panel width varies from 2.5m to about 6m. The design considerations for a diaphragm wall include panel size and shape, number and type of joints, support spacing, subsoil conditions, reinforcing methods etc. The stability is provided through an embedment of the wall on the ground working as a cantilever structure and eventually a system of anchors, so the wall is subject to shear stresses and bending

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

moments. One of the main benefits is the minimization of used material, in contrast to the needs of rigid retaining structures. For the study is focus on the optimization of design of diaphragm wall system. For that comparison is done for the value of bending moments and structural displacements for different wall heights, thickness, panel width and shapes .The analysis of a flexible diaphragm wall is a classic example of interaction soil structure. The interaction between the soil and the structure depends on the applied load of the soil and the reaction of the structure. Design of diaphragm walls requires experience and understanding of the principles of both soil mechanics and structural engineering. A proper design must allow for the knowledge of the properties of the soil (geologic profile, groundwater, geotechnical parameters) and for the presence of whatever boundary conditions exist: neighboring buildings, facilities and surcharge loads. Objective of the study is to find the optimized section of the diaphragm wall for a particular soil condition and for a particular depth.

II. METHODOLOGY

The analysis of a flexible diaphragm wall is a classic example of interaction soil-structure. The interaction between the soil and the structure depends on the applied load of the soil and the reaction of the structure. Lateral pressure acting behind the sheeting wall is contributed majorly by soil mass and ground water pressure. Their distribution has been recommended by many investigators and verified by field studies, but actual pattern somewhat varies widely with the retaining system adopted and deflection of sheeting occurred. However, for a very rigid wall with a condition that only a little deflection is allowed to occur, the K_0 condition may be the most critical state. Probably the most commonly used design loading pattern for braced wall proposed by Terzaghi and Peck (1967), is a trapezoidal pressure distribution with a value close to K_0 state at upper portion and approximately to 80% of K_0 condition at lower portions.

Lateral earth pressure is a significant design element in a number of foundation engineering problems. Underground structures require a quantitative estimate of the lateral pressure on a structural member for the either a design or stability analysis. The lateral earth pressure is of three types At rest, active and passive. The lateral earth pressure acting on the either side of the wall is computed using Rankin's analysis.

A. Soil in Active side

The active earth pressure coefficient is given by,

$$K_a = \frac{1 - sin\emptyset}{1 + sin\emptyset}$$

The active earth pressure is given by,

$$P_a = K_a.\gamma.h - 2C.\sqrt{K_a} + K_a.q$$

As the plot is located in a congested area and there are chances that heavy loads due to moving machineries can increase in the earth pressure acting on the retaining wall, the surcharge loads has to be considered in the analysis and design. But the exact calculation of the actual surcharge is difficult. Hence it can be assumed that the soil is stressed to the maximum. This consideration can be assumed to be on the safer side as if the overburden pressure increases beyond the safe limit of pressure the soil will fail in shear. The safe pressure considering the shear failure of the soil is the safe bearing capacity of the soil. In failure of the soil can be by general shear failure, local shear failure or by punching shear failure.

B. Soil in Passive side

The soil in the passive side is assumed to behave as a series of springs. So the diaphragm wall behaves as a beam resting on elastic foundation. The spring constants of these soils springs can be computed by various methods. Here, vesic equation has been considered for the calculation of the soil subgrade modulus and spring constants can be calculated from these subgrade reaction coefficients. The smaller the discrete elements used during the analysis of the wall below the excavation the more refined the analysis will be. So 0.5m long elements can be considered for the modeling of the wall below the excavation.

The Vesic's equation is,

$$K_s' = 0.65 \times \sqrt[12]{\frac{E_S.B^4}{E_f.i_f}} \times \frac{E_s}{1 - \mu^2}$$

Volume 4 Issue XII, December 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

$$K_s = \frac{K'_s}{B}$$

The following formulae are used to calculate the individual spring constants,

1) *Top spring value*

$$K_t = \frac{BL}{24}(7K_{s1} + 6K_{s2} - K_{s3})$$

2) *Intermediate spring value*

$$K_i = \frac{BL}{12}(K_{s\,i-1} + 10K_{s\,i} + K_{s\,i+1})$$

3) *Bottom spring value*

$$K_n = \frac{BL}{24}(7K_{s\,n} + 6\,K_{s\,n-1} - K_{s\,n-2})$$

The water pressure should be computed and applied at all depths below the water table. It gives a triangular pressure variation, with zero at the top and $P_w$at the bottom. Analysis has to be done using the above determined earth pressure and soil spring constants and by using SAP2000 software. SAP2000 is the most reliable package used for analysis purposes for diaphragm walls. Codes used are IS 456-2000 and IS 9556-1980.

III. ANALYSIS

A. Soil Report

For the analysis purpose, earth pressure and soil spring constants are calculated according to the soil data collected from a site at Ernakulum.

Table 1 SOIL REPORT

LEVEL (m)	SPT (N)	Types of Soil	Bulk Density	Saturated unit weight	Cohesion	Angle of Friction
0	2	Silty sand	16	18	0	28
-2	2	Very soft clay	14	16	13	0
-4	5	Medium stiff clay	16	18	33	0
-6	2	Very soft clay	18	20	13	0
-8	6	Medium stiff clay	18	20	40	0
-10	7	Medium stiff clay	18	20	46	0
-18	16	Very stiff clay	18	20	106	0
-22	13	Clayey sand	18	20	0	30

1) *Surcharge Calculation:* Surcharge load is calculated for the condition that the soil is stressed to its maximum. The ultimate bearing capacity of the soil,

$$q_{ult} = c.N_c.S_c + q,N_q + 0.5B.\gamma.N_\gamma.S_\gamma$$

The surcharge on the retention side of the wall is taken as 50 kN/m^2, considering the effect of nearby buildings and heavy machineries used for construction.

2) *Earth Pressure Calculation:* Earth pressure on active side of the diaphragm wall is calculated by using the Rankines theory. Earth pressure is obtained for 2m, 4m, 6m, 8m, 10m, 18m and 22m depth as the cohesion or angle of friction of the soil changes.
3) *Calculation of Spring Constants:* For the calculation of spring constant by using Vesic's equation modulus of subgrade reaction is found for every 0.5m depth of soil. Then by using the values of modulus of subgrade reaction values of spring constants are obtained.

Volume 4 Issue XII, December 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Table 2 Modulus of subgrade reaction at 0.5m intervals

Depth below the excavation level (m)	Modulus of Subgrade Reaction K_s
0.5	2700
1	2700
1.5	2700
2	2700
2.5	2700
3	2700
3.5	2700
4	2700
4.5	2700
5	2700
5.5	2700
6	2700
6.5	2700
7	2700
7.5	2273
8	2273
8.5	2273
9	2273
9.5	2273
10	2273
10.5	2273
11	2273

Table 3 Spring constant at 0.5m Interval.

Depth below the excavation level (m)	Spring Constant K_s
0.5	675
1	1350
1.5	1350
2	1350
2.5	1350
3	1350
3.5	1350
4	1350
4.5	1350
5	1350
5.5	1350
6	1350
6.5	1350
7	1332.21
7.5	1154.29
8	1136.5
8.5	1136.5
9	1136.5
9.5	1136.5
10	1136.5
10.5	1136.5
11	568.25

Volume 4 Issue XII, December 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

4) *Modelling:* For analyzing diaphragm wall, modeling has been done for different sections, such as T section and Rectangular section in SAP2000 software. For a particular depth of wall and for a particular soil conditions different models were made by changing the thickness, width of the panel and by changing the depth of the web.

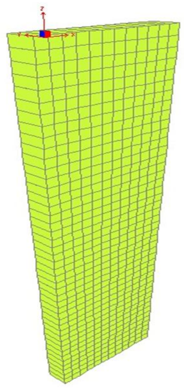


Fig 2 Rectangular Section

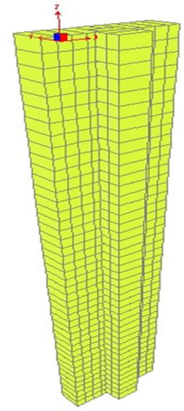


Fig 3 T- Section

IV. RESULTS

A. Rectangular Section

Table 4 Deflection and Bending Moment for Rectangular Section

Model	Deflection (m)	Bending Moment (kNm)
2.5 R 0.6	1.7253	460.8355
2.5 R 0.8	1.1714	472.2875
2.5 R 1.1	1.0908	479.0571
3.5 R 0.6	2.3003	614.3198
3.5 R 0.8	1.5619	629.8394
3.5 R 1.1	1.2105	638.8843
4.5 R 0.6	2.3004	614.3621
4.5 R 0.8	1.5619	629.9002
4.5 R 1.1	1.2105	638.9544

From the table, it is clear that as thickness increases, deflection decreases. This is because with increase in thickness, stiffness of the member will increase which reduces the deflection. By considering the bending moments it is clear that with increasing width of the panel, bending moment increases. This is simply because with increase in width, the load carrying area increases, which therefore increases bending moment. Hence considering above results we can infer that model with 1.1m thickness and 2.5m panel width (2.5R1.1) is the most optimum.

1) *Section*

Table 5 Deflection and Bending Moment for T-Section

Model	Deflection (m)	Bending Moment (kNm)
2.5 T 0.6	1.1672	133.8362
2.5 T 0.8	1.1121	179.9209
2.5 T 1.1	1.0675	251.3374
3.5 T 0.6	1.1336	139.1248
3.5 T 0.8	1.0911	176.6262
3.5 T 1.1	1.0568	237.5878
4.5 T 0.6	1.2559	242.6292
4.5 T 0.8	1.1633	294.6489
4.5 T 1.1	1.0898	368.0277
5.5 T 0.6	1.3152	321.1664
5.5 T 0.8	1.1955	370.9447
5.5 T 1.1	1.1031	436.3838

Volume 4 Issue XII, December 2016
ISSN: 2321-9653

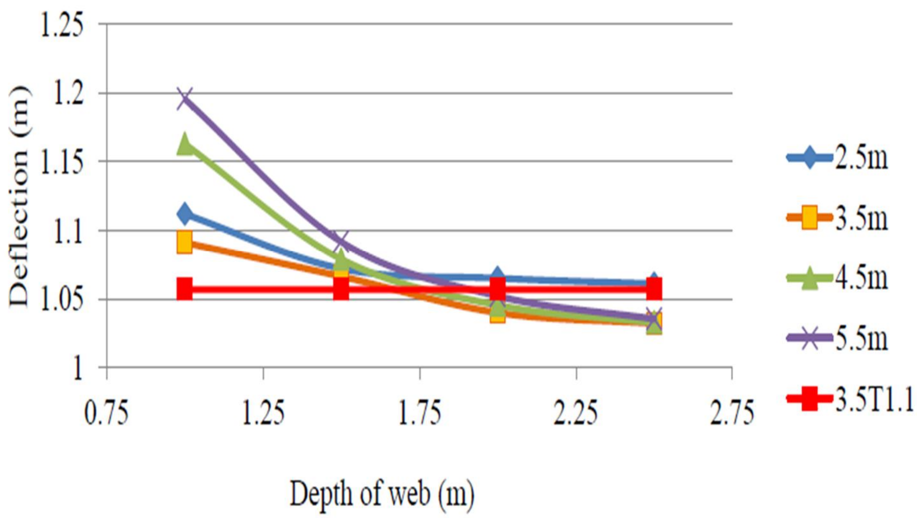
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

On comparing the different deflections from various models, it is clear that for 1.1m thickness, deflection is least. This is simply due to the fact that with increase in thickness, stiffness of the member increases, which will reduce deflection and there is a dip in bending moment at 3.5m panel width. Therefore, the model with 1.1m thickness and 3.5m panel width (3.5T1.1) is the most optimum model.

2) *Effect of web depth:* From the above results, the optimum T-section is found out as 3.5T1.1. For this section, web depth has been varied to analyze its effect on deflection and bending moment for different web thickness.

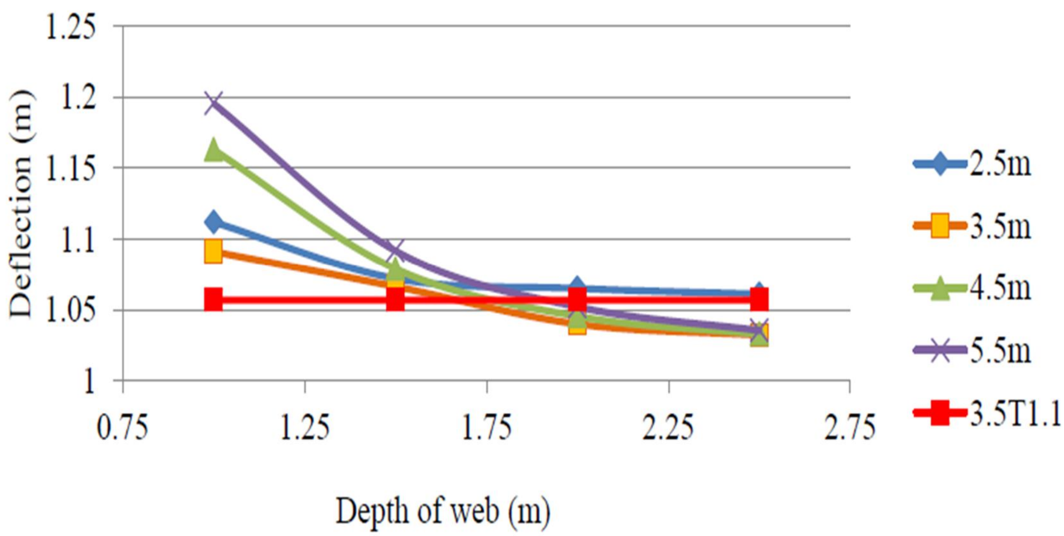
For 0.6m thick panels,

Graph 1 Variation of deflection for T-Section with change in depth of webfor 0.6m thickness



3.5T1.1 is considered as the optimized section for the given conditions which has the minimum deflection of 1.056m. From the graph we can see some values are lying below the 35T1.1 line. Those are the models 3.5T0.6 (2), 3.5T0.6 (2.5), 4.5T0.6 (2.5) and 5.5T0.6 (2.5).For 0.8m thick panels,

Graph 2 Variation of deflection for T-Section with change in depth of webfor 0.8m thickness

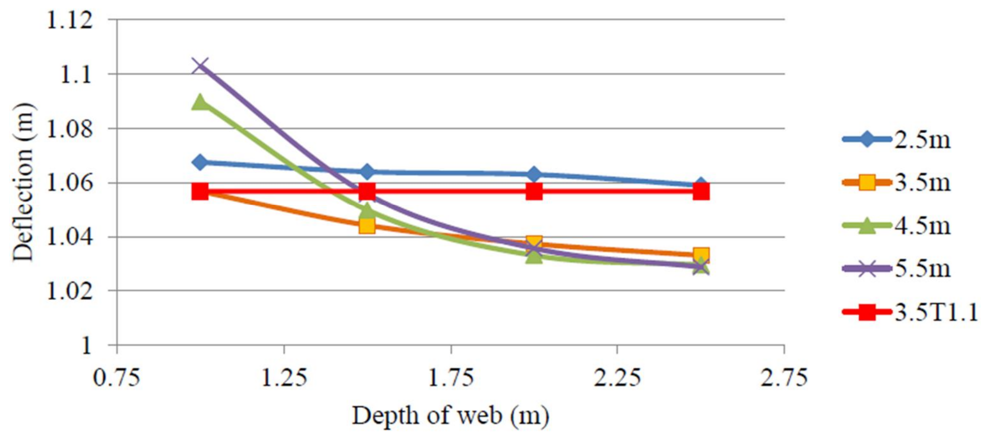


The models having values less than the value of 3.5T1.1 section are 3.5T0.8 (2), 3.5T0.8 (2.5), 4.5T0.8 (2), 4.5T0.8 (2.5), 5.5T0.8 (2) and 5.5T0.8 (2.5).

For 1.1m thick panels,

Volume 4 Issue XII, December 2016
ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Graph 3 Variation of deflection for T-Section with change in depth of webfor 1.1m thickness

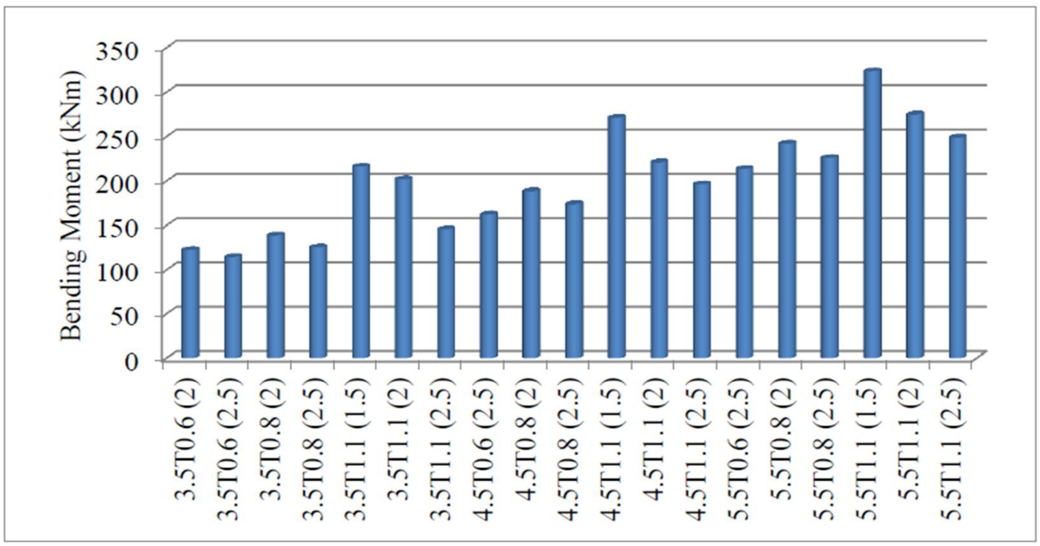


The models having value less than the value of 3.5T1.1 section are 3.5T1.1 (1.5), 3.5T1.1 (2), 3.5T1.1 (2.5), 4.5T1.1 (1.5), 4.5T1.1 (2), 4.5T1.1 (2.5), 5.5T1.1 (1.5), 5.5T1.1 (2) and 5.5T1.1 (2.5).

So as the depth of the web increases deflection and bending moment decreases. Since for both 3.5T0.6 (2.5) and 5.5T1.1 (2.5) has lesser deflection than the optimum section, 3.5T0.6 (1) then we can say that by increasing web depth of the T shaped diaphragm wall, thickness of the section can be decreased and flange width of the section can be increases with in a limit. So an economic section with lesser thick wall or with wide flanges can be used if there is extra space for the web.

To find the optimum section, bending moments of the shapes which have lesser deflection than 3.5T1.1 is considered.

Graph 4 Variation of bending moment for T-Sections with lesser deflectionthan 3.5T1.1 section



On comparing the values of the bar chart, as the thickness of the section increases BM increases. Also as the depth of web increases BM decreases and as the flange width increases BM increases. The model with lesser BM from above all value is 3.5T0.6 (2.5). Therefore, the model with width of flange 3.5m, thickness 0.6m and depth of flange 2.5m is considered as the optimum section.

V. CONCLUSION

The conclusions obtained by the study on Section optimisation of diaphragm wall are,

A. To find an optimal section for a diaphragm wall, variations of design parameters are considered and modelling is done with a rectangular section and a T section only for the particular soil condition and particular depth.

B. From evaluating the results, if plot area is not an issue, 3.5T1.1 (1.1m thick, 3.5m panel width) is the most optimum. Otherwise, 2.5R1.1 (1.1m thick, 2.5m panel width) is the most optimum section.

C. By considering the variation of the web depth, section 3.5T0.6 (2.5) (3.5m panel width, 0.6m thick and 2.5m depth of web) is considered as the optimum section.

REFERENCES

[1] Paolo Gazzarrini, P.Eng (2006), Diaphragm Walls: A Solution For Deep Excavations In Difficult Soil Conditions With Superficial Water Table, Sea To Sky Geotech Inc, West Vancouver, BC.

[2] A. Totsev (2006), Numerical analysis of anchored diaphragm walls (Relationship between FEM and SRM), University of ACEG – Sofia.

[3] Jamshid Sadrekarimi, Maryam Akbarzad (2009), Comparative Study of Methods of Determination of Coefficient of Subgrade Reaction, Department of Geotechnical Engineering, University of Tabriz, Tabriz, Iran.

[4] Nicoleta-Maria Ilies, Vasile-StelianFarcas, Marius Pop (2014), Design optimization of diaphragm wall, 8th International Conference Interdisciplinary in Engineering, INTER-ENG 2014, 9-10 October 2014, Yirgu-Mures, Romania.

[5] Yajnheswaran B, Akshay P.R, Rajasekaran C, Subba Rao, (2015), Effect of Stiffness on Performance of Diaphragm Wall, 8th International Conference on Asian and Pacific Coasts.

[6] Parth D Shah, Prof. Binita A Vyas (2015) Parametric Study of Diaphragm Wall, IJSTE - International Journal of Science Technology & Engineering , Volume 1, Issue 11.

[7] RadhikaBhandary, Asha U Rao, Narayan Sabahith, Nischitha.P.R (2015), Optimization of anchored diaphragm RCC wall in c- φ soil using genetic algorithm, International Journal of Technical Research and Applications.

[8] Z.L.Wan, Y.Yuan, C.F.Lee (2015), Genetic algorithm for optimizing retaining structure in soft ground excavation, The University of Hong Kong Libraries, University of Honk Kong.

[9] IS 9556 – 1980, "Code of practice for Design and construction of diaphragm wall", Bureau of Indian Standards, New Delhi

[10] IS 456 : 2000, "code of practice of plain and reinforced concrete ", Bureau of Indian Standards, New Delhi

[11] IS 1498 : 1970, "classification and identification of soils of general engineering purpose", Bureau of Indian Standards, New Delhi