International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 08 Issue: 03 | Mar 2021 www.irjet.net p-ISSN: 2395-0072

PERFORMANCE EVALUTION OF CANTILEVER RETAINING WALLS WITH RELIEF SHELVES

Chethan D. V[1], Thejaswini R M[2], L. Govindaraju[3]

[1]*P.G Student, Department of Civil Engineering, U.V.C.E, Bangalore University, Jnana Bharathi Campus, Bengaluru.*
[2]*Research scholar, Department of Civil Engineering, U.V.C.E, Bangalore University, Bengaluru.*
[3]*Professor, Department of Civil Engineering, U.V.C.E, Bangalore University, Jnana Bharathi Campus, Bengaluru.*

Abstract - *The present study focus on the provision of shelves on the cantilever retaining wall which may reduce the thickness of the stem of the wall and thus resulting in cost reduction. Parametric study is carried out to find the effect of number of shelves, width of shelves, shelf position and variation in the length of shelves, displacements and the maximum bending moment on the wall with and without relief shelves. Reduction in lateral thrust due to provision of relief shelve reduces the bending moment at the stem bottom.*

The study reveals that in the cantilever retaining wall the best location for the single shelve is observed to be in between 0.5h (h = height of stem) for the maximum reduction in earth pressure, reduced bending moments and deflection. Deflection and bending moment of the stem is reduced by about 40% and 44% by providing shelf at 0.5h and length of shelve up to the shear failure plane than the without shelve. Cross sectional area of the retaining wall can be reduced up to 30% by providing shelve at the 0.5h. The best location for the double shelves is observed to be in between 1/3 h and 2/3h for the maximum reduction in earth pressure, reduced bending moments and deflection. Deflection and bending moments of the stem is reduced by about 70% and 65% by providing shelve at 1/3h and 2/3h, length of shelfs are up to shear failure plane.

***Key Words*: Cantilever retaining wall, pressure relief shelves, Earth pressure.**

1. INTRODUCTION

Retaining wall is a structure designed and constructed to resist the lateral pressure of soil when there is a desired change in ground elevation that exceeds the angle of repose of the soil. Cantilever retaining wall with pressure relief shelves is considered as a special type of retaining wall. The concept of providing pressure relief shelves on the backfill side of a retaining wall reduces the total earth pressure on the wall, which results in a reduced thickness of the wall and ultimately in an economic design of a cantilever wall.

Darshan and Keerthi Gowda (2016), Chauhan and Dasaka (2016), Chougule et.al (2017), Hany F. Shehata (2016) have been carried out studies on the retaining wall with relief shelves by maintaining constant length of shelve. Not have many studies have been carried out to explore the effect of the length of the relief shelve on the lateral earth pressure distribution on the retaining wall.

2. SCOPE AND OBJECTIVES

- Propose of work involves modelling and analysis of retaining wall with and without relief shelve by using numerical tool SAP2000.
- The effects of relief shelve with its location and length on the earth pressure distribution is estimated.
- To find the deflection and bending moment of the cantilever retaining wall by providing relief shelves.
- To assess the stability of the cantilever retaining wall by providing relief shelves.
- To find the reduction in lateral earth pressure on the retaining wall by providing relief shelves.
- To optimize the cross section of the retaining wall by providing relief shelves.

3. ANALATICAL CALCULATION

Cantilever retaining wall without relief shelve at mid height of stem:
Height of backfill to be supported (H) = 8m, 10m, 12m.
Unit weight of soil (γ) = 18kN/m^3
Angle of internal friction of soil (ϕ) = 30^0
Coefficient of friction at base = 0.5
Bearing capacity of soil (q_f) = 200kN/m^2
Grade of concrete M_{25} and steel F_e500
Depth of foundation =1.5m
Base width (B) = 4m, 5m, 6m.
Thickness of stem (T_o) = 0.7m, 0.9m, 1m.
Thickness of base slab (T_b) = 0.7m, 0.9m, 1.1m.
Height of stem (h) = 7.3m, 9.1m, 10.9m.
Coefficient of active earth pressure K_a= (1-sinϕ)/ (1+sinϕ) =0.33
Cantilever retaining wall with relief shelve at mid height of stem:
Height of backfill to be supported (H) = 8m, 10m, 12m.
Base width (B) = 3.5m, 4.5m, 5m.
Thickness of stem (T_o) = 0.4m, 0.5m, 0.7m.
Thickness of base slab (T_b) = 0.6m, 0.7m, 0.8m.
Height of stem (h) = 7.4m, 9.3m, 11.2m.
Projection of relief shelve towards heel = 2m, 2.5m, 3m.

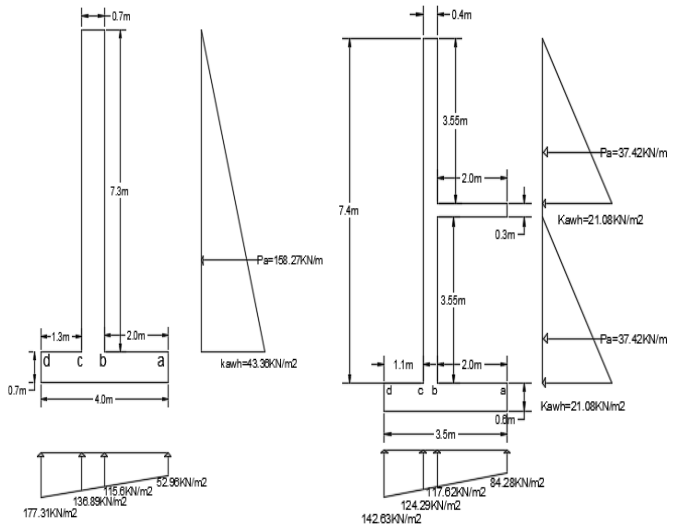

Fig. 1: Lateral Earth Pressure Diagram of 8m retaining wall

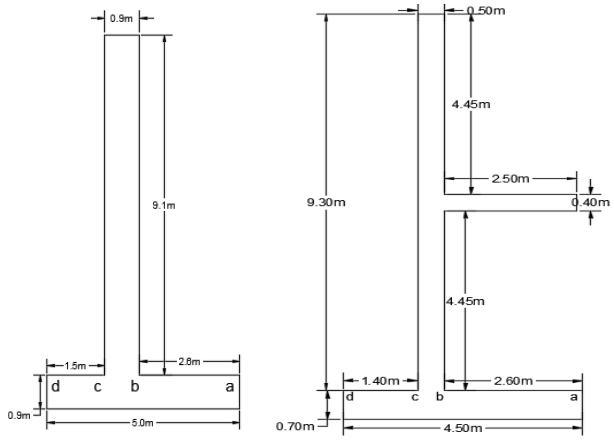

Fig. 2: Cross section of 10m cantilever retaining wall.

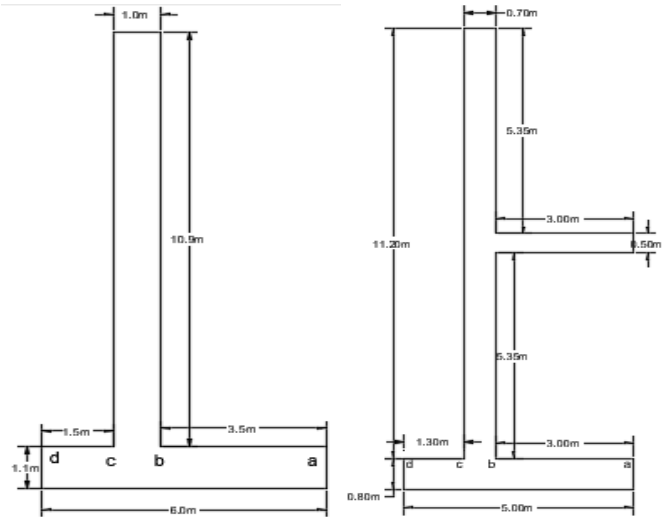

Fig. 3: Cross section of 12m cantilever retaining wall.

Table 1: Comparison of analytical results of retaining wall (RW) with and without relief shelve.

Description	8m RW without shelve	8m RW with shelve	10m RW without shelve	10m RW with shelve	12m RW without shelve	12m RW with shelve
Thickness of stem (m)	0.7	0.4	0.9	0.5	1.0	0.7
Width of base slab (m)	4.0	3.5	5.0	4.5	6.0	5.0
Thickness of base slab (m)	0.7	0.6	0.9	0.7	1.1	0.8
Length of relief shelve(m)	-	2.0	-	2.5	-	3.0
Thickness of relief shelve(m)	-	0.3	-	0.4	-	0.5
Moment of stem at bottom (kN-m)	385	232.50	746.01	469.04	1282	799.5
Moment of stem at shelve (kN-m)	-	44.28	-	87.23	-	151.5
Eccentricity (e)	0.36	0.15	0.18	0.19	0.61	0.38
Pressure intensity P_{max} (kN/m^2)	177.31	142.63	219.3	176.69	301.52	265.37
Pressure intensity P_{min} (kN/m^2)	52.96	84.28	141.39	105.4	73.04	99.14
FOS against Sliding	1.45 (Un-Safe)	2.61	1.52	2.96	1.31 (Un-safe)	3.2
FOS against Overturning	2.95	2.22	3.02	3.15	3.08	2.7

From Table-1 comparing of the models with and without shelves, it is evident that the geometric parameters like thickness of stem, length of base slab and thickness of base slab of the retaining wall gets decreases when the shelves are provided. It can be seen that FOS against sliding for retaining wall without shelve might have the chance for shear failure, but if the relief shelves are provided then FOS against sliding is always safe.

4. NUMERICAL MODELING AND ANALYSIS

3D modelling and analysis are carried out by using SAP2000 per meter length of wall. Analysis of stem, shelve, heel slab and toe slab are considered as cantilever beams.

4.1 Analysis of cantilever retaining wall without shelve (CRWWS)

Height of the retaining wall considered is 8m. The horizontal earth pressure on the wall can be calculated by using the formula $K_a\gamma h$.

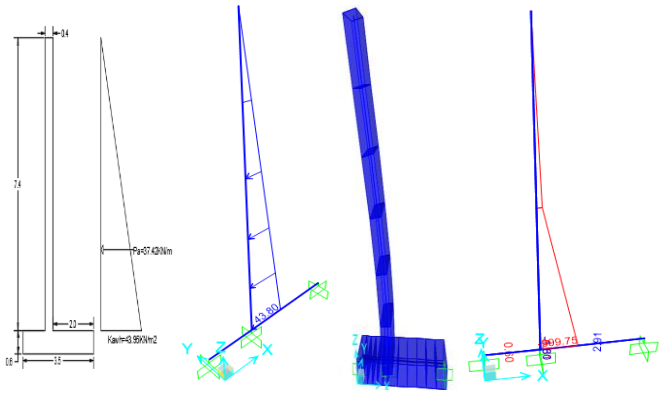

Fig 4: Deflection and BMD diagram of 8m high wall.

4.2 Analysis of cantilever retaining wall with single shelve (CRWSS)

The retaining wall of 8m is considered. Shelve is provided at the middle height of the stem, and the length of the shelve is provided 2m up to the shear failure plane. The horizontal earth pressure on the wall can be calculated by using the formula $Ka\gamma h_1$ and $K_a\gamma h_2$.

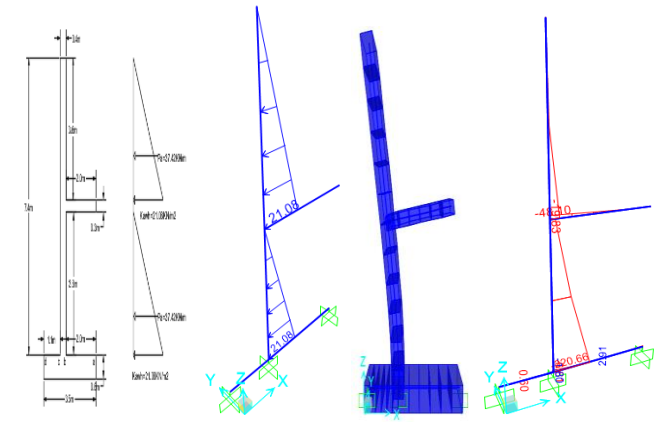

Fig 5: Deflection and BMD diagram of 8m high retaining wall with single shelve.

4.3 Analysis of cantilever retaining wall with single shelve (CRWSS)

The retaining wall of 8m is considered. Shelve is provided at the middle height of the stem, and the length of the shelve is provided 3m up to the shear failure plane. The horizontal earth pressure on the wall can be calculated by using the formula $Ka\gamma h_1$ and $K_a\gamma h_2$.

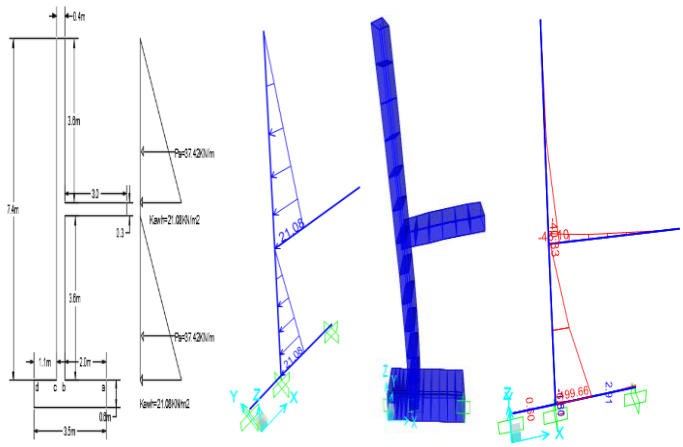

Fig 6: Deflection and BMD diagram of 8m high retaining wall with single shelve.

4.4 Analysis of cantilever retaining wall with double shelves (CRWDS)

Here the retaining wall of 8m is considered. Top shelve is provided at the h/3 of the stem height, bottom shelve is provided at the 2h/3 height of the stem, and the length of the shelves are 2m provided up to the shear failure plane. The horizontal earth pressure on the wall can be calculated by using the formula $Ka\gamma h_1$, $K_a\gamma h_2$ and $K_a\gamma h_3$.

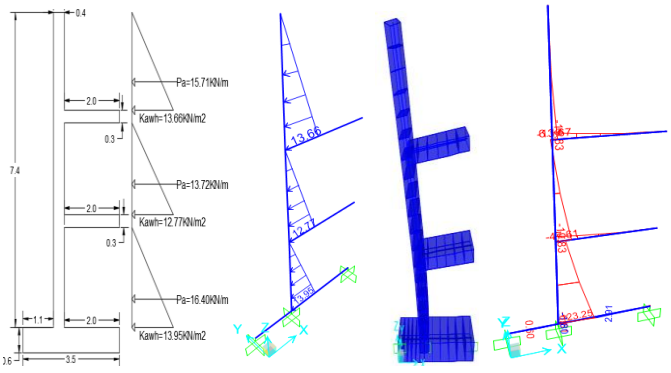

Fig 7: Deflection and BMD diagram of 8m high retaining wall with double shelves.

5. RESULTS AND DISCUSSION

The present work makes an effort to reduce deflection and bending moment of the cantilever retaining wall and to increase stability of the retaining wall by introducing relief shelves.

Table-2 Comparison of displacement, bending moment for a 8m height T_0=0.7m (T_0= thickness of stem) CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top in mm	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	5.8	-	-	385	-	-
CRWWS with shear key	6.9	-	-	385	-	-
CRWSS						
Shelve 2m length	3.5	1.3	-	210.11	41.16	-
CRWDS						
Shelves 2, 2m length	1.7	1.0	0.4	113.89	42.57	12.83

D = displacement, BM = bending moment, SF = shear force, CRWWS = cantilever retaining wall without shelve; CRWSS = cantilever retaining wall single shelve; CRWDS = cantilever retaining wall double shelves.

From Table-2 displacement and bending moment of stem can be reduced by 39% and 45%for single shelve and 70% and 70% for double shelves as compare to retaining wall without shelves.

Table-3 Comparison of displacement, bending moment for a 10m height T_0=0.9m CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top in mm	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	8.2	-	-	745.98	-	-
CRWSS						
Shelve 2.5m length	4.8	1.8	-	402.12	89.12	-
CRWDS						
Shelves 2.5, 2.5m length	2.2	1.3	0.5	212.65	79.44	24.94

From Table-3 the displacement and bending moment of stem can be reduced by 41% and 46%for single shelve and 73% and 71% for double shelves as compare to retaining wall without shelves.

Table-4 Comparison of displacement, bending moment for a 12m height T_0= 1.0m CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	14.8	-	-	1282	-	-
CRWWS with shear key	16.7	-	-	1282	-	-
CRWSS						
Shelve 3m length	8.6	3.2	-	687.80	152.87	-
CRWDS						
Shelves 3, 3m length	3.9	2.3	0.8	360.36	135.08	42.96

From Table-4 it can be concluded that displacement and bending moment of stem can be reduced by 41% and 46%for single shelve and 73% and 71% for double shelves as compare to retaining wall without shelves.

Table-5 Comparison of displacement, bending moment, shear force for a 8m height T_0= 0.4m CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	33	-	-	399.75	-	-
CRWSS						
Shelve 2m length	20	7.4	-	220.6	48.10	-
Shelve 3m length	16.7	6.4	-	199.60	48.10	-
CRWDS						
Shelves 3, 3m length	10.2	6	2	123.25	47.61	13.67

From Table-5 it can be concluded that displacement and bending moment of stem can be reduced by 39% and 44%for single shelve and 69% and 69% for double shelves as compare to retaining wall without shelves.

Table-6 Comparison of displacement, bending moment, shear force for a 10m height T_0= 0.5m CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top	D at 1stShelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	53	-	-	796.28	-	-
CRWSS						

Shelve 2m length	32	12	-	438.3	95.25	-
CRWDS						
Shelves 3, 3m length	16.8	9.8	3.33	247.82	98.23	27.59

From Table-6 it can be concluded that displacement and bending moment of stem can be reduced by 39% and 45%for single shelve and 68% and 69% for double shelves as compare to retaining wall without shelves.

Table-7 Comparison of displacement, bending moment, shear force for a 12m height T_0= 0.7m CRWWS, CRWSS, CRWDS from the SAP-2000 analysis.

Title	D at top	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
CRWWS	49	-	-	1390.71	-	-
CRWSS						
Shelve 2m length	29.4	11	-	760.14	166.05	-
CRWDS						
Shelves 3, 3m length	14.7	8.7	3	418.46	160.24	46.75

From Table-7 it can be concluded that displacement and bending moment of stem can be reduced by 40% and 45%for single shelve and 70% and 69% for double shelves as compare to retaining wall without shelves.

Table-8 Comparison of displacement, bending moment, shear force for a 10m height, T_0= 0.5m CRWDS with varying the length of shelves from the SAP-2000 analysis.

Length of the shelves	D at top	D at 1st Shelve	D at 2nd shelve	BM at bottom	BM at 2nd shelve	BM at 1st shelve
	mm	mm	mm	kN-m	kN-m	kN-m
2.5m, 2.5m	16.8	9.8	3.33	247.8	98.23	27.59
2.5m, 2.0m	18	10.5	3.6	260.31	98.23	27.59
2.0m, 2.5m	18.7	10.7	3.6	260.31	110.73	27.59
2.0m, 2.0m	19.8	11.4	3.8	272.8	110.73	27.59
2.0m, 1.5m	20.8	12	4	282.8	110.73	27.59
1.5m, 2.0m	21.3	12.2	4	282.81	120.73	27.59
1.5m, 1.5m	22.2	12.7	4.2	292.81	120.73	27.59
1.5m, 1.0m	22.9	13.1	4.3	300.30	120.73	27.59
1.0m, 1.5m	23.3	13.3	4.3	300.3	128.73	27.59
1.0m, 1.0m	24	13.7	4.4	307.8	128.73	27.59

From Table-8 displacement and bending moment can be reduced by 68% and 68% for double shelves of length 2.5m, 58% and 63% for double shelves of length1.5m, 54% and 61.3% for double shelves of length 1.0m, in comparison of retaining wall without relief shelve.

7. CONCLUSIONS

The cantilever retaining wall with relief shelve is proved to be advantageous over the cantilever without relief shelve. Based on the work carried out the following conclusions can be drawn.

1. The best location for the single shelve is observed to be in between 0.5 h for the maximum reduction in earth pressure, decreased bending moments and deflection.
2. Deflection of the stem is reduced by about 40% by providing shelve at 0.5h and length of shelve up to the shear failure plane than the deflection given without shelf.
3. Bending moment at the bottom of the stem is reduced by about 44% by providing shelve at 0.5 h and length of shelve up to shear failure plane than the bending moment given without shelve.
4. Cross sectional area of the retaining wall can be reduced up to 30% by providing shelve at the 0.5h and length of shelve up to shear failure plane. Hence it will be economical.
5. The deflection reduces by increasing the length of the shelve but the variation is less.
6. While comparison of displacement and bending moment for 2m and 3m length shelves, the reduction of the displacement is just 10% and bending moment is just 6%. Hence the increase in the length of shelve by additional 1m does not seen to be economical.
7. The best location for the double shelves is observed to be in between 1/3 h and 2/3h for the maximum reduction in earth pressure, decreased bending moments and deflection.
8. Deflection of the stem is reduced by about 70% by providing shelve at 1/3h and 2/3h.
9. Bending moment of the stem reduced by about 65% by providing shelve at 1/3h and 2/3h.
10. In order to make the economical section length of both shelves are provided with 1.5m. Since the difference between the moments is 5% and deflection is 10% as compared to 2.5m length shelves for 10m height retaining wall.
11. By providing relief shelves, the retaining wall is safe against sliding so there by eliminating the need for shear key.
12. Cantilever retaining walls with double shelves of heights 8m, 10m, 12m are economical and stable as

compared to the same retaining walls without shelve.

13. Increase in the height of the retaining wall with increase in the number shelves will make the structure stable.

REFERENCES

[1] Dharshan K, Keerthi Gwoda B S-stability enhancement of cantilever earth retaining wall with pressure relief shelf by soft computing technique, Advanced Engineering and Applied Science: An International Journal-17 December 2016.

[2] Chauhan, V.B. and Dasaka, S.M. (2016), Reduction of surcharge induced earth pressure on rigid non-yielding retaining wall using relief shelves. Proc. of Indian geotechnical Conference-Geotechnology towards global, 15-17 December 2016, IIT Madras, Chennai, India. Paper ID: 502.

[3] Chougule A. C, Patankar J. P, Chougule P. A (2017)-effective use of shelves in cantilever retaining walls, IRJET, Volume 4 Issue; 07, July-2017

[4] Hany F. Shehata- retaining walls with relief shelves, Springer International Publication, 30 March 2016.

BIOGRAPHIES

Chethan D. V,
P.G Student, Department of Civil Engineering, U.V.C.E, Bangalore University, Jnana Bharathi Campus, Bengaluru.

Thejaswini R. M.
Assistant professor in Govt. S.K.S.J.T. Institute.
Research scholar, Department of Civil Engineering, U.V.C.E, Bangalore University, Bengaluru.

L. Govindaraju,
Professor, Department of Civil Engineering, U.V.C.E, Bangalore University, Jnana Bharathi Campus, Bengaluru.