IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

Reduction of Lateral Earth Pressure Acting on Retaining Wall

[1]Mahesh P Shettar, [2]Deepdarshan KP
[1]Assistant Professor, [2]Civil Engineering
[1]Wollega University nekemte ,
[2]Wollega University Nekemte Ethiopia

Keywords: earth pressure reduction, retaining wall, relief shelf, FLAC^{3D}.

INTRODUCTION

Retaining walls are an integral part of almost all infrastructure projects, to support vertical or near vertical backfills. As the sectional dimensions of retaining wall are function of lateral earth pressure on wall, so reducing the lateral earth pressure on wall with also reduce the sectional dimension of the wall and will leads to overall economy to the structure. Construction of relief shelves at various elevations into the backfill (Bowles 1997, Ray Chaudhuri *et al.* 1973 Yoo *et al.* 2012), use of tire chips as light weight backfill (Tweedie 1998); provision of compressible inclusion (Ertugrul and Trandafir 2011), are some of the techniques used by several researchers to achieve the reduction of earth pressure on retaining wall. The lateral earth pressure also gets reduced due to the provision of relief shelves and hence the overturning moments due to total thrust on the retaining wall are also significantly reduced enabling economy in the design (Phatak 1997). The numerical study using finite element method were also carried out to investigate the behaviour of retaining wall with relief shelf and found that the stability of wall enhances with increasing the width of relieving plate (Farouk 2015). A similar study has also investigated the possible reasons behind the failure of a cantilever retaining wall with relief shelves, which is located in the heart of Hawassa city, Ethiopia and also laid suitable relief shelf parameters by using computational tool (Chauhan *et al.* 2016). Although such type of walls has already been used in past but mechanism and design parameter estimation are still in immature state for these retaining walls.

Hence, present study is aimed to understand the behaviour of such walls and to explore the effectiveness of relief shelves for lateral earth pressure reduction with the small scale physical model tests and full scale numerical model study.

PHYSICAL MODEL TESTS

To study the influence of relief shelf on lateral earth pressure distribution on wall, 1-g small scale physical model tests are carried out in a stainless steel tank having dimensions of 1.2m length, 0.31m width and 0.7m depth. A mechanical jack was fixed at the non-backfilled side of the tank to hold the wall in position to obtain at-rest condition. Details of the experimental setup are shown in Fig. 1.

retaining wall

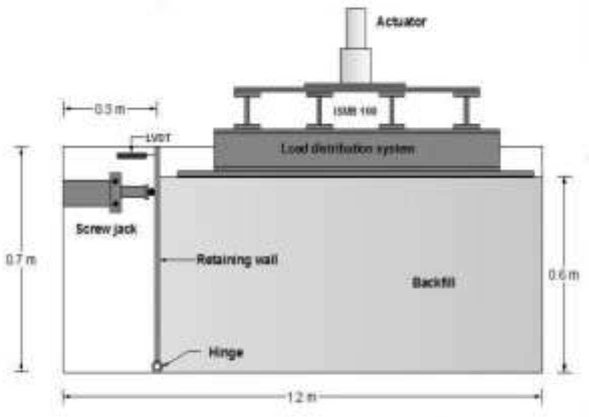

Fig. 1. Detailed diagram of experimental setup of physical model test

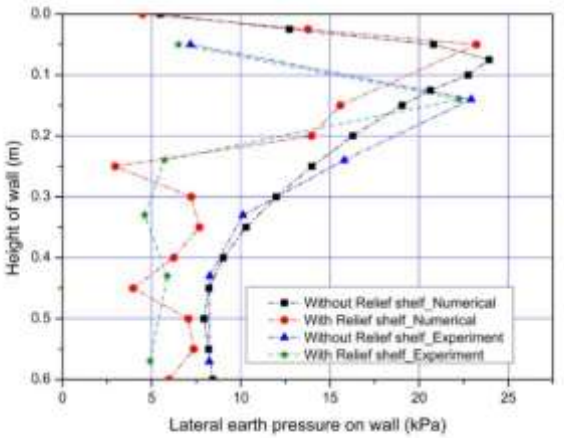

Fig. 2. Comparison of physical model and numerical analysis with and without relief shelves

Modified travelling pluviator is used to prepare uniform sand bed of 80% relative density (friction angle 39° and bulk unit weight 16.5 kN/m^3) while maintaining a height of fall 0.3 m. Six diaphragm type earth pressure cells (EPCs) are fixed along the height of model retaining wall plate to get the lateral earth pressure distribution on wall plate. In order to apply uniformly distributed static loading on the surface of backfill, load distribution system as shown in Fig. 1 was placed in such a way that load can be distributed uniformly at 45^{o} through the backfill. Static surcharge of 10-50kPa is applied with an increment of 10kPa using hydraulic actuator. To evaluate the effectiveness of relief shelf, physical model tests are carried out with and without relief shelves with various and combinations of position and width of relief shelves in the laboratory. Out of these tests, experimental finding of lateral earth pressure distribution on 0.6 high wall with static surcharge of 50kPa with 2 relief shelves (width 10 cm each placed at 0.2m and 0.4m depth of wall) and without relief shelves are shown in Fig. 2 and it is noted that lateral earth pressure below the relief shelves gets reduced substantially.

MODELING OF RETAINING WALL WITH RELIEF SHELVES

To investigate further about the effectiveness of relief shelves, numerical simulations are carried out with 8m high wall with 3 relief shelves of same widths are provided at different heights of the wall (Fig. 3). The thickness of relief shelf is kept constant as 0.2 m.

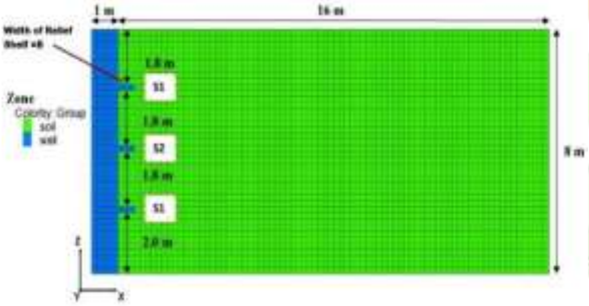

Fig. 3. Numerical grid of rigid retaining wall with relief shelves (Not to scale)

Dry cohesionless soil has been selected as backfill. Physical properties and chosen model for the backfill soil and retaining wall are selected from a similar study on retaining wall with relief shelves (Chauhan *et. al.* 2016). In the present study, width of relief shelf is varied from 0.4-1.8 m, to examine the distribution of lateral earth pressure at various sections of wall and total thrust reduction. Length of wall is considered as 1.0 m for analysis. Conventional retaining wall without relief shelves is hereafter referred to as RS 0.0. Retaining wall with relief shelves is shown in Fig. 3, where B represents width of relief shelf, which is varied as 0.4m, 0.6m, 0.8m, 1.2m, 1.4m, 1.6m and 1.8m (B/h ratio ranging from 0.22-1.0, where h represents intermediate height of wall between two consecutive relief shelves) having thickness of 0.2m and referred to as RS 0.4, RS 0.6, RS 0.8, RS 1.0, RS 1.2, RS 1.4, RS 1.6 and RS 1.8m respectively. Fixed boundary condition at bottom of model and roller boundary condition at vertical end of soils are chosen to represent field conditions to numerical grid considered in the present study to simulate the rigid retaining wall. The rigid wall is modelled as elastic material and not allowed to move to simulate non-yielding condition (at-rest) of wall. The interface between wall and soil is modelled as linear spring-slider system with interface shear strength defined by the Mohr-Coulomb failure criterion ($FLAC^{3D}$ 2011). For the validation of numerical model used in present study, lateral earth pressure profiles of experimental findings of wall with two relief shelves and without relief shelf are presented in Fig 3. Once the model reaches to equilibrium condition, a static surcharge of 50kPa is applied in form of strip loading on the backfill surface at 0.5 m away from the edge of wall.

RESULTS AND DISCUSSION

In the present analysis, rigid retaining walls with three relief shelves provided at different heights of wall having equal widths are analysed with $FLAC^{3D}$. The lateral earth pressure distribution, total lateral thrust, backfill settlement and deflection of relief shelves are analysed and discussed below.

Earth pressure distribution of all walls with and without relief shelves have been studied and shown in Fig. 4. It can be observed that lateral earth pressure in topmost segment of wall increases with the increase in width of relief shelf ranging from 0.4-1.8m. This behaviour may be attributed to the fraction of applied surcharge load carried by topmost relief shelf. As the width of relief shelf increases; a greater portion of surcharge is taken care by the topmost relief shelf itself. Once loading on relief shelf increases, vertical pressure also increases, leading to increase in the lateral earth pressure on wall, but in lower sections of wall height, lateral earth pressure has reduced significantly below the relief shelf compared to wall without relief shelf with increase in width of relief shelf having width more than 0.8m (B/h=0.44). This behaviour of lateral earth pressure profile may be attributed to the surcharge above the relief shelf is being carried by relief shelves itself, and soil overburden and static surcharge is not getting transferred to the soil below the relief shelf as much as it is in the case of wall without relief shelf. Similar behaviour is also noted with the finding of physical model test results discussed above. It is noted that when the width of relief shelf is equal to or greater than 1.0 m (B/h=0.55), significant reduction in lateral earth pressure is observed between of sections of wall lying between any two relief shelves. A noteworthy amount of total thrust reduction of 4-27.5% is obtained by provision of relief shelves of various widths (Fig. 5). Although, for the relief shelves of width 0.4-0.6m, reduction is insignificant i.e. ranging 4-5.5%, but, once the width of relief shelf is increased beyond 0.6m, reduction is very significant and linearly proportional to width of relief shelf up to a width of 1.4m (B/h=0.77).

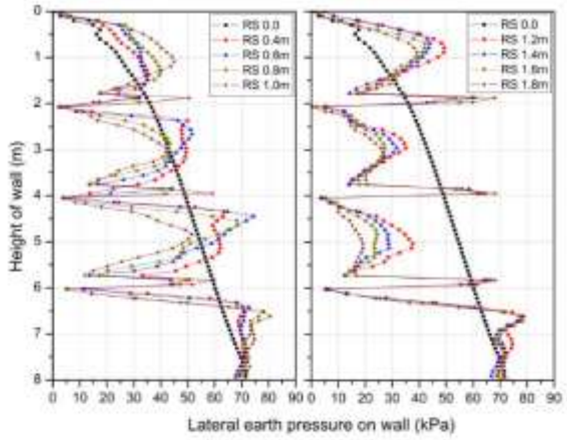

Fig. 4. Comparison of lateral earth pressure on the wall with and without relief shelves

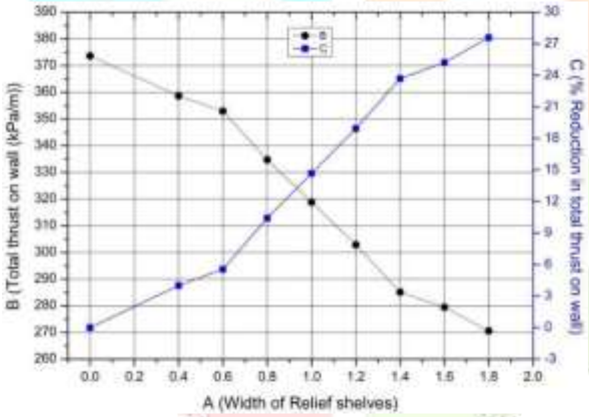

Fig. 5. Total thrust and reduction in thrust on retaining walls

Although there is an increase in overall reduction of lateral thrust even beyond the width of relief shelf of 1.4m but this benefit is not appreciable neither in terms of percentage reduction in total thrust nor in terms of economy of the structure with higher width of relief shelves.

Deflection of any load carrying structural member has to take care of, so that it should not cross the serviceability limit criteria. Maximum deflection of all relief shelves from top to bottom (S1, S2 and S3) are compared and summarized in Table 1. Maximum deflection is found at topmost relief shelf and it decreases from top to bottom relief shelf for all retaining walls. Moreover, maximum deflection of relief shelf also increases with width of relief shelf which is due to increase in the higher fraction of surcharge carried by the relief shelf. Maximum deflection of relief shelves has immensely increased when the width of relief shelf is greater than 1.4m (B/h=0.77). This behaviour may be attributed to greater part of applied surcharge (50 kPa) is supported by higher width of relief shelf and thickness of such relief shelves (0.2m) is not significant to support that much of surcharge, which has excessively increased the deflection of relief shelves having width greater than 1.4m.

Table 1. Maximum vertical deflection (mm) profile of relief shelves

Wall type	B/h	S1	S2	S3
RS 0.4	0.22	2.32	1.82	1.22
RS 0.6	0.33	3.21	2.11	1.51
RS 0.8	0.44	4.84	3.11	2.02
RS 1.0	0.55	7.12	4.09	2.88
RS 1.2	0.66	9.97	5.74	2.92
RS 1.4	0.77	13.4	6.75	4.19
RS 1.6	0.88	50.4	7.57	4.81
RS 1.8	1.00	55.9	8.72	7.22

Surface settlement of backfill is an important serviceability criterion for retaining walls. Excessive backfill settlement leads to collapse of backfill soil and subsequently failure of surrounding structures. Fig. 6 represents the surface settlement of all retaining walls considered in this study.

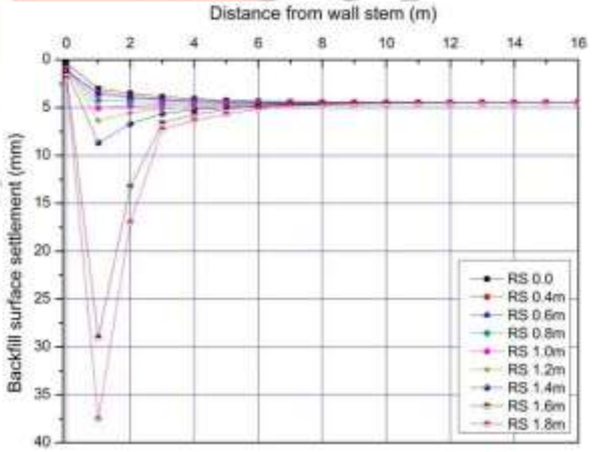

Fig. 6. Backfill Surface settlement profile of backfill

Backfill settlement near the wall is small (2-5mm) and it increases as one moves away from wall for all walls having width of relief shelves 0-1.0m and attains a maximum value of 5mm at a distance of 6m away from wall face. For walls having wider relief shelves (more than 1.0m), surface settlement near the wall is higher compared to other portions of backfill surface. As it is discussed earlier that with increase in width of relief shelf, deflection of relief shelf also increases, which has promoted the higher backfill settlement near the wall. When the width of relief shelf is higher than 1.4m (B/h=0.77), sudden increase in backfill surface settlement is observed near the backfill which is due to the higher deflection of relief shelf as discussed above. Effect of provision of relief shelves on backfill surface settlement has continuously been diminished with increasing distance from stem and achieved the same profile, as that of walls without relief shelves beyond 6m away from stem.

Among all the studied cases of retaining wall with relief shelves, RS 1.4 (B/h=0.77) provides maximum benefit in terms of reduction in total thrust, without leading to excessive deflection of relief shelves and backfill surface settlement. Width of relief shelf should not increase beyond a certain value as relief shelves having higher width experience large deflection leading to higher backfill surface settlement, which may affect the serviceability of nearby structures. Parametric study with various number of relief shelves at different height levels of wall and position of surcharge placement is underway, which may enhance the efficacy of the retaining walls with relief shelves.

CONCLUSIONS

Present study examines the effectiveness of relief shelves on lateral earth pressure reduction, which has concluded that provision of relief shelves on non-yielding rigid retaining wall provides significant amount of reduction in total thrust on wall by means of small scale physical model tests and numerical analysis. For retaining wall of 8m height having surcharge of 50kPa placed at 0.5m away from wall face, provision of 3 relief shelves having width ranging from 0.4-1.8m can reduce total thrust in range of 4-27.5%. It is also noteworthy that backfill surface settlement near the wall having static surcharge increases with the increase in width of relief shelf. Also, it is observed that deflection of relief shelf is proportional to the width of relief shelf, and it also decreases from top shelf to bottom shelf for a given retaining wall with relief shelves having static surcharge loading.

Among all the studied cases of retaining wall with relief shelves having width of 1.4m (B/h=0.77), proves viable, without leading to excessive deflection of relief shelves and backfill surface settlement. Although, it is worth mentioning that with increase in width of relief shelf, reduction in total thrust also increases but for a given height of wall and surcharge loading, there exists a certain bracket for appropriate width of relief shelf which provided maximum benefit in reducing the total thrust on wall while satisfying the criteria for serviceability within limits. This range of width of relief shelf depends on factors like height of wall, number and thickness of relief shelf, magnitude and position of surcharge loading etc. So, it is customary to examine aforementioned factors before deciding the number, position, width and thickness of relief shelf to be provided for any retaining wall.

REFERENCES

1) Bowles, J.E. (1997), *"Foundation analysis and design"*, 5th Edition, McGraw-Hill, Singapore.
2) Chaudhuri, P.R., Garg, A.K., Rao, M.V.B., Sharma, R.N., Satija, P.D. (1973). "Design of retaining wall with relieving shelves." Jornal of Indian Road Congress, Vol. 35, No. 2, pp. 289 - 325.
3) Chauhan, V.B., Dasaka, S.M., Gade, V.K. (2016). "Investigation of failure of a rigid retaining wall with relief shelves". Japanese Geotechnical Society, doi: 10.3208/JGSSP.TC302-02
4) Ertugrul, O. L. and Trandafir, A.C. (2011). "Reduction of lateral earth forces acting on rigid non-yielding retaining walls by EPS geofoam inclusions." *Journal of. Materials Civil Engg.*, Vol. 23, No. 12, pp. 1711-1718.
5) Farouk, H. (2015) "Effectiveness of using shelves with cantilever retaining walls". AEI 2015, pp.627–637. doi:10.1061/9780784479070.055
6) FLAC 3D, 5.0 (2011). 3-Dimensional Finite Difference Code, Itasca, Minneapolis, USA.
7) Phatak, D.R. (1979). "Analysis and model studies of flexible retaining wall with short horizontal relieving shelf". *Journal of Indian Roads Congress*, Vol. 40, No. 3, pp. 699-715.
8) Tweedie J.J., Humphrey, D.N., Standford, T.C. (1998) Tire shreds as light weight retaining wall backfill: Active conditions. Journal of Geotechincal and Geoenvironmental Engg. Vol. 124, pp. 1061-1070.
9) Yoo, W., Kim, B, Moon, I. and Park, Y. (2012). "Comparison of the Lateral Earth Pressure on the Retaining Wall with the Relieving Platform by Model test and Numerical Analysis" Journal of Korea Academia-Industrial cooperation Society, Vol. 13, No. 5, pp. 2382-2389.