REVIEW ON BEHAVIOUR AND DESIGN OF RETAINING WALLS

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Abstract— **Retaining wall is the structure which withstands the lateral earth pressure exerted by water pressure, surcharge load and self-weight of the wall. Due to advancement in the technologies of highway construction, instability of the retaining wall to cause embankment land slide has become common. In conventional approach of constructing the retaining walls, there are several disadvantages like more construction time, cost, manpower and environmental impacts makes these conventional methods ineffective and uneconomic. For the precise analysis, ETABS and GEO5 which is finite element-based software, is used in this work. By the Conventional and software approach (the r/wall are modelled and analyzed for stability in ETABS and GEO5 software), comparison shows whether a software analysis is best for a convention approach is good or not. Also by software analysis stability check to be done at different heights of retaining wall.**

Keywords: Retaining wall, Overturning, Stability, Deflection, Displacement.

I. INTRODUCTION

General

Structure which holds the soil, water or any other materials in their actual position so that erosion of these materials does not occur is known as retaining wall. Some places where slope is so high, geographical conditions do not the mass to remain in its natural slopes. These materials which are hold by retaining walls is called backfill. Stabilizing hillsides and control erosion are the main functions of retaining walls. The heavy soil mass is supported by retaining walls in various fields of civil engineering such as hydraulics, irrigation structures, highways, railways, tunnels, mining etc. During the roadway construction sometimes, it is necessary to construct these structures where there is over rugged terrain with steep slopes. These walls decrease the grades and land requirement alongside the roads.

Earthquakes have caused permanent deformations in retaining wall in many historical earthquake. In some cases, retaining walls have collapsed during earthquake with disastrous physical and economic consequences. During earthquake, however, inertial forces and changes in soil strength may violate equilibrium and cause permanent deformation of wall. There are several theories, experimental investigations & numerical studies done to evaluate dynamic response of the retaining wall system In some cases, there is a lack of land available besides the travel way then retaining walls become necessary to allow acceptable slope conditions and for safer construction. In those cases where slopes are quite steep, soils are unstable or heavy runoff occurs these walls help to stem erosion. Failure, whether by sliding, tilting, bending or some other mechanism, occurs when permanent deformations becomes excessive (not in permissible limit).

Types of retaining walls

In this present time, there are different kinds of retaining walls used which are classified on the basis of their shape, material used, resisting action or casting methods etc. Some of these conventional retaining walls are:

a) Cantilever type retaining wall: Cantilevered retaining walls are made from an internal stem of steel-reinforced, cast-in-place concrete or mortared masonry (often in the shape of an inverted T). These walls cantilever loads (like a beam) to a large, structural footing, converting horizontal pressures from behind the wall to vertical pressures on the ground below. Cantilever retaining wall is economical up to height of 3-8m.
b) Gravity type retaining wall: Gravity retaining wall depends on its self-weight only to resist lateral earth pressure. Commonly, gravity retaining wall is massive because it requires significant gravity load to counter act soil pressure. Sliding, overturning, and bearing forces shall be taken into consideration while this type of retaining wall structure is designed. It is economical for a height up to 3m. Material used concrete, stone etc.
c) Buttress/Counterfort retaining wall: It is a cantilever retaining wall but strengthened with counter forts

monolithic with the back of the wall slab and base slab. Counter fort spacing is equal or slightly larger than half of the counter-fort height. Counter-fort wall height ranges from 8-12m.

d) Anchored retaining wall: This type of retaining wall is employed when the space is limited or thin retaining wall is required. Anchored retaining wall is suitable for loose soil over rocks. Considerably high retaining wall can be constructed using this type of retaining wall structure system. Deep cable rods or wires are driven deep sideways into the earth, then the ends are filled with concrete to provide anchor. Anchors (tiebacks) acts against overturning and sliding pressure.
e) Piled retaining wall: Pile retaining wall are constructed by driving reinforced concrete piles adjacent to each other. Piles are forced into a depth that is sufficient to counter the force which tries to push over the wall. It is employed in both temporary and permanent works
f) Crib retaining wall: Crib retaining walls are a form of gravity wall. They are constructed of interlocking individual boxes made from timber or pre-cast concrete. They are constructed of interlocking individual boxes made from timber or pre-cast concrete. It is suited to support planter areas, but it is not recommended for support of slopes or structures.
g) Gabion retaining wall: Gabion retaining wall walls are multi-celled, rectangular wire mesh boxes, which are filled with rocks or other suitable materials. It is employed for construction of erosion control structures. It is also used to stabilize steep slopes.
h) Soil nailing R/wall: Soil nailing may be a technique that will not reinforce and strengthen existing ground. It consists of putting in closely spaced bars into a slope or excavation as construction income from the highest down. Soil nailing is an efficient and economical methodology of constructing a wall for excavation support, support of hill cuts, bridge abutments, and high ways in which. This method is effective in cohesive soil, broken rock, sedimentary rock or fixed face conditions.

Purpose of Retaining wall

a) This wall prevents the soil or other material at places with sudden elevation changes.
b) Earth retaining structures are used to hold back the earth and maintain the difference in the ground surface height.
c) Retaining structures are designed to withstand the grounds or backfill; other externally exerted loads transmit these forces safely to a foundation.
d) Retaining walls serve as a functional product to prevent sinkholes from destroying your landscape structure. They are used to stabilize the sloping landscapes and provides level surfaces on slopes.
e) If your property is not prevented from infiltrating, then rainwater runoff can completely damage your land. This can protect your landscape design, also prevent floods from inflowing the area.
f) Retaining walls additionally give your landscape an aesthetically pleasing design.

Applications of Retaining wall

a) Construction of basement below ground level in buildings.
b) In the bridge, work consists of the wing walls and abutment.
c) To maintain slopes in hilly areas.
d) As side walls of bridge approach roads.
e) Providing lateral support to the embankment.
f) Protect soil from erosion

Objective

The objective of the paper review is as follows:

a) To model a retaining wall structure with a software program i.e. GEO 5 and check out the software results.
b) To find bearing capacity of the soil.
c) To check the retaining wall against overturning, sliding, slip.
d) To find out the factor of safety and overall stability for the desired condition.

II. LITERATURE REVIEW

Su Yang, Amin Chegnizadeh, Hamid Nikraz (2013) (1) In this they conclude how the retaining walls behave under the seismic conditions. They elaborate the actual condition of the retaining wall under earthquake they mainly focus two analytical theories one of coulombs wedge failure theory and one sub-method of this is elasticity analysis method. Also analyse MO (Mononobe and okabe) method. And describe the limitation of MO method. According to them Current theories, experimental findings and numerical studies for retaining walls subject to dynamic excitation have been briefly listed in a generally chronological order. Numerical analyses are an accurate way to solve relevant problems, while experiments are good but incur big cost to conduct an accurate one. In spite of these, the MO method is still a current main approach for practical use due to its simplicity. But the MO method becomes impractically complex when more factors like the influence of pseudo– dynamic, logarithmic failure plane etc. is being considered, not to mention the widely known assumptions that are inherent with the MO method. It is found that the results from the elasticity method are from 2.5 to over 3 times higher

K. Jagadeesh, K. Suresh and Dr. K. Uday (2015) (2) In this they analyse the multitier retaining wall. In this they analyse the stability of retaining wall external as well as internal. They took well graded as well as poorly graded soil for the study and the same study is carried out by GEO5 Software and form the finding it has been conclude that intensity of surcharge of the upper tier to the lower tier has been calculated by using GEO5 Software, according to the results it is observed that to increase in the pull out resistance there would be minimum length of reinforcement. The stability of the retaining wall depends upon shape or geometry of retaining wall.

HuaWen, Jiu-jiang Wu, Jiao-li Zou, Xin Luo, Min Zhang, and Chengzhuang Gu (2016) (3) In their research they use GEOBAGS filled with construction waste (demolished concrete waste) and prepare a model in proportion of a prototype. There retaining walls constructed from geo bags filled with construction waste are a new flexible supporting structure characterized by easy construction, low costs, and good supporting effects and facilitate the recycling of construction waste. They took this concept from ancient Egypt time. They conduct this model test on different slopes and length of the Geo bags (Q1, Q2, Q3, Q4 and Q5). Accordingly they find mode of failure of retaining wall, load carrying capacity, mode of failure of the slopes. By their study provides helps to use waste construction material effectively, basic end conclusion of the model was the ultimate loads that the slope tops in cases Q2 andQ3 could bear were 87.5%125% higher than that of the slope top in case Q1. The greatest horizontal wall displacements in cases Q2 and Q3 were 75.2%-79.4%lower than that in case Q1 under the same load of 24 kPa, and the retaining walls constructed from geo bags filled with construction waste were found to provide significant supporting effects to the slopes. The ultimate loads that the slope tops in cases Q2 and Q5 could bear were 25%125% higher than that of the slope top in case Q4. The greatest horizontal wall displacements in cases Q2 and Q5 were 45.3%-49.7% lower than that in case Q4 under the same load of 36 kPa.

Karthik Babu C and Keerthi Gowda B S (2016) (4) In the study is basically on counter fort retaining walls with and without pressure relief self using soft computing techniques (SAP200). They gives a brief about this SAP200 software. They conclude a design of counter fort wall with conventional method as well as SAP200 software with and without pressure relieve wall and make comparative that which one is good In the present study comparison of conventional counterfort earth retaining wall with pressure relief shelf attached counterfort earth retaining wall is studied. Positions of pressure relief shelves are varied H/3, H/2, 2H/3 positions to analyze the behavior of retaining wall. The moments developed by the retaining earth in the counterfort earth retaining wall with pressure relief shelf are always less compared to conventional retaining wall. During the absence of relief shelves, 12 % reduced moment are recorded by SAP-2000 analysis in comparison with manual (conventional) method of analysis of counterfort earth retaining wall. 33%, 50.5% and 61.53% of reduction of moments are recorded when there is adoption of relief shelves at H/3, H/2 and 2H/3 positions of the stem in comparison to the moments of counterfort earth retaining wall without the pressure relief shelf. Due to the reduction moments, stability of the counterfort earth retaining wall is increased against sliding and overturning. Computation of displacement of stem at top of the wall can be effortlessly done by using SAP-2000. This cannot be possible by manual approach. About 122, 99 and 86.7 mm displacement of stem at top were recorded at (H/3, H/2, 2H/3 positions) respectively. Hence counterfort earth retaining wall with pressure relief shelf at 2H/3 positions is very well suited to design the counterfort earth retaining wall. Performing analysis of counterfort earth retaining wall by using SAP-2000 is very much advantageous compared to manual techniques. It saves time; repeated iterative analysis could be done with effortlessly. A less experienced (new) design engineers can be successfully use SAP-2000 for analysis of counterfort earth retaining wall Hence counterfort earth retaining wall with pressure relief shelf at 2h/3 positions is very well suited to design the counterfort earth retaining wall. Performing analysis of counterfort earth retaining wall by using SAP-2000 is very much advantageous compared to manual techniques. It saves time; repeated iterative analysis could be done.

Han Shang Yu, Li Kai Ren and Qiu Fang (2018) (5) Their study is on Construction Technique about The Reinforced Concrete Retaining Wall's Lateral Displacement Repairing. This repairing technique is very useful and their study is also very help full in construction world because it describe the method that how to repair r/wall when got laterally displaced. In this they describe all material required for this repairing and work procedure for the repairing as well. They also ensure and mentioned Construction Quality Control Points and Quality Assurance Measures taken before during and after the repairing. This conclude Due to the influence of many uncertain factors, the retaining wall has a certain degree of lateral displacement during the process of using. Based on the force characteristics and lateral deformation of retaining wall, a kind of lateral displacement repairing technology of reinforced concrete retaining wall was proposed in this paper. In view of the stability of retaining wall lateral displacement repairing and the improvement of construction efficiency, a kind of lateral displacement repairing technology of reinforced concrete retaining wall was proposed. Meanwhile, the construction process and quality control points of the technology are systematically analyzed to demonstrate the rationality and engineering practical. Based on the need of the retaining wall lateral displacement repairing, the construction process and application effect of the technology were analyzed, and the research engineering application value of the technology was illustrated.

Dr. Dhamdhere, Dr. V. R. Rathi and Dr. P. K. Kolase (2018) (6) In this study about the design criteria of the cantilever and counter fort retaining wall with pressure relieving wall. Also study the results of stability of retaining walls, cost optimization and their behaviour of bending moments at different heights so it is helpful in designing the cantilever and counter fort at adequate heights accordingly all the data has been described by help of graphs which is very helpful for construction and selection purposes. The conclude The bending moment in toe and heel is less for retaining wall with relieving platform than cantilever retaining wall. The area of steel for toe and heel is less for retaining wall with relieving platform than cantilever retaining wall. By providing platform, the stability against sliding in increases much more. And the FOS against sliding and overturning is almost double in retaining wall with relieving platform than cantilever retaining wall. And measure conclusion is we also get interrelationship between height of wall and various parameters of retaining wall like dimensions, area of main steel, bending moments for different part of retaining wall and cost of construction.

Ankit C. Mahure and Prof. M. N. Umare (2019) (7) In their research they conclude dynamic behaviour of the r/wall at their different heights. The major problem of instability of walls is mainly depends on earth pressure distribution on the wall and the response of wall against the earth pressure, especially, under dynamic/seismic loading condition. So they take a problem and analysis the behaviour, stability and strength as well on the different height of the retaining wall structure. The study basically helps that what kind of retaining wall is suitable at what height. The main conclusions they got by their research,

- Difference in steel increases with increase in heights, the reason behind that the required Ast will increases with increase in height.
- Maximum steel required for L shape retaining wall than the cantilever retaining wall. Due to The thickness of steam in L shape retaining wall is more than the cantilever retaining wall.
- Difference in concrete increases with increase in height. The reason behind that the L shape retaining wall having greater wall thickness than the cantilever retaining wall.
- L Shape retaining wall consumes more concrete than the cantilever retaining wall.

Ganesh C. Chikute, Ishwar P. Sonar (2019) (8) The main aim of their case study was how best the gobin wall among the other as the suggest itself Techno-Economical Analysis of Gabion Retaining Wall against Conventional Retaining Walls. They describe the material needed and work methodology for the gobin walls while taking actual case study of Bank erosion at Ordinance factory, Kirki, Pune. They make a proper comparative of gobin wall with other conventional retaining wall in term of cost of construction, speed of construction, material quantity needed which is very helpful in future. According to them The construction cost of Gabion Wall as compare to Rubble Masonry, RCC Cantilever, RCC Counterfort, Graviloft retaining wall are 0.3%, 54.12%, 10.72% , 9.56% less respectively. Gabion Wall is ideally suited for remote area where skill Labour, advance machinery, material is difficult to arrange.

Jyoti P. Bhusari, Rajashri S. Ghodke (2019) (9) In this they study the structural behaviour of cantilever retaining wall with pressure relieving shelves. By this we knew about how these pressure relieving wall helps in decreasing the net effect of lateral earth pressure and Bending moment as well. But in this they also try to find the ideal location of the pressure relieving walls in the cantilever r/wall so that maximum amount of net forces can be reduces. The deflection also gets reduced about 95 percent if we provide shelf of 3.5m at height of 0.5h. Overall they conclude that, retaining wall with shelves can be considered as an effective solution of the high retaining walls according to the study.

Anjali Diwalkar (2020) (10) In this they design and study the outcomes of retaining wall and conclude that various systems are implemented to support laterally the soil. Retaining walls might face failure because of sliding, overturning, and bending. Gross pressure and its point of application plays vital role in its failure. Coulomb’s method and Rankine’s method used to evaluate the lateral earth pressure on retaining wall for static condition. The retaining wall with relieving platform is safer against overturning and sliding as compared to cantilever retaining wall. In the gravity type of walls the sequence of construction is also important factor to be considered in the design.

Suk -Min Kong, Dong-Wook Oh, So-Yeon Lee, Hyuk-Sang Jung and Yong-Joo Lee (2021) (11) In their study they analyse reinforced retaining wall failure based on reinforced length. They did numerical 3D analysis i.e. modelling by using PLAXIS 3D (It widely utilised finite element analysis programed for 3D geotechnical engineering). In this they plotted a graph b/w height of retaining wall vs horizontal displacement for straight retaining wall vs. curved retaining wall and this way the find out the role of r/f (length wise) in budging and settlement. The overall failure of the reinforced retaining wall appears in the form of wall bulging, which decreases as the reinforcement length increases. In the numerical analysis, different reinforcement lengths, i.e., 1 and 3 m, were used in the straight and curved sections, respectively. In the curved sections, the reinforcement effect in terms of the vertical displacements was the same. However, the horizontal displacements in the straight sections decreased by 9.72% at the top of the wall (4m point) as a result of the reinforcements applied to the curved sections. Therefore, instead of using the same reinforcement length, it is economical to employ different lengths into straight and curved sections. In the future, the authors intend to conduct research on the optimal stiffener length and its details through model tests.

III. SUMMARY AND CONCLUSION

This paper review work was a small effort towards perceiving that how retaining wall will behave in several conditions and study about the design of retaining wall. Hence through this project it was tried to appreciate the effectiveness and role of the retaining wall that can help real life in several ways.

The following conclusions were drawn at the end of the study:

a) Behaviour of retaining wall at different heights is helpful for the selection of suitable retaining wall and also we know about the behaviour of retaining wall under seismic condition.
b) Effect use of waste construction material using them. In the geobags for the retaining wall stability.
c) Effectiveness of the GOBIN retaining wall with respect of convention retaining wall structure
d) Come to know about the uses of the pressure relieving walls and work of it in construction of retaining wall.
e) Effect of reinforcement on the retaining wall stability.

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