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A REVIEW ON THE FAILURE CAUSES OF REINFORNCED RETAINING WALLS.

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Abstract

Usually, retaining wall failure is not being referred to the total/complete failure or collapse but rather describes signs and indications by which failure possibilities and wall instability could be predicted and can be saved if dealt with properly. Retaining wall sliding, collapsing, overturning are types of total collapses that cannot be reformed, thus the sole solution for these failures are rebuilding the wall. However, even if the retaining wall collapses completely, it is unlikely that there will be additional signs of problems that may be observed and repaired before the wall is completely damaged. Overall, most retaining walls could be repaired and preserved after assessing and indicating the reason for the failure/defect.

Introduction

In this article, various parameters, which might go wrong and consequently provide signs of deficiencies, are discussed in the following points.

Real problems in lateral earth pressure involve more than simple loads produces by soil against a retaining wall. Earth pressure is not a unique property of the soil or rock, but it is a function of the material that the retaining structure must support, of the loads that the soil behind the structure must carry, the groundwater condition and the amount of deflection the retaining structure undergoes. The pressure exerted by the soil on these structures is known as earth pressure and must be determined before a satisfactory design can be made. Soil mechanics theories have dealt with earth pressure on retaining walls, but unfortunately, engineers using these theories have not always recognized the importance of the assumptions made in development. Therefore, the increasing use of retaining walls is accompanied by many and partial failures, as the construction is based on rules and formulas that meet only limited conditions. For example, wall designs backfilled with soft clay are often based on pure sand analysis, and wall designs that support cracked structures due to foundation movement are often wall trends. The only margin between success and failure was often an oversized factor of safety.

A satisfactory retaining wall must meet the following requirements.

a. The wall can statically withstand the earth pressure acting on the wall.
b. The wall foundation can support both the weight of the wall and the force generated by the earth pressure acting on the wall without:

- Overturning or soil failure or ground damage
- Wall and foundation sliding.
- Undue settlement

Earth pressure on the retaining wall depends on the condition of deformation or slope of the wall, soil characteristics, and water quality. To maximize economics, retaining walls are usually designed for active pressures such as those developed by dry, non-sticky backfills, but as needed, any yield, soil, and You can develop the design according to the water condition.

Common causes of retaining wall breakage

The most common causes of retaining wall breakage are:

- Improper placement of reinforcements
- Saturated backfill
- Weep hole that don't weep
- Design mistake
- Calculation and estimation errors
- Unexpected load
- Errors in software selection and use
- Error in summarising
- Foundation issues
- Inappropriate specifications and notifications
- Poor construction
- Retaining wall age

Literature Review

Retaining walls are structures that laterally support steep ground to prevent collapse. It was built primarily to optimize the use of limited space. In addition to the retaining wall survey, the stability of steep slopes was also consistently surveyed. Kimetto et al. analyzed slope stability with geotextile, and Salamatpoor and Salamatpoor improved slope stability with mixed soil materials. Nadie et al. evaluated the stability of the slope by examining the infiltration of water from the gravel. Next, Nandy et al. proposed a method to evaluate the seismic response of a slope based on the ground shear wave velocity.

Safety when using reinforced retaining walls is ensured by installing horizontal reinforcements to reduce earth pressure by taking advantage of the frictional resistance created by backfilling. Due to its simplicity, this approach is considered economical. Therefore, articles on reinforced soil retaining walls continue to be published.

Kim observed the behavior of the soil supported by the retaining wall through a model test. Then they defeat the ceremony. An expression that takes into account the height of the retaining wall, the spacing between the reinforcing bars, and the length of the reinforcing bars. The floor was simulated with aluminum rods with a thickness of 1.6 mm and 3.0 mm. Vertical walls were constructed outdoors to observe the stability or collapse of retaining walls reinforced through photography. Using an expression. The required reinforcement length was 1.40 m, which was between the lengths of Cases 1 and 2. This confirmed that the case conditions for the study were appropriate.

$$LH = 0.0975D + 0.2296 \qquad (2)$$

L: Reinforcement length; H: Retaining wall height. And D: Reinforcement application interval. In the case of retaining walls, the stress concentration generated in the curved part exceeds the stress concentration generated in the straight part. This phenomenon leads to buckling, tearing and collapse of the anterior wall. In addition, due to limited research, lack of design criteria and relevant information can lead to insecure designs.

Ki et al. Through laboratory model tests, the behavior of the reinforced retaining wall was analyzed according to the shape of the convex and concave surfaces. In the shape of both walls, the maximum horizontal displacement occurred in the curved section. In addition, the horizontal displacement that occurred was larger in the convex reinforcing retaining wall than in the concave wall. Based on the above, the conditions for the convex reinforced soil retaining wall were selected. And in this study, we compared the behavior of curved and straight parts with respect to the length of the reinforcement.

Lee et al. investigated the extent of damage to the reinforced retaining wall and used numerical analysis to analyze the behavior of straight and curved sections (convex and concave). In their study, the height of the reinforced soil retaining wall was 5.2 m and the length of the reinforcement was 4.2 m. Lee et al found that the horizontal displacement and subsidence of the curved part was greater in the convex wall than in the concave reinforced retaining wall. In this study, a 5.2 m convex retaining wall was adopted, and reinforcement materials of various lengths were examined to determine the optimum length.

Kong et al. predicted the breaking behavior of curved and straight parts based on the height of the reinforced retaining wall using 3D numerical analysis. Bulging was observed to increase with wall height, with greater horizontal displacement in the curved section than in the straight section. This study is based on four cases by Kong et al. The height of the wall in Case 2 was considered to be 5.2m (2018). This means that the minimum height of 5m of reinforced soil retaining wall is met. Their study found that horizontal displacement increases with wall height. This tendency was also observed in this study.

Lee et al. saw the deterioration of the drainage channel of the retaining wall as the cause of the bulge of the wall. Next, the range of the displacement wall was predicted based on the results of the field test. Numerical analysis was used to calculate the soil nail reinforcement interval and evaluate its stability to eliminate buckling. The length and spacing of the soil nails were calculated to be 5.0m and 1.5m, respectively. In addition, their study confirmed that horizontal displacements (ie, bulges) rarely occur after strengthening areas where displacements commonly occur. In this study, we will compare the reinforcing effect of the reinforcing length by using the geogrid, which is mainly used as a retaining wall reinforcing material in addition to the clay nails. Geogrids may be used in future field trials.

Several studies have been conducted on reinforced retaining walls and reinforcements. Current research has shown that using the same length of reinforcement for the straight and curved parts of the retaining wall is problematic for ease of construction. This approach can lead to wall collapse accidents due to inadequate reinforcement, or it can be uneconomical due to excessive reinforcement. We will propose strategies to improve economic efficiency by installing reinforcing bars of different lengths in bent and straight parts.

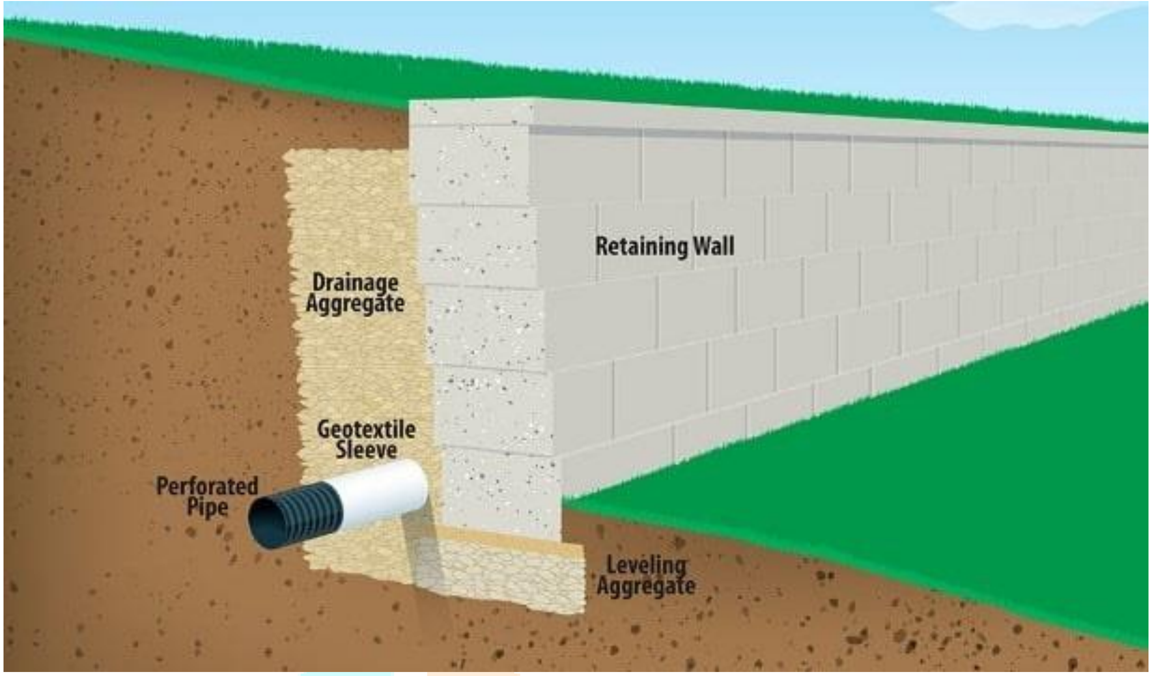
Various causes for retaining wall failures and their explanation:

Retaining Wall Failure due to Improper Reinforcement Placement:

Reinforcement size, depth, and spacing should be checked when wall stem exhibits sign if issues such as cracking and extreme deflections. Reinforcement size and depth can be determined either by devices for example magnetic field measuring pachometer. This device is used to find out reinforcement positions and depths up to approximately 100 mm with acceptable accuracy, or to achieve more accurate measurements. The device can also locate the rebar and knock out the concrete to determine the exact size and depth of the rebar. Surprisingly, there are situations where rebar is installed on the other side of the wall. This may be due to a contractor error or a detailed error. After checking the actual size, depth and position of the reinforcing bars and possibly using the collected core samples to test the strength of the trunk concrete, perform reverse design calculations to estimate and improve the actual design capabilities.

Retaining wall damage due to saturated backfilling

The design of the retaining wall assumes that the backfill is granular and drainage is good. If surface water is allowed to penetrate the backfill, wall pressure will increase significantly. This can be avoided by leveling the backfill surface and keeping the water away from the wall, or by diversion and disposal of the water in a drainage channel near the retaining wall. In addition, inadequate backfilling, for example with clay, swells and leads to a significant increase in pressure. Finally, a good example of backfilling is crushed fine-grained gravel. This ensures proper drainage and prevents pool water from forming behind the walls. **Figure #** shows a drainage system that can be used to avoid hydrostatic pressure.

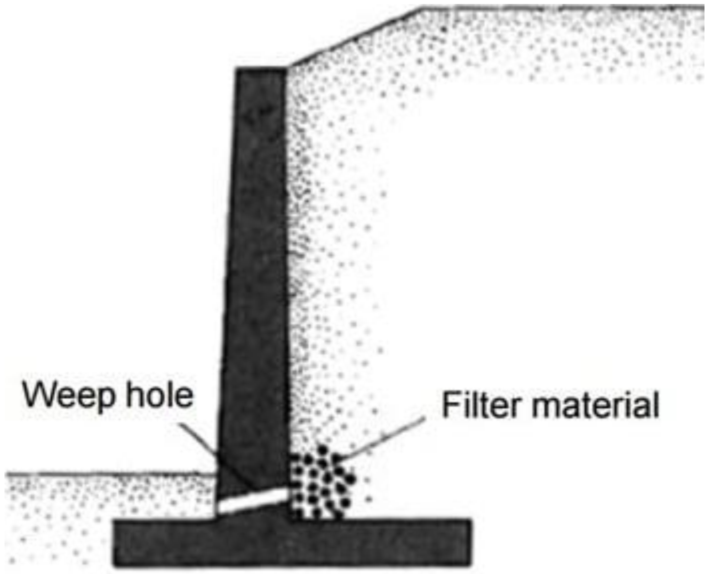


Retaining wall with proper drainage system

Retaining wall damage due to tear holes not crying

Due to the lack of filters, for example, gravel and broken rocks lined up along the base of a wall can clog weeds and cause drainage problems. In the masonry retaining wall, the mortar at the side joints is removed to create a drainage port, and the distance between the drainage ports is about 80 cm. Penetration holes in reinforced concrete retaining walls must be at least 7.5 cm in diameter and must not exceed 1 m in spacing. Alternatively, the designer can decide. **Figures 2** and 3 show the penetration holes in the retaining wall.

Weep hole in retaining wall



Providing weep hole in retaining wall to drain water

Design defects due to incorrect information

Retaining wall failures due to planning errors are a fairly exceptional case when an experienced structural engineer designs the wall. Nevertheless, designers may receive inadequate or incorrect information that is extremely harmful.

Retaining wall damage due to calculation error

Experienced designers can easily notice these mistakes. However, it is very important for new designers to reconfirm their designs as they have the opportunity to make calculations. As a result, costly fixation of the wall after construction can be avoided.

Unexpected load

Since this is an information issue between the client and the designer, good communication between the various people involved in the design is essential. Unexpected loads can occur due to additional charges that the designer does not consider. In addition, it could have been a steeper slope backfill or wind load.

Errors when using software

Designers need to be familiar with the program's capabilities, outputs, and limitations when entering data accurately and using the design software. In addition, it is advisable to perform quick calculations for verification, especially if you are in doubt about the results.

Retaining wall damage due to detailed error

The details should be clear, correspond to design calculations, and prevent suspicious interpretations. Ambiguous details can lead to inaccurate reading of information. For example, that dowel extended 0.15 m instead of 0.6 m into the stem.

Foundation Issues

The guidelines are available for foundation design that engineers/designer can use with the help of site investigation report, but in some possible cases these investigation is not provided. Lack of site investigation could lead to foundation problems because Codes restricted soil bearing and designers should use conservative values. Furthermore, designers should be aware about compressible soil, backfill material, water table, and other factors that might decrease sliding resistance or lead to large differential settlement.

Insufficient specifications and notes

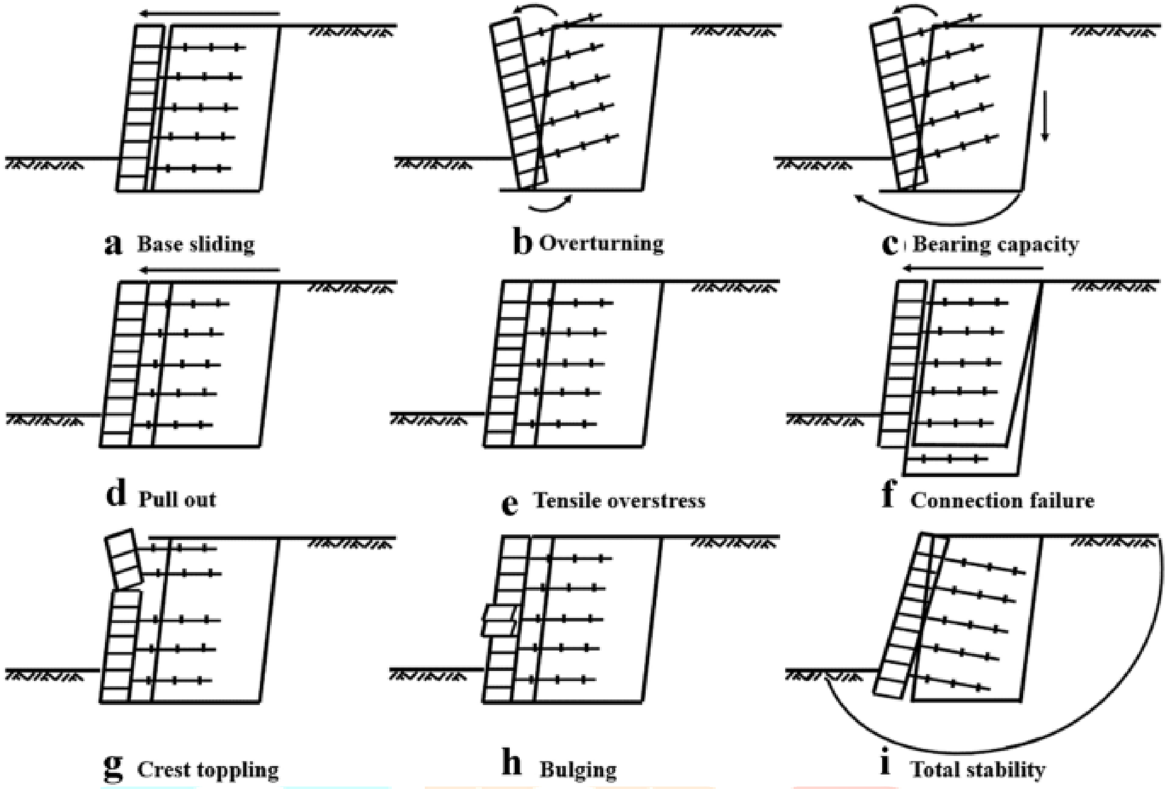
If differences found between site conditions and its drawings, or unexpected conditions is come across the engineer should be contacted to for the steps to be followed. If standards and details both have differences, the most restricted must be followed. Finally, all changed instructions must be conformed and affected parties should be informed. These measures are taken avoid problems that could lead to detrimental effect on the retaining wall.

Retaining Wall Failure due to Poor Construction

Poor construction practices might be due to unscrupulous or inexperienced contractor works that is carried out as per standards and specified plans. Inadequate mortar, or grouting, or improper steel reinforcement placements are compelling examples of poor construction. it is recommended to understood construction requirement and conditions and review the plan properly.

Retaining Wall Failure due to Age

When a retaining wall is stood for about fifty years or more without showing distress indication, therefore there are possibilities that it may stand for another fifty years or more in the future and will not need to take any actions. However, this is not the case in seismic regions, or adding new surcharges, or drainage change above the wall, so maintenance or seismic evaluation would be suitable to verify whether the wall can take new loads or withstand another earthquake



Patterns of wall collapse

Obviously, the suitable selection of retaining wall reinforcement is critical. The construction of a retaining wall without considering various factors, such as reinforcement type, length, and spacing, leads to collapse or financial loss. In general, the reinforcements should receive sufficient frictional force or passive resistance at the contact surface between the reinforcement and soil. They must also possess sufficient tensile strength, strain capacity, and durability.

The recommended maximum and minimum ranges of vertical spacing of reinforcements are 80–100 and 20–30 cm, respectively, and the reinforcement length is calculated using the given Equation. Hence, the maximum reinforcement effect can be derived at a minimum cost by employing different reinforcement lengths for the straight and curved parts.

L=(H−z)tan(45∘−φ2)+Ka·Sv·FSp2tanφuwL=(H−z)tan(45∘−φ2)+Ka·Sv·FSp2tanφuw

(1)

L: Reinforcement length; *H*: Height of retaining wall; *z*: of reinforcement location;

φ: Shearing resistance angle; K_a: Active earth pressure coefficient;

S_v: Vertical offset of reinforcements; FS_p: Factor of safety against breaking; φ_u: (2/3)φ.

Conclusion

Retaining wall design needs to be thorough, and engineers need to at least understand the assumptions in deriving these equations.

In order to prevent the increase in hydrostatic pressure, it is necessary to use a backfill material with excellent drainage. In unavailable situations, it is necessary to prevent water from entering the backfill to prevent an increase in hydrostatic pressure.

The word failure does not necessarily mean catastrophic failure. Some B. slight slippage of the retaining wall, such as, should of course be called inadequate performance and is not a serious obstacle.

Hope this helps with a general understanding of retaining wall design and construction challenges.

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