Retaining Walls and Why They Sometimes Fail

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Abstract

This paper provides a discussion on the various types of retaining walls commonly used in Malaysia. The factors that can influence the selection of the type of wall are given. The main reasons why retaining walls fail are also highlighted and it can be concluded that most failures are due to deficiency in design and inadequate drainage.

INTRODUCTION

Retaining wall is one of the most common structures encountered. As its name implies it is to retain earth and extra land can be recovered. With land at premium prices, the high cost of the walls is justifiable. It is commonly used in highways, bridge abutments, basements and water-retaining structures such as swimming pools and reservoirs. Figures 1 and 2 show collapsing grounds where retaining walls are required.

Failures of retaining walls are getting more frequent, especially during the rainy periods and they do attract a lot of attention.

Figure 1: This slope is about 13m high: a counterfort wall was used to retain the earth

Figure 2: The slope has already failed and urgently required protection

The success of a retaining wall depends on a good design, good construction practice and proper supervision. The selection of the types of wall can be crucial in high height and when there is a large surcharge loading.

TYPES OF RETAINING WALL

There are many types of retaining structures and they are generally divided into three categories namely gravity wall, reinforced concrete retaining wall and cantilevered retaining wall. Only the commonly used walls in Malaysia are discussed.

1. GRAVITY WALLS

Gravity walls are walls that use their massive weights and weight of the backfill to resist the lateral forces. The early retaining structures are mortared stones gravity walls.

Masonry gravity walls

Masonry walls are usually made of bricks, stones or rocks. Brick walls are perhaps the simplest form of retaining wall and are only used for low heights. It is often used in drains.

The other simple and widely used masonry gravity wall is the rubble wall (Figure 3). Although it is commonly used in short height, some walls have been constructed to heights of more than 9m (Figure 4). Limestone is one of the most commonly used rocks in rubber wall construction. If limestone rocks are readily available and there is ample space for construction, rubble wall can be an economical option, especially for medium height walls.

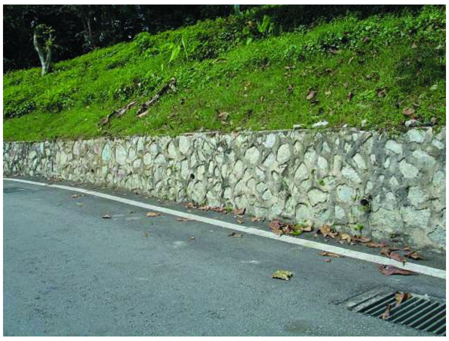

Figure 3: The common rubble wall

Figure 4: A tall rubble wall

Gabion walls

Another simple to construct gravity wall is the Gabion wall. It is made of rows of rock filled cages called gabions. It has the advantage of not requiring heavy equipment to construct and is often used in difficult to assess areas. Gabion walls are ideal as temporary retaining structures, as they are simple and fast to construct. They are tolerable to settlement and their permeability and flexibility make them favourable in river works. Figure 5 shows a typical gabion wall that is built near a river.

Figure 5: Gabion walls are ideal for use along riverbank

Crib Walls

These walls are formed by building a series of interlocking precast reinforced concrete units in the form of crib structures (see Figure 6). The spaces between the units are filled with coarse granular materials such as crushed rocks which provide good drainage. Some cribs walls are constructed to very high heights. However, walls of more than 7 m high may be sensitive to transverse differential settlements (*reference: Tschebotarioff*). Driving of piles near a crib wall has been known to cause transverse displacements.

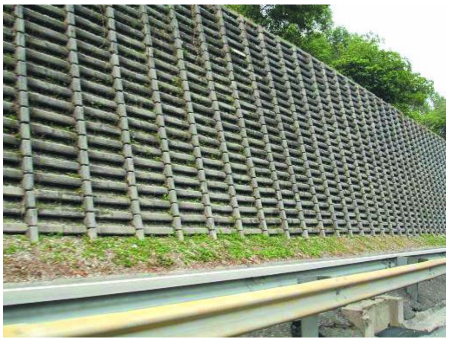

Figure 6: A typical crib wall

Soil Reinforced Walls

One of the most common soil reinforced walls in Malaysia is the Reinforced Earth wall (Reinforced Earth is a trade name). Reinforced Earth or RE walls as they are commonly called, consist of reinforcing the soil with galvanised steel strips and vertical precast concrete panels are connected to these steel strips to form a retaining wall. RE walls are flexible, simple to construct, can cope with curves and have aesthetically pleasing finishes (Figure 7). The invention of Reinforced Earth has drastically changed the building of

Figure 7: An attractive reinforced earth wall

highway embankments. They are extensively used in highway projects.

2. REINFORCED CONCRETE WALLS

Reinforced concrete cantilever retaining walls

Reinforced concrete cantilever walls are the most common type of retaining walls. They are commonly known as RC walls and can be L or inverted T shaped. The maximum height for these walls is 8m; for taller walls the structural members can be large and become uneconomical. Precast reinforced concrete cantilever wall are used in main drains (Figure 8).

Counterfort walls

Counterfort walls are similar as cantilever except counterforts are provided on the earth side between wall and base to support the wall. The

Figure 8: Precast RC walls are commonly used for drains

walls are essentially designed as one-way slabs spanning horizontally between the counterforts. Counterfort walls are suitable for great heights normally up to 14m or where high surcharge loads are present. An example of a counterfort RC wall that was constructed to 13m high is shown in Figure 9.

3. CANTILEVERED WALLS

Bored pile walls

Contiguous bored piles are increasingly being used as retaining walls in basements (Figure 10) and

Figure 9: A classic example of a counterfort wall

highways. These walls are constructed as a series of bored piles at close spacing. These piles can be reinforced to withstand both vertical and horizontal loadings. They are expensive but may be necessary for critical works or where space is restricted. Often reinforced concrete facing walls are constructed over the piles to provide better finishes. Figure 11 shows contiguous bored piles which are used to retain earth along a riverbank.

Diaphragm walls

Diaphragm walls are commonly used in deep basement and one common

Figure 10: Contiguous bored pile wall used in basement

method is by drilling and grabbing. These techniques are similar to the construction of rectangular piles known as barrette piles.

WHY DO RETAINING WALLS FAIL?

Retaining walls can fail due to improper design, improper construction and inadequate supervision. The main causes of failures are as follows;

a. Design

Many of the failures in retaining walls can be traced to deficiency in design. Quite often, the selection of the wrong type of wall may lead to a poor design. For instance the use of rubble wall for great heights may be a recipe for failure. There are many failures of reinforced concrete cantilever walls constructed to over 10m high. Counterfort walls should have been used instead. Another common mistake is the non-usage of raking piles when retaining walls are to be founded on piles. The engineer should be responsible for the design of surface and ground water drainage control.

b. Hydrostatic pressure

The most common cause of failure of a retaining wall is action of water. The hydrostatic pressures are normally not catered for in design. It is amazing that the drainage is often ignored or poorly provided in the construction. Improper constructed drainage (or worst no provision) can induce high hydrostatic pressure, which will cause devastating effect. Retaining Wall Design by GEO (Reference 1) provides some excellent methods of drainage control. Upon completion of the construction of a retaining wall, there should be a test to verify that the weep holes are working. Good drainage from weep holes is very important (Figure 12). A classic example of failure of a RC sea wall because of no provision for drainage (Figure 13).

c. Poor backfill

Poor backfill is another common cause of failure. The general practice is to backfill with whatever soil that is available at the site. Clayey silt backfills such as ex-mining slime should be removed. Clay backfills should be avoided if possible. Backfilling materials used should be granular and free draining such as sand. Figure 14 shows a RC wall failure because of poor backfill materials used.

Figure 11: Bored pile wall used to retain the riverbanks. Note the drainage pipes are provided

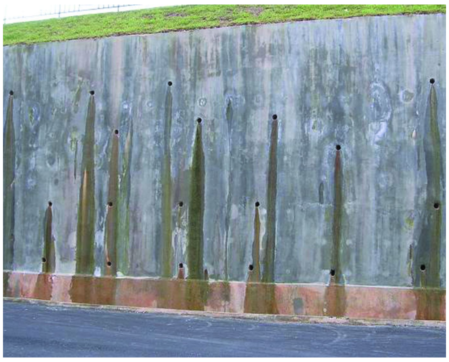

Figure 12: These weep holes are working very well indeed

Figure 13: Failure of a sea wall because of no provision for drainage

Figure 14: RC wall failure because of poor backfill materials used

d. Ignorance of large surcharge loads

Another cause of failure is the ignorance or refusal of the designer in considering large surcharge loads. Often retaining walls have to support vertical loads as well as its natural job of retaining materials. There is an example where a reinforced concrete cantilever wall had to support a four-storey building! This is another recipe for disaster.

e. Unanticipated loading

Compaction of backfilled by heavy equipment may impose high surcharge loading on the wall. Generally it is advisable to use hand compactors. Traffic loads are often not anticipated in design.

AESTHETICS

The appearances of the wall are often ignored or overlooked. Many RC walls look like the wall as shown in figure 15, stained and with unsightly construction joints. Figure 16 also shows unsightly blemishes of a cantilever reinforced concrete wall which is due to water from the weep holes. Should this be considered a failure? The faces of reinforced earth walls can be of different pattern and some are now even made of coloured concrete to look attractive.

An example of an aesthetically pleasing retaining wall is shown in Figure 17.

SELECTION OF WALLS

Many factors should be considered when deciding the type of wall to be used.

The selection of retaining walls depends on the following:

1. height of the wall
2. surcharge load
3. soil condition
4. availability of space for construction
5. ground water and rainfall density
6. availability of raw materials
7. aesthetic value
8. design life
9. consequences of failure

Figure 15: RC wall stained and unsightly construction joints

Figure 16: Unsightly blemishes of a cantilever reinforced concrete wall which is due to water-borne detritus from the weep holes.

Figure 17: An aesthetically pleasing wall

CONCLUSION

Although the retaining wall is one the most common structures, failures of walls are common. It can be concluded that most failures are due to deficiency in design and inadequate drainage. It is one failure where lesson learnt will not be repeated.

Proper supervision is required to ensure that retaining walls are constructed to specification. Surface rain drainage control is as important as ground water drainage. Another good practice is to have free drainage backfills; it is worth the extra cost.

Aesthetics is beginning to play an important part in the design and construction of retaining walls. Retaining wall may not have to be unsightly, it can be aesthetically pleasing.

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One very important factor to consider in the design retaining wall is the consequences of failure. If the failure of a retaining wall is catastrophic, then the wall should be designed to a much higher factor of safety. ■

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