
ICOPMAS

Effects of Changing Water Level on Stability of Reinforced Earth Marine Wall

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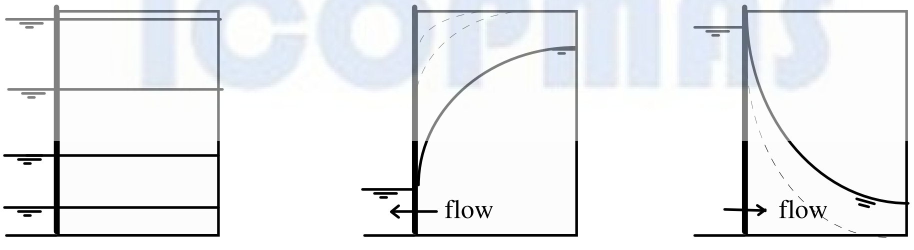
Abstract

One of applications of reinforced earth is in marine works. In this application a reinforced soil wall may be used as a quay wall, wharf structure or a seawall to protect the coastline against wave action. When a reinforced soil wall is used as a seawall, it must be designed to withstand against the marine environment. Changing water level in front of the wall is one of marine parameters, which could affect the stability of the structure. This paper evaluates the effects of changing water level especially saturation and rapid draw down on stability factors of reinforced soil marine wall. For this purpose a model wall was subjected to different cases of changing water level and the amount of safety factors of the wall were computed by a computer program developed by the author. The study shows that the rapid draw down of water table from top of the wall can increase the tensile force in the reinforcement by three times, which inherently decreases the safety factor of the structure.

Introduction

When a reinforced soil wall is constructed in marine environment, it must be designed to withstand against marine parameters such as submergence, changing water level due to tide, wave forces and ship attack [۲]. One of marine parameters, which may have deleterious effect on stability of the structure, is changing water level, especially in the case of rapid draw down of water table in front of the wall [۴], [۶]. Rapid change of water level in front of the wall is almost occurs in presence of high sea waves. This papers aims to evaluate the effects of changing of water level especially rapid draw down on stability factors of reinforced earth marine wall. To determine this effect, different cases of changing water level may be considered. In the first case, the water table is assumed to be stable and horizontal on the inside and outside of the wall but the different depths (Figure ۱a). This case is suitable for simulating tide effects on the wall behaviour. In the second case, the water level in the backfill of the wall is higher than in the front of the wall, and water seeps out from the backfill (Figure ۱b). This case simulates the rapid draw down of the water table at the front of the wall. In the third case, the water table at front of the wall is higher than in the backfill, and water seeps into the wall. In this case the water pressure acting on the facing panels reduces the tensile forces of the strips and provides more stability for the wall. Since the third case has no deleterious effects on the stability of the structure, only the first two categories studied in this research.



a) b) c)

Figure ۱: Different categories of changing water level

This study was done by numerical modelling. The numerical modelling was done using the computer program ADRES, developed by the author. This program is able to carry out seepage computations as well as the internal and external analysis of reinforced earth walls by

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Computer Program

The computer program ADRES was developed and used to investigate the effect of water draw-down on the strength of reinforced earth walls [۵]. The program ADRES is able to analyse and design a reinforced earth wall in dry and saturated conditions. All three cases of changing water level (Figure ۱) can be introduced to the program. This program uses the finite difference method to calculate the profile of water table inside the backfill.

Case Study

A typical reinforced earth wall was used as a case study for numerical modelling. The selected structure was a reinforced earth wall constructed and tested in Kuala Lumpur, Malaysia [۳]. The wall was ۸,۵m high, and was constructed by using ۶m long reinforcing strips and standard concrete facing panels (Figure ۲). High adherence ribbed galvanised mild steel strips with a thickness of ۵ mm and ultimate tensile strength of ۴۰۰ MPa were used in this project. The vertical and horizontal spacing of the reinforcements was ۰,۷۵ m. The backfill material was mining sand with an internal friction angle of ۴۰ degrees, and a soil-reinforcement friction coefficient of ۰,۶.

To evaluate the effect of changing water level, the wall was firstly analysed under flat water tables located at levels ۰, ۰,۷۵, ۱,۵۰, ۲,۲۵, ۳,۰۰, ۳,۷۵, ۴,۵۰, ۵,۲۵, ۶,۰۰, ۶,۷۵, ۷,۵۰ and ۸,۲۵ metre from the toe of the wall. For each level, maximum tensile force in the reinforcements, safety factor against rupture failure, and safety factor against bond failure of reinforcements were determined. For calculation of these parameters, the Coherent Gravity Method was used. The results were plotted in Figures ۳ and ۴. As these figures indicate, simultaneous raising of water level in and outside of the wall, decreases the maximum tension in the strips and increases the safety factor against rupture failure, while the safety factor against bond failure is constant.

In another case, the water level inside the wall was considered to be horizontal varying from zero to the height of the wall, while there was no water head at the front of the wall. The analysis results are shown in Figure ۵ and Figure ۶. In this case, raising the water level inside the backfill increases the maximum tension in the reinforcements, and decreases the safety factor against rupture failure and the safety factor against bond failure.

In the third case, the wall was analysed during water draw down from top of the wall. The wall was firstly assumed to be fully submerged with the water level at the top. The water was then permitted to seep out and the water table was calculated at various periods during draw down. The profile of the water table at different times during draw down is shown in Figure ۷. The maximum tension in the strips, the safety factor against rupture failure, and the safety factor against bond failure are given in Figures ۸ and ۹. From these figures, the minimum values of safety factors against bond and rupture failure is related to the beginning of draw down process. In this time, water table inside the backfill is at top of the wall while in front of the wall is zero. The characteristics of the most critical situation in each of the above cases are compared in Figure ۱۰ and Figure ۱۱. The figures indicate that the minimum internal stability of the wall is related to the water table inside the backfill being at the maximum level, with no water head at the front of the wall. In this case, the structure exhibits the minimum safety factor values against rupture and bond failure.

Conclusion

Numerical studies on partially and fully submerged reinforced soil wall with cohesion-less material shows:

- Submerging the wall is associated with decreasing the maximum tensile force in the strips located under the water level, while it has no considerable effect on the maximum tensile force in the strips located above the water level. The decrease in maximum tensile force is due to the buoyancy effect.

- Submerging a reinforced earth wall with cohesion-less material does not have any deleterious effect on internal stability of the structure.
- Rapid draw down of water table causes a significant decrease in stability of the structure. The most critical case occurred when the water table in the backfill is in maximum level (top of the wall) and water table at front of the wall is at zero level.
- Rapid water draw down causes a major increase in maximum tensile force in the reinforcements especially in the lowest layer. This is because of the difference in water levels inside and outside the soil mass. After rapid draw down, the water level at front of the wall becomes zero, while the water level inside the wall is still high. This difference in water level causes a hydrostatic pressure to act on the back of the facing panels, resulting in a higher tensile force in the reinforcements.

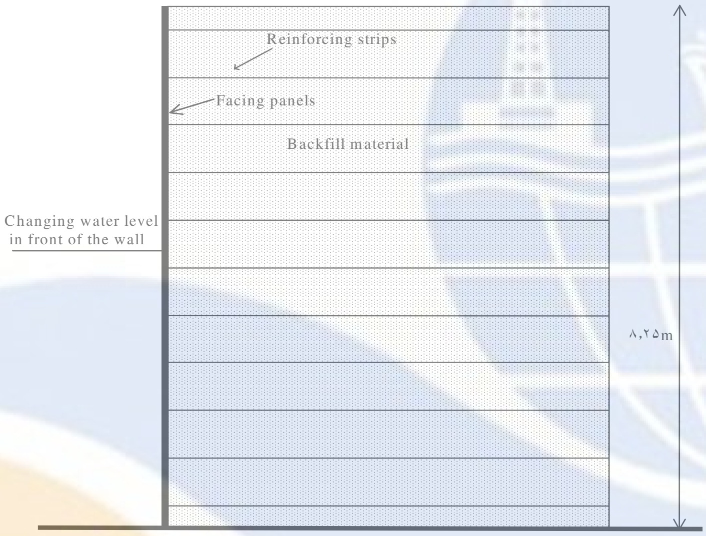

Figure ۲: Sketch of the model wall

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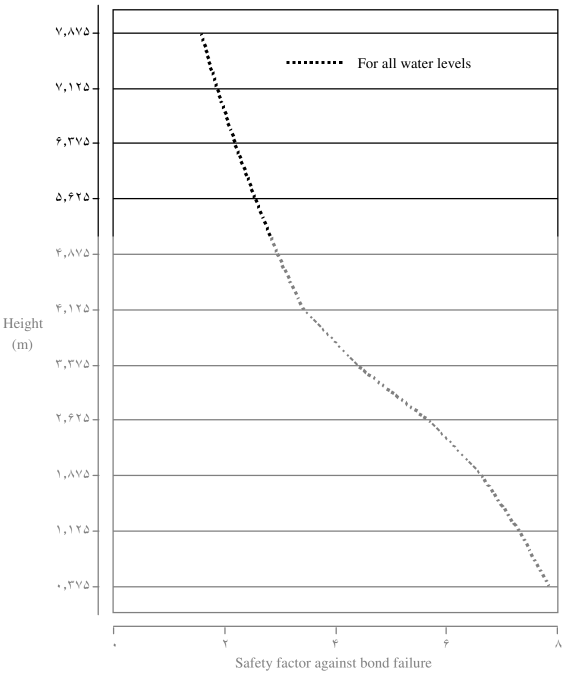

Figure ۴: Safety factor against bond failure for different water levels (Horizontal water table inside and outside of the wall)

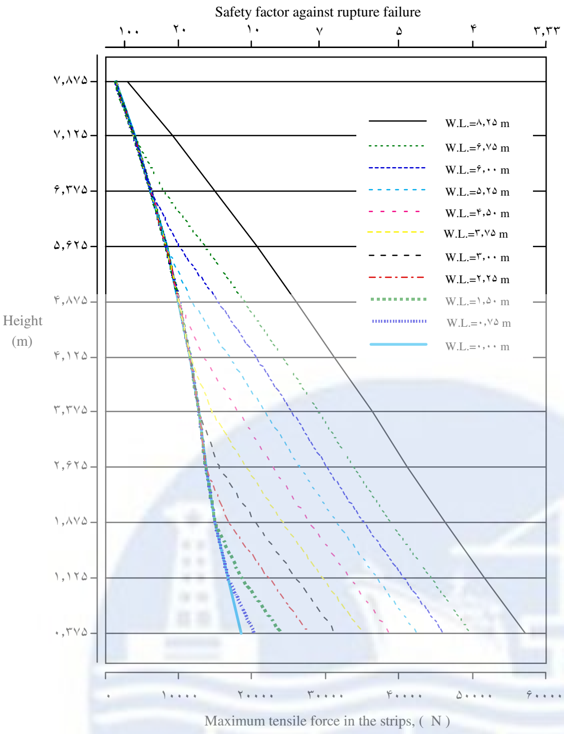

Figure ۵: Maximum tensile force in the strips and safety factor against rupture failure for different water levels (Horizontal water table inside the wall only)

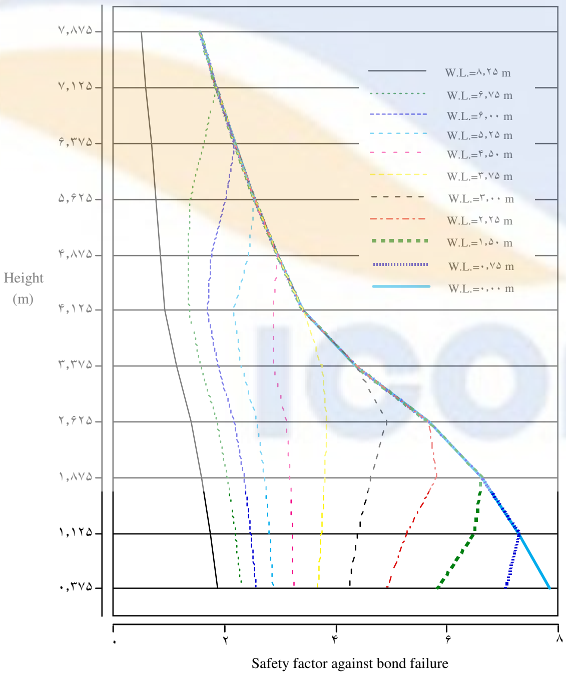

Figure ۶: Safety factor against bond failure for different water levels (H orizontal water table inside the wall only)

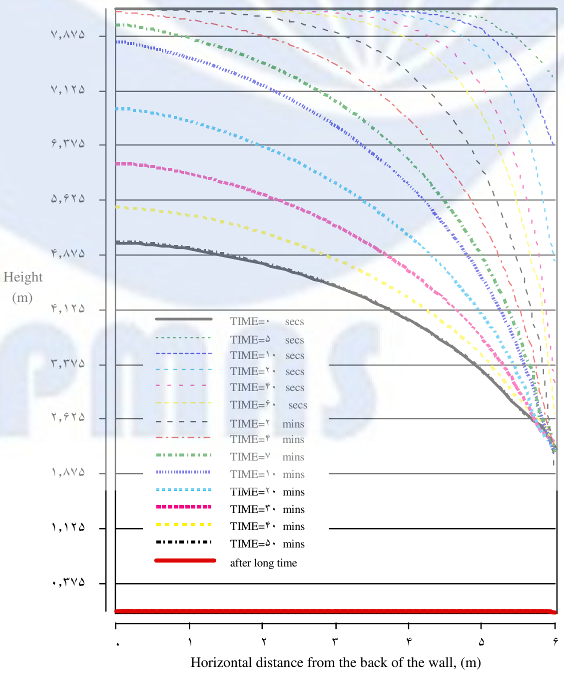

Figure ۷: Profile of water table during water drawdown from top of the wall

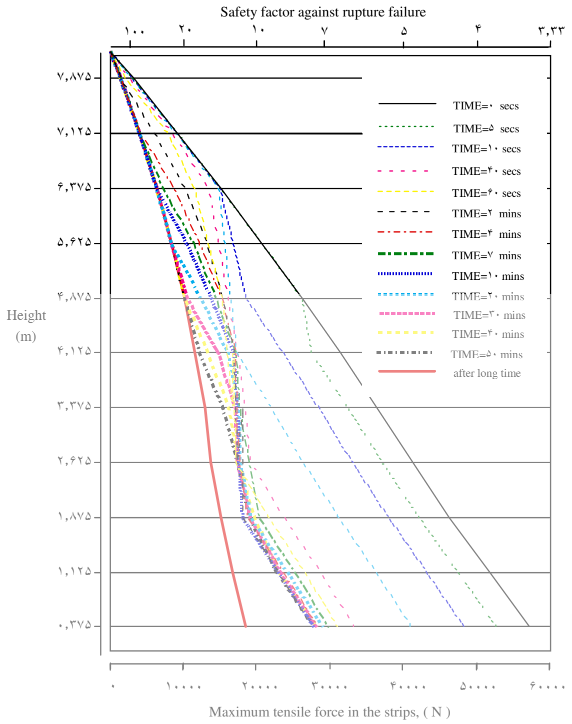

Figure ۸: Maximum tensile force in the strips and safety factor against rupture failure during water draw down from top of the wall

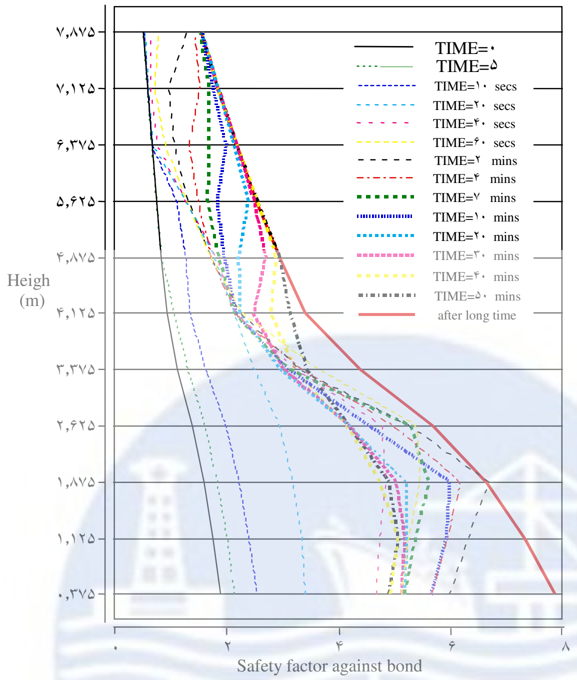

Figure ۹: Safety factor against bond failure for different water profiles during water draw down from top of the wall

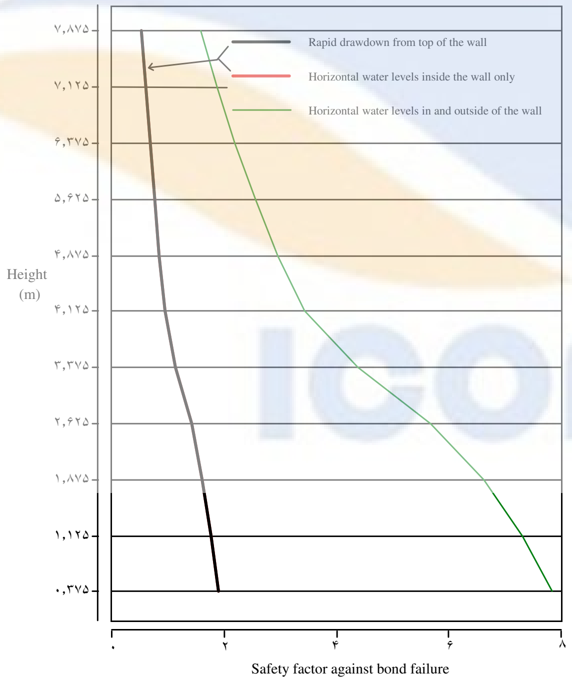

Figure ۱۰: Critical values of maximum tensile force in the strips and safety factor against rupture failure obtained for different cases of changing water level

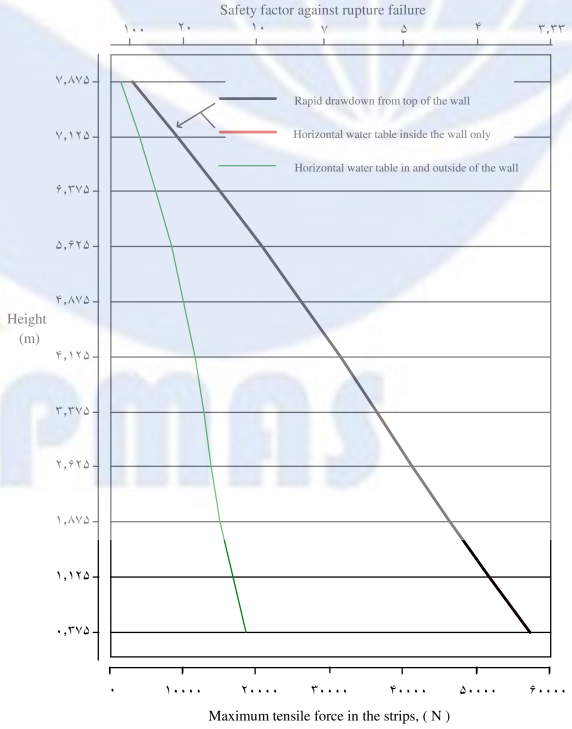

Figure ۱۱: Critical values of safety factor against bond failure obtained for different cases of changing water Level