PERFORMANCE OF PULLOUT RESISTANCE OF ANCHORED EARTH SYSTEM BY FIELD PULLOUT TEST

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ABSTRACT

Anchored Earth System had been developed from combination of the techniques used in reinforced earth and soil anchoring. Instead of using steel strip as a reinforcement, Anchored Earth System consist of round steel bar (tendon) with precast concrete block attached at the free end of each of the reinforcing steel bars, and it is backfilled with granular material or suitable earth fill. This research project can be considered a case study of anchored reinforced soil wall which investigates the performance of Anchored Earth System due to its pullout capacity. In this study, pullout resistance which contributed by friction between the backfill material and the shaft surface of reinforcing tendon, and the passive earth pressure against the concrete anchor block, can be evaluated through pullout tests. The main problems to be studied in this project are the results obtained from field pullout test are different from the calculated theoretical values and there is a non-zero intercept at relationship of pullout force against overburden pressure. The field pullout tests were carried out in three conditions: i) with reinforcing tendon only; ii) with anchor block only; and iii) with both reinforcing tendon and anchor block together in order to determine the sharing of resistance in the system. The pullout test was also done under soaked condition. The average interaction coefficient α' = 1.99 and bearing factor β = 6.32 were determined by back analysis. It was found that the sharing of load between the tendon and the anchor block in anchored earth system is not equal, but most of the resistance is contributed by the bearing passive of anchor block where approximately 30 % of resistance contributed by residual frictional resistance and 70 % contributed by peak bearing passive resistance. The pullout resistance in soaked condition observed to be lower than in unsoaked condition due to the increase in pore water pressure that reduced the shear resistance.

ABSTRAK

Sistem Tanah Tertambat telah dikembangkan dari kombinasi teknik yang digunakan dalam tanah bertetulang dan tanah tertambat. Di sebalik penggunaan jalur keluli pipih sebagai tetulang, Sistem Tanah Tertambat menggunakan jalur keluli bulat (tendon) dan blok konkrit pratuang yang dipasang pada hujung bebas tendon. Tanah timbus belakang yang digunakan adalah tanah berbutir. Projek penyelidikan ini merupakan kajian kes ke atas dinding penahan bertulang yang tertambat untuk menyiasat prestasi Sistem Tanah Tertambat terhadap kapasiti tarik keluar. Dalam kajian ini, rintangan terhadap tarik keluar yang disumbangkan oleh geseran antara bahan kambus belakang dengan permukaan tendon dan tekanan pasif tanah terhadap blok konkrit boleh dinilai melalui ujian tarik keluar. Masalah utama kajian ini adalah keputusan yang diperolehi dari ujian lapangan berbeza daripada nilai kiraan secara teori dan adanya nilai pintasan pada hubungan daya tarik keluar terhadap tekanan beban atas. Ujian tarik keluar di lapangan dilakukan dalam tiga keadaan: i) ke atas tendon sahaja; ii) ke atas blok konkrit sahaja, dan iii) ke atas gabungan tendon dan blok konkrit untuk menentukan perkongsian rintangan tarik keluar dalam Sistem Tanah Tertambat. Ujian juga dilakukan dalam keadaan terendam. Purata pekali interaksi α' = 1.99 dan nilai pekali galas β = 6.32 telah diperolehi melalui analisis kembali. Analisis juga menunjukkan rintangan terhadap tarik keluar tidak dikongsi secara sama rata antara tendon dan blok penambat. Sekitar 30% dari rintangan terhadap daya tarik keluar adalah sumbangan geseran baki antara tendon dan bahan timbus belakang dan 70% disumbangkan oleh rintangan pasif tanah puncak dan blok penambat. Keputusan ujian dalam keadaan terendam menunjukkan rintangan terhadap daya tarik keluar adalah lebih rendah disebabkan kenaikan tekanan air liang yang menurunkan rintangan ricih.

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A	–	Facing area of anchor block
A_s	–	Friction area
A_p	–	Projected area of the expanded toe towards the pullout direction
B	–	Width
B_a	–	Long term width of anchor head
B_s	–	Long term horizontal projection area of shaft or loop
C	–	Constant
c	–	Cohesion
D	–	Diameter of tendon
d	–	Depth
F_A	–	Bearing passive resistance
F_R	–	Shaft friction resistance
F^*	–	Pullout resistance factor
F_a	–	Force resulting from adhesion mobilization
F_p	–	Resulting force due to passive resistance
F_{sg}	–	Resulting force due to friction mobilization
F_t	–	Pullout force
$F_{\gamma q}$	–	Force coefficient
F_1, F_2	–	Tension force
F_{corr}	–	Corrected pullout force
F_{dum}	–	Dummy pullout force
F_{max}	–	Maximum pullout force recorded
f	–	Friction coefficient between grains and reinforcement

f_b	–	Soil-geosynthetic pullout interaction coefficient
f_{ms}	–	Partial material factor
f^*	–	Pullout friction coefficient
h	–	Height
K_P	–	Coefficient of passive earth pressure
K_0	–	Coefficient of pressure at rest
L	–	Length of tendon
L_{ej}	–	Length of anchor shaft beyond the potential failure plane
m	–	Gradient of graph
N_c, N_γ, N_q	–	Bearing capacity factor
N_w	–	Number of transverse member
P	–	Ultimate pullout load
P_{aj}	–	Bearing resistance
P_d	–	Pullout strength
P_f	–	Frictional resistance
P_p	–	Passive pressure
P_R	–	Pullout resistance
P_{sj}	–	Shaft or loop resistance
P_u	–	Ultimate pullout resistance
P_y	–	Pullout resistance at yield
Q, R	–	Modification factor
Q_{ult}	–	Ultimate bearing capacity
q_p	–	Horizontal confining pressure at expanded toe
R_p	–	Pullout resistance
t_a	–	Long term height of anchor head
α'	–	Interaction coefficient
β	–	Bearing factor
δ	–	Skin friction angle between reinforcement and soil
ε_1	–	Major principle strain
ε_3	–	Minor principle strain
ϕ'	–	Friction angle

γ	–	Unit weight of soil
φ'_p	–	Peak angle of shearing resistance under effective stress condition
μ	–	Coefficient of soil/reinforcement friction
μ_s/G_{SY}	–	Soil-geosynthetic interface apparent coefficient of friction
τ	–	Maximum shear strength
τ_f	–	Failure shear stress
σ_a'	–	Average normal stress
σ_n'	–	Normal effective stress
σ_v'	–	Overburden pressure
σ_{vj}'	–	Vertical applied pressure
σ_{vo}	–	Normal stress
σ_x	–	Horizontal stress
σ_y	–	Increased normal stress due to shearing
σ_z	–	Vertical stress
σ_1	–	Major principle stress
σ_3	–	Minor principle stress

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Retaining wall is a structure that provides vertical or nearly vertical support to a differential level of masses of soil and holds back soil from another structure such as buildings on top, and it may prevent slope instability or erosion from happening. The supported material is termed as backfill. Retaining walls generally can be classified to various types: (i) Gravity Wall, which rely on their own self-weight or any soil resting on top for the sustainable of stability against the horizontal lateral earth pressure; (ii) Semi-gravity Wall, with minimum amount of reinforcing steel in order to minimize the wall size; (iii) Cantilever Wall, which derives part of its stability from the weight of the soil located above the footing at the back of the wall; and (iv) Counterfort Wall, that consist of counterfort that tie the wall and base slab together in order to reduce the shear and bending moments. The failure of a retaining wall may usually caused by tilting or sliding along the base which parallel to its original position. Each of the failure type as mentioned above is associated with a downward movement which is named as wedge-shaped body of soil or the sliding wedge.

Reinforced soil wall is a combination of soil and reinforcing element. Each of the elements has their own properties and strength. The fundamental is the reinforcing elements embedded in soil contribute tensile strength to soil. The interaction between reinforcing elements and soil through friction or adhesion thereby provide tension and shear to strengthening the soil.

1.2 Historical Background of Reinforced Soil Wall

The concept of earth reinforcement is the basic principles illustrated naturally by animals and birds and the action of tree roots. It is believed that the earliest reinforced soil wall concept was first applied in the ancient time. During the ancient times, the brick was made with straw reinforcement by the Egyptians. One of an earlies reinforced soil structures, Ziggurat of the ancient city of Dur-Kurigatzu as shown in Figure 1.1, which was built by the Babylonians since 2500 BC was reinforced with woven mats of reed laid horizontally on a layer of sand and gravel at vertical spacing varying between 0.5 and 2.0 m (Lee, 2006).

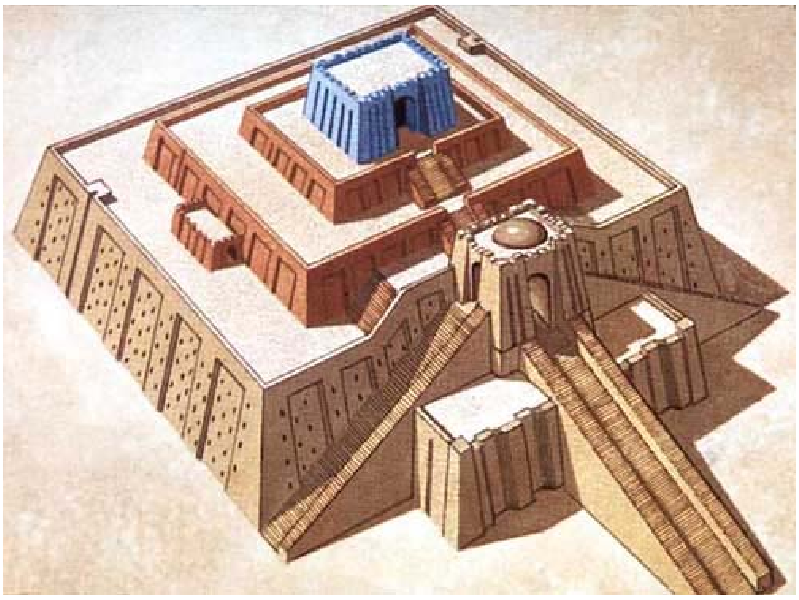

Figure 1.1 The earliest reinforced soil structure, Ziggurat in Mesopotamia (Lee, 2006).

In fact, many parts of Asia are using bamboo and straw to strengthen soil mass. Natural materials were used as reinforcement to construct a large portion of the Great Wall of China. In the Gansu province for instance, some section of Great

Wall were built using loess soil, which was reinforced with reeds and twigs at every 150mm lift (Lim, 2003).

The timber wharf shown in Figure 1.2, parts of which have been preserved in the Thames mud for 1200 years is believed built by Romans (Jones, 1985). The structure was formed from oak baulks and having a vertical face held in place by timber reinforcing elements embedded in the backfill.

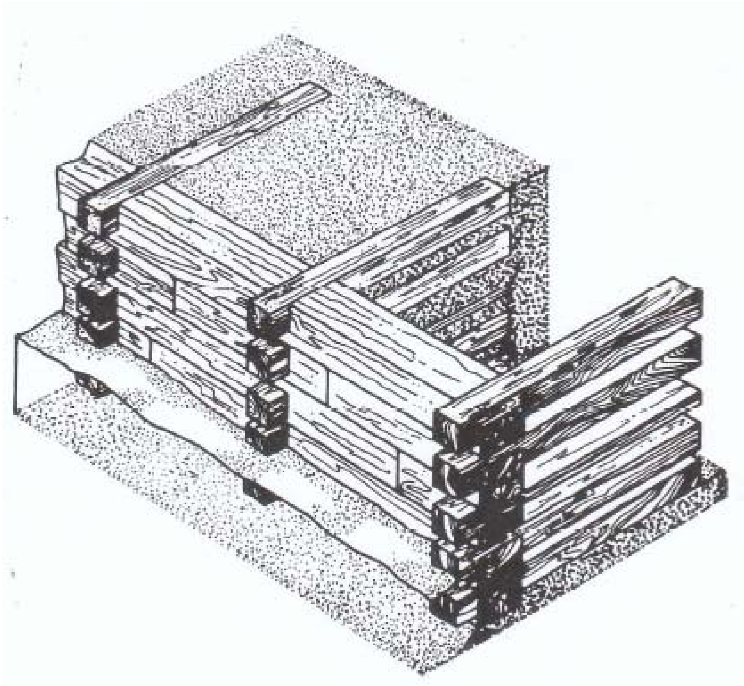

Figure 1.2 The timber wharf (Jones, 1985).

In year 1822, Col. Pasley (Jones, 1985) successfully introduced a form of reinforced soil for military construction in the British Army he proved that significant reduction is possible in the lateral pressure acting on the retaining walls if the backfill were reinforced by horizontal layers of brushwood, wooden planks or canvas.

The modern concept of reinforced soil structure was made by Munster in year 1925 (Jones, 1985). An earth retaining wall using an array of wooden reinforcing members and a light facing was produced by Munster. The systems created by Munster are still valid and become the core of one of the reinforced soil construction techniques among the many. The following Figure 1.3 is the diagram of Munster earth retaining structure.

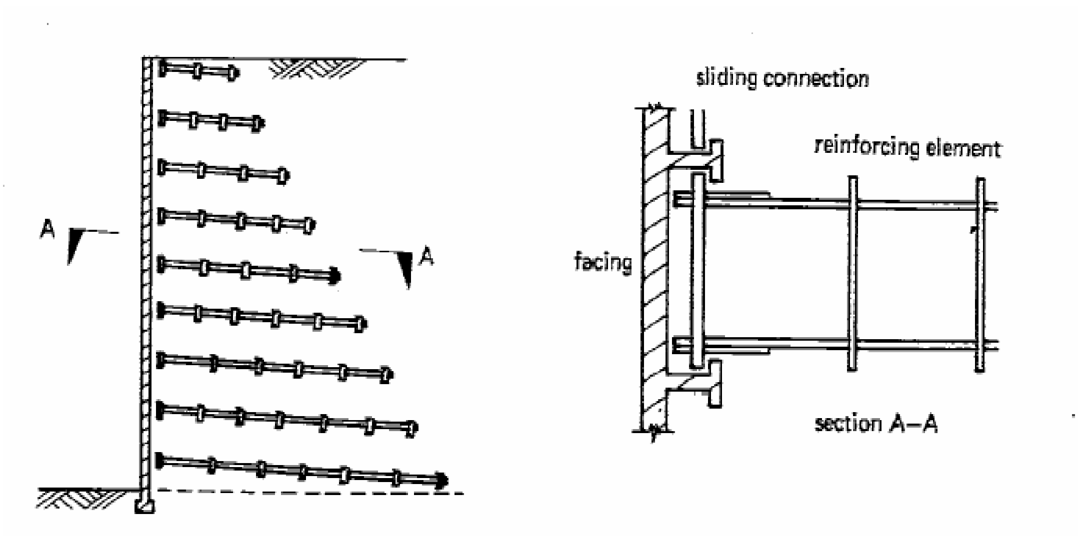

Figure 1.3 Munster earth retaining structure (Jones, 1985).

During 1930s, Andre Coyne (Jones, 1985) had introduced a type of engineered reinforced soil wall Mur Echelle (ladder wall). The ladder wall consists of a mass granular filling unified by a row of tie members each having a small end anchors, together with a thin cladding membrane. The use of ladder wall was not widely used due to the reason of World War II (Lee, 2006). The following Figure 1.4 is the diagram of Coyne retaining wall.

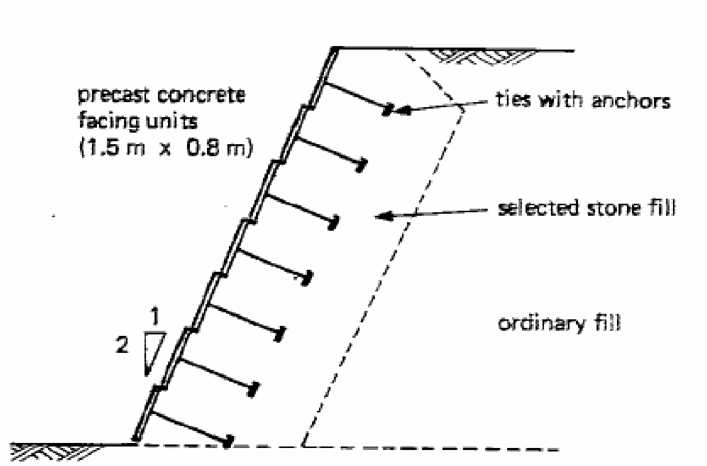

Figure 1.4 Coyne retaining wall (Jones, 1985).

The reinforced soil concept was applicable and growth throughout the world after the French Architect, Henri Vidal invented the Reinforced Earth. The first Reinforced Earth was constructed in 1966 in Pyrenees Mountains of France (Lee, 2006). The Reinforced Earth wall using flat metallic strips to strengthen the soil mass. The reinforcing strips interact with the soil through interface friction and allow the soil mass to be kept stable even with a near vertical face. The successful application of Vidal's concept has led to development of better reinforcement materials and has been widely used today.

After the success of invention of Reinforced Earth Wall, several other proprietary and non-proprietary systems have been developed and used. Among them are Hilfiker Retaining Wall (FHWA-RD-89-043, 1989), which uses welded wire mesh type and facing system developed in the mid of 1970's, VSL Retained Earth (FHWA-RD-89-043, 1989) which using steel strips of steel grid as reinforcement, geotextile reinforced soil wall which is well developed since 1980 (FHWA-RD-89-043, 1989) etc. Anchored Earth System is one of the reinforced soil systems that modified from Reinforced Earth System.

1.3 Problem Statement

One of the internal stability of Anchored Earth System is governed by pullout resistance developed by frictional shaft surface along the reinforcing bar and passive earth pressure against anchor block. The shear strength of the frictional component should be fully relies on the parameter friction angle, ϕ', if all the parameter is set to be constant for comparison purposes. However, the result obtained from field pullout test is different from the theoretical value calculated and there is a non-zero intercept at relationship of pullout force against overburden pressure. Besides, the filed test results obtained might have discrepancies because is beyond the control.

1.4 Aim and Objectives

The purposes of this study carried out are:

(i) To evaluate the sharing of pullout resistance between reinforcing tendon and concrete anchor block.

(ii) To compare the performance under soaked and unsoaked condition.

(iii) To find the interaction coefficient α' and β in comparison with design code.

1.5 Scope of Work

The first step in the research project is to review of background of technical literature which inclusive the field and laboratory pullout test that have been carried out by other researchers to understand the concept and development of reinforced soil.

This research project can be considered a case study of anchored reinforced soil wall which investigate the performance of Anchored Earth System due to its pullout capacity. The field pullout test was carried out by using same type of backfilling, which is river sand with friction angle of 36^{o}, reinforcing tendon of 20 mm in diameter and 6.4 m in length with anchor block size of 200 mm x 200 mm at the free end of the reinforcing tendon. The test was done by constant pulling rate of 0.3 mm per minutes until the reinforcing tendon failed as breaking or pullout. The mentioned pullout rate is suggested by Roads and Traffic Authority of New South Wales (RTA). In fact the pullout rate of 0.3 mm per minutes may still too high but due to the practicality of the field test, it may not allow the pullout rate to be reduced much further. The pullout rate shall not be too high to avoid the build up of pore water pressure and a sudden friction during the pullout test.

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