Cairo University

PERFORMANCE OF INVERTED U-SHAPED RETAINING WALL

By

Ahmed Hassan Ahmed M. El-Orabi

A Thesis Submitted to the
Faculty of Engineering at Cairo University
in Partial Fulfillment of the
Requirements for the Degree of
MASTER OF SCIENCE
in
Civil Engineering - Public Works

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Under the Supervision of

Prof. Dr. Abdelsalam M. Salem

Professor of Geotechnical Engineering
and Foundations

Faculty of Engineering, Cairo University

Dr. Rami M. El-Sherbiny

Associate Professor of Geotechnical
Engineering and Foundations

Faculty of Engineering, Cairo University

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Approved by the
Examining Committee

Prof. Dr, Abdelsalam M. Salem,	Thesis Main Advisor
Dr. Rami M. El-Sherbiny,	Thesis Advisor
Prof. Dr. Mohamed I. Amer,	Internal Examiner
Prof. Dr. Sherif Wissa Agaiby, Director at Dar Al-handasah (Shair and Partners)	External Examiner

FACULTY OF ENGINEERING, CAIRO UNIVERSITY
GIZA, EGYPT
2018

Engineer's Name: Ahmed Hassan Ahmed M. El-Orabi
Date of Birth: 16/12/1986
Nationality: Egypt
E-mail: eaorabi@gmail.com
Phone: +201002218202
Address: Giza, Egypt

Registration Date: 1/09/2010
Awarding Date: -/-/2018
Degree: Master of Science
Department: Civil Engineering- Public Works

Supervisors: Prof. Dr. Abdelsalam M. Salem
Dr. Rami M. El-Sherbiny

Examiners:

Prof. Dr. Abdelsalam M. Salem	(Thesis main advisor)
Dr. Rami M. El-Sherbiny	(Thesis advisor)
Prof. Dr. Mohamed I. Amer	(Internal examiner)
Prof. Dr. Sherif W. Agaiby Director at Dar Al-Handasah (Shair and Partners)	(External examiner)

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PERFORMANCE OF INVERTED U-SHAPED RETAINING WALL

Key Words:
Retaining walls; Cantilever type; RC wall; Fill; Inverted L-shaped

Summary:

Gravity type retaining walls have been traditionally used as retaining structures in fill areas. However, the footprint of gravity walls increases with increasing height, which may cause challenges in narrow area with limitations on base width. Inverted U-wall may provide an alternative to gravity wall system in areas with base width limitations. Moreover, the proposed system mainly provides cost benefit compared to cantilever or counterforted or gravity type retaining walls. It also provides movements smaller compared to other gravity wall types.

Acknowledgments

This research is developed in the years 2011 to 2015 during my participation as a researcher student in Cairo University, Egypt. The objective of this research was the analysis of stress-deformation behavior of a non-traditional composed retaining wall using Finite Element code and also the investigation of the Limit Equilibrium state for this non-traditional system.

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Nomenclature

Symbol	Description
B_g	Width of the gravity wall
B.C.	Bearing Capacity
D	Dead man length
E	Wall embedment
E50	Plastic straining cause of a deviatoric loading
Eoed	Plastic straining cause of primary compression
Eur	Elastic unloading/reloading
H_g	Height of the gravity wall
H_L	Exposed Height of the U-shaped wall
H_T	Total Retained Height
K_a	Coefficient of earth pressure in the active side
K_p	Coefficient of earth pressure in the passive side
L	Relief floor length
m	Stress dependent stiffness according to power law
Pa	Atmospheric pressure
P^{ref}	Reference pressure

R	Interface coefficient
S_u	Undrained shear strength
ΔV_L	Vertical wall deformation
VH_L	Horizontal wall deformation
$Ø'$	Angle of shear strength
σ'_{vo}	Overburden pressure

Abstract

Gravity type retaining walls have been traditionally used as retaining structures in fill areas. However, the footprint of gravity walls increases with increasing height, which may cause challenges in narrow area with limitations on base width. Inverted U-wall may provide an alternative to gravity wall system in areas with base width limitations. Moreover, the proposed system mainly provides cost benefit compared to cantilever or counterforted or gravity type retaining walls. It also provides movements smaller compared to other gravity wall types.

The proposed wall system is composed of an inverted U-shaped reinforced concrete wall, extended from the toe of the wall to an intermediate level of the total height. A short gravity wall is constructed on top of the inverted U-wall to the top of the retained height. The inverted U-wall is a monolithic reinforced concrete frame, which is composed of relief floor/slab, stem, deadman and a small embedment.

The purpose of this research is to study the performance of the proposed wall system in terms of global factor of safety, induced straining actions, and wall movements, to understand the mechanism of load transfer and to evaluate the optimum wall configuration. The different aspects of wall geometry are thoroughly investigated by conducting a comprehensive parametric study using 2-D finite element and 2-D limit equilibrium analysis.

The results of the sensitivity analysis revealed a good performance compared to the traditional systems. The optimum wall configuration is discussed and compared with cantilever type walls. Significant cost reduction is achieved, as the exerted soil pressure is reduced due to development of soil arching resulting in reduced straining actions (lesser design cross section). The concrete volume is reduced by 45% compared to cantilever retaining walls. In addition, a design framework was developed in terms of preliminary wall sizing and loading setup.

Chapter 1 : Introduction

1.1. Overview

The main factors that govern successful design of structures are safety and economical factors. In order to achieve these factors; designers should be aware of the latest design theories which leads to safe and economic design. Earth retaining structures are those structures; which have a special nature of behavior under loading. This special nature of behavior is an output of soil/structure interaction complexity.

There are many parameters which influence the design of earth retaining structures such as, selection of proper soil parameters; either deformability parameters or strength parameters; selection of proper soil model, and selection of proper interface parameters. Furthermore, Understating of the behavior of earth retaining structure is the first step to reach a successful design.

Literature encountered the work of many researches, addressing the mechanical behaviour of the traditional earth retaining walls (e.g. Gravity and cantilever walls). Many authors investigated governing design parameters. Moreover, many theories have been developed in order to achieve safe and economic design.

Gravity type retaining walls have been traditionally used as retaining structures in fill areas. However, the footprint of gravity walls increases with increasing height, which may cause challenges in narrow area with limitations on base width. Inverted U-wall may provide an alternative to gravity wall system in areas with base width limitations. Moreover, the proposed system always provides cost benefit compared to cantilever or counterforted or gravity type retaining walls. In addition, lateral movement of the proposed wall is less than others of gravity type.

An inverted U-Shape wall is proposed for limited base width that consists of:

- Stem embedded at the toe,
- Relief floor acting as a tie-back,
- Dead-man, and
- Limited height gravity wall.

The purpose of this investigation can be summarized as follows:

- Assess the stability of the proposed wall system against overall stability using limit equilibrium & F.E. methods.
- Perform a comprehensive parametric study using two dimensional numerical modeling to evaluate:
    - Wall movements
    - Induced straining actions (Bending moment & Normal forces).
- Develop a design framework and identify key factors to achieve a safe and economic design.
- Cost comparison between regular L-shaped and inverted U-shaped walls.