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DESIGN OPTIMIZATION OF CURVE PROFILE RETAINING WALL

SITI THALISAH BINTI AHMAD

A project report submitted in partial fulfilment of the
requirements for the award of the degree of
Master of Engineering (Civil- Structure)

Faculty of Civil Engineering
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DECEMBER 2007

I declare that this project report entitled "*Design Optimization of Curve Profile Retaining Wall*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Special for:

Beloved mum and dad

Rahani binti Mut & Ahmad bin Wahab

Dearest brothers and sisters

Syahrul Nazar, Shahrul Zikry, Fatin Sofia, Fatin Jamila, Fatin Asma’ & Fatin Afiqah

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ABSTRACT

Precast concrete retaining wall is an ancient type of construction material made with concrete cast in a reusable mold or form and cured in a controlled environment, then transported to the construction site and lifted into place. The objectives of this study are to determine the best curve and thickness of precast concrete curved slab of retaining wall and to compare the result of finite element analysis with the laboratory testing result. Two size of sample with variable curve height and thickness were analyzed using finite element software. The laboratory testing that involved in this study is bending test on the curved slab. According to the result of finite element analysis in this study, displacement is reduced with the increment in both curve height and thickness of the sample. Comparison between the results of finite element analysis with the laboratory testing results is in good agreement.

ABSTRAK

Tembok penahan konkrit pratuang adalah salah satu bahan binaan yang diperbuat daripada konkrit yang dituang ke dalam acuan guna semula dan diawet dalam persekitaran yang terkawal, kemudian dihantar ke tapak pembinaan dan diletak di tempat yang ditetapkan. Objektif kajian ini adalah untuk menentukan lengkung dan tebal terbaik bagi tembok penahan papak lengkung konkrit pratuang dan membuat perbandingan di antara keputusan analisis unsur terhingga dan keputusan ujian makmal. Dua saiz sampel dengan ketinggian lengkung dan tebal yang berbeza telah dianalisis menggunakan perisian unsur terhingga. Ujian makmal yang terlibat dalam kajian ini adalah ujian lenturan ke atas papak lengkung. Berdasarkan analisis unsur terhingga, lenturan berkurang dengan kenaikan tinggi lengkung dan tebal sampel. Perbandingan di antara keputusan analisis unsur terhingga dan keputusan ujian makmal menunjukkan hasil yang memuaskan.

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LIST OF SYMBOLS

P	-	Pressure
k_a	-	Active coefficient of lateral earth pressure
k_p	-	Passive coefficient lateral earth pressure
γ	-	Dry unit weight of soil
γ_{sat}	-	Saturated unit weight of soil
γ_w	-	Unit weight of water
H	-	Depth of wall
T	-	Thicknees of sample
c	-	Soil cohesion
ϕ	-	Drained friction angle
s	-	Shearing resistance
y	-	Height of curve
y_c	-	Peak of curve height
L	-	Length of curve profile

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CHAPTER I

INTRODUCTION

1.1 Introduction

Retaining structure such as retaining wall is commonly encountered in foundation engineering, and it may support slopes of earth masses. It will stabilize soil and rock from downslope movement or erosion. Retaining walls are generally made of masonry, stone, brick, concrete, steel or timber. Mostly, steel sheet-pile and concrete retaining wall are applied for the purpose.

Retaining walls of the gravity and semigravity types are sometimes used. Earlier in the 20th century, taller retaining walls were often gravity walls made from large masses of concrete or stone. The design of such structures is relatively simple in comparison with that of cantilever walls. But, these types of retaining walls were not easy to construct and need many labours. So, these factors influenced the high cost of construction.

Hence, works have been carried out to provide an appropriate structural solution in terms of both performance and economy for slope protection system. The suitability of such innovations needs to be carefully appraised before they are introduced in practice. Today, taller retaining walls are increasingly built as composite gravity walls such as geosynthetic or steel-reinforced backfill soil with precast facing; gabions, crib walls or soil-nailed walls.

Nowadays, precast concrete retaining walls are widely introduced in the market as an installer-friendly structural system because it is easier to handling, placing and transporting. It is claimed that the system provides simple, reliable and economical solutions for slope protection.

1.2 Problem Statement

According to Askin and Fuat (1996), optimum design of retaining walls has been the subject of a number of studies carried out by Alshawi *et al.* (1988); Dembicki and Chi (1989); Fang *et al.* (1980); Keskar and Adidam (1989); Pochtman *et al.* (1989); and Rhomberg and Street (1981). These studies deal with various aspects of optimal design, including optimal shapes, maximizing of structural stability, minimization of bending moment, and optimum location on sloping hillsides.

Present study is focused on the current system available such as reinforced concrete-cantilever retaining walls. Today, the precast panel of retaining walls system has been widely used due to many advantages over the cast in-situ concrete retaining walls. Precast panel with practical application of arches (curve profile) was introduced to reduce the bending moments in the structure. Thus, only compressive forces will be resisted.

But, the information about an appropriate solution of this curve profile retaining wall is still lacking. Very few studies have been performed on the dynamic behaviour of arches with variable curvature. Therefore, this study is carried out in order to obtain the optimum design of curve profile retaining wall. Existing curved slab profile of Wellguard System need to be analyzed to provide an appropriate structural solution in terms of both performance and economy for river bank protection system.

1.3 Objective of Study

The objectives of this study are:

i) To determine the best curve and thickness of precast concrete curved slab of retaining wall.
ii) To compare the result of finite element analysis with the laboratory testing result.

1.4 Scope of Study

The scopes of this study are:

i) Finite Element analysis – variable curve height (175, 200, 225 and 250 mm) and thickness (80, 100, 120 and 140 mm) of concrete curved slab W22 (2000 mm x 1770 mm) and W23 (3000 mm x 1770 mm) was analyzed using LUSAS Modeller software.

ii) Laboratory Testing – bending test on the curved slab W22 (2000 mm x 1770 mm) and W23 (3000 mm x 1770 mm).

1.5 Importance Of The Study

This study assisted in order to manufacture more economical precast concrete curved slab of retaining wall according to the best curve and thickness obtained by finite element analysis. The curved profile of concrete slab gives the elegant appearance for a moderate price. Precast earth retaining structures will be the most installer-friendly structural system on the market because of the following advantages:

i) Temporary works - dewatering & water diversion are not required. Therefore, minimum disturbance will be occurred during the installation.
ii) Machineries – only light machinery is used for the installation. Hence, minimum access and platform for installation works is required.
iii) Working area - minimal spacing.
iv) Installation method - easy to install.

v) Work speed - fast & shorter construction time.

vi) Product structure - toe & slope protection.

vii) Maintenance - easy to desilt & repair.

CHAPTER II

LITERATURE REVIEW

2.1 Retaining Wall

Retaining wall is a structure that provides lateral support for a mass of soil and that owes its stability primarily to its own weight and to the weight of any soil located directly above its base. Retaining walls constitute inherent parts of many foundations and their design is one of the functions of the foundation engineer (Peck *et al.*,1974).

In the past, most the retaining walls were usually constructed using stone masonry. Since that time concrete, either plain or reinforced, has been the predominant material. The most common types in current use are gravity, semigravity, cantilever, counterfort, and crib walls.

All retaining walls are expected to withstand the pressure of the earth that they support. Hence, proper design and construction of this structure require a thorough knowledge of the lateral forces that act between the retaining structure and the soil masses being retained. These lateral forces are caused by lateral earth pressure (Das, 1994).

The character of the material used for backfill has an important influence on the forces acting against the inner face of a retaining wall. Clean sands or gravels are considered superior to all other soils because they are free draining, and do not become less stable with the passing of time (Peck *et al.*,1974).

2.1.1 Types of Retaining Wall

Several types of retaining walls are described as follows:

a) Gravity wall

Gravity walls as shown in Figure 2.1 depend on the weight of their mass (stone, concrete or other heavy material) to resist pressures from behind and will often have a slight 'batter' setback, to improve stability by leaning back into the retained soil. For short landscaping walls, they are often made from dry-stacked (mortarless) stone or segmental concrete units (masonry units). Dry-stacked gravity walls are somewhat flexible and do not require a rigid footing in frost areas.

Earlier in the 20th century, taller retaining walls were often gravity walls made from large masses of concrete or stone. Today, taller retaining walls are increasingly built as composite gravity walls such as: geosynthetic or with precast facing; gabions (stacked steel wire baskets filled with rocks), crib walls (cells built up log cabin style from precast concrete or timber and filled with soil) or soil-nailed walls (soil reinforced in place with steel and concrete rods).

b) Sheet pile wall

Sheet pile walls are often used in soft soils and tight spaces (Figure 2.2). Sheet pile walls are made out of steel, vinyl, fiberglass or plastic sheet piles or wood planks driven into the ground. Structural design methods for this type of wall exist but these methods are more complex than for a gravity wall. As a rule of thumb; 1/3 third above ground, 2/3 below ground. Taller sheet pile walls usually require a tie-back anchor "dead-man" placed in the soil some distance behind the wall face, that is tied to the wall face, usually by a cable or a rod. Anchors must be placed behind the potential failure plane in the soil.

Proper drainage behind the wall is critical to the performance of retaining walls. Drainage materials will reduce or eliminate the hydrostatic pressure and increase the stability of the fill material behind the wall (assuming of course, that this is not a retaining wall for water).

c) Cantilevered wall

Prior to the introduction of modern reinforced-soil gravity walls, cantilevered wall was the most common type of taller retaining wall. Cantilevered walls (Figure 2.3) are made from a relatively thin stem of steel-reinforced, cast-in-place concrete or mortared masonry (often in the shape of an inverted T). These walls cantilever loads (like a beam) to a large, structural footing; converting horizontal pressures from behind the wall to vertical pressures on the ground below. Sometimes cantilevered walls are butressed on the front, or include a counterfort on the back, to improve their stability against high loads. Buttresses are short wing walls at right angles to the main trend of the wall. These walls require rigid concrete footings below seasonal frost depth. This type of wall uses much less material than a traditional gravity wall.

d) Anchored wall

As shown in Figure 2.4, this version of wall uses cables or other stays anchored in the rock or soil behind it. Usually driven into the material with boring, anchors are then expanded at the end of the cable, either by mechanical means or often by injecting pressurized concrete, which expands to form a bulb in the soil. Technically complex, this method is very useful where high loads are expected, or where the wall itself has to be slender and would otherwise be too weak.

e) Soil nailing

Soil nailing is a technique in which soil slopes, excavations or retaining walls are reinforced by the insertion of relatively slender elements - normally steel reinforcing bars. The bars are usually installed into a pre-drilled hole and then grouted into place or drilled and grouted simultaneously. They are usually installed untensioned at a slight downward inclination. A rigid or flexible facing (often sprayed concrete) or isolated soil nail heads may be used at the surface.

f) Soil-strengthened

A number of systems exist that do not simply consist of the wall itself, but reduce the earth pressure acting on the wall itself. These are usually used in combination with one of the other wall types, though some may only use it as facing (i.e. for visual purposes).

g) Gabion meshes

This type of soil strengthening, often also used without an outside wall, consists of wire mesh 'boxes' into which roughly cut stone or other material is filled. The mesh cages reduce some internal movement/forces, and also reduce erosive forces.

h) Mechanical stabilization

Mechanically stabilized earth, also called MSE, is soil constructed with artificial reinforcing via layered horizontal mats (geosynthetics) fixed at their ends. These mats provide added internal shear resistance beyond that of simple gravity wall structures. Other options include steel straps, also layered. This type of soil strengthening usually needs outer facing walls to affix the layers to and vice versa.

The wall face is often of precast concrete units that can tolerate some differential movement. The reinforced soil's mass, along with the facing, then acts as an improved gravity wall. The reinforced mass must be built large enough to retain the pressures from the soil behind it. Gravity walls usually must be a minimum of 50 to 60 percent as deep (thick) as the height of the wall, and may have to be larger if there is a slope or surcharge on the wall.