UNIVERSITI PUTRA MALAYSIA

STUDYING STRUCTURAL BEHAVIOR OF CONCRETE FACED ROCKFILL DAM USING FINITE ELEMENT METHOD

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By

FAYDA F. A. Al-OBAIDI

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for Degree of Master of Science

October 2005

Specially Dedicated

To my

Late Father (Fadhil Abass)
MY Mother (Mahia Jasim)
My Late Brother (Feras)
My Elder Brother (Ferkrit)
My Elder Sister (Dr. Firial)

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Master of Science

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October 2005

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Concrete faced rock fill dam has been increasingly popular among dam engineers due to their inherent advantages over other type of dams. The construction of concrete faced rockfill dam has been conducted in full swing in recent years. But still there is some crucial problems needed further investigation.

In this study an attempt has been made to investigate various aspects related to the structural analysis of concrete face rockfill dams, this involved, physical modelling, constitutive modelling, effect of concrete slab and simulation of sequence of construction.

To model sequential stages of construction of concrete faced rockfill dam the Dead-Birth-Ghost element technique was used. The physical modeling was carried out using finite-infinite elements to represent bedding media, eight and six noded isoparametric elements were used for modeling the dam body and the concrete face respectively. Moreover the interfacial behavior between the concrete face and the body of the dam was modeled using interface element. The constitutive modeling has

body of the dam was modeled using interface element. The constitutive modeling has been accounted by employing the hyperbolic nonlinear elastic model. So based on the above physical and material modeling a two dimension linear and nonlinear finite element program with different type of isoparametric elements was written. The verification of the program was well established by analyzing certain bench mark examples.

The applicability of the above program has been illustrated by analyzing two concrete faced rockfill dam namely; Kavar dam currently under construction in Iran (53.5 m), and Bakun dam currently under construction in the state of Sarawak Malaysia (205 m).

The results indicates that the sequences of construction, reservoir filling and nonlinear material behavior have significant effects on the structural response of the dam in terms of displacement and stresses and need to be considered for accurate prediction of the structural behavior of the dam and focuses on the effect of face slab on the distribution of deformation and stresses developed due to the static loading including gravitation and reservoir loading.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Master Sains

KAJIAN KELAKUAN STRUKTUR EMPANGAN BATUAN BERPERMUKAAN KONKRIT MENGGUNAKAN KAEDAH UNSUR TERHINGGA

Oleh

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Empangan batuan berpermukaan konkrit menjadi semakin popular di kalangan jurutera kerana kelebihan semula jadi yang dimilikinya berbanding dengan empangan yang lain. Walaupun pembinaan empangan jenis ini telah banyak dilaksanakan sejak kebelakangan ini. Namun masih terdapat beberapa masalah yang memerlukan penyelidikan selanjutnya.

Dalam kajian ini, satu penyelidikan telah dilakukan untuk menyiasat beberapa aspek berkaitan dengan analisis struktur empangan batuan berpermukaan konkrit. Di dalam penyelidikan ini melibatkan model fizikal, model linear dan tidak linear, kesan kepada tapak konkrit dan simulasi dalam urutan pembinaan.

Untuk model turutan pembinaan empangan ini secara berperingkat, kaedah unsur *Death-Birth-Ghost* telah digunakan. Model fizikal pula dilakukan dengan menggunakan unsur terhingga-tidak terhingga bagi mewakili tapak tanah, unsur 8-nod isoparametrik untuk model struktur empangan dan unsur 6-nod isoparametrik untuk model permukan empangan konkrit. Di samping itu, kelakuan sentuhan di

untuk model permukan empangan konkrit. Di samping itu, kelakuan sentuhan di antara permukaan konkrit dan struktur empangan itu telah dimodel dengan menggunakan unsur *interface*. Model linear dan tidak linear juga diambil kira dengan menggunakan model kenyal hiperbolik tidak linear.

Berdasarkan model fizikal dan bahan binaan yang dinyatakan, satu aturcara komputer berasaskan unsur isoparametrik yang berbeza bagi unsure terhingga linear dan tidak linear telah tulis di. Kejituan perisian computer yang dihaslkan ini telah diuji denga, membuat perbandingan antara keputusan kajian ini dengan analisis yang telah dilakukan oleh penyelidik terdahulu.

Aplikasi atucara komputer ini telah dipamerkan dengan menganalisis dua empangan batuan berpermukaan konkrit, iaitu Empangan Kavar di Iran (53.5 m) dan Empangan Bakun di Sarawak, Malaysia (205 m). Kedua-dua empangan ini masih dalam pembinaan.

Keputusan analisis menunjukkan bahawa turutan pembinaan, pengisian takungan air dan kelakuan tidak linear bahan binaan memberikan kesan penting terhadap reaksi struktur empangan tersebut dari segi anjakan dan tegasan. Ini amat penting untuk membuat jangkaan kelakuan empangan tersebut dan mem fokus tumpuan kepada kesan permukaan tapak terhadap pengagihan anjakan tiada tegasan tegasan-tegasan yang berlainan yang terhasil daripada beban statik iaitu beban graviti dan air.

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I certify that an Examination Committee met on 6th October 2005 to conduct the final examination of Fayda F. A. AL-Obaidi on her Master of Science thesis entitled "Studying Structural Behavior of Concrete Faced Rockfill Dam Using Finite Element Method" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

FAYDA F. AL-OBAIDI

Date: 16/12/2005

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CHAPTER 1

INTRODUCTION

1.1 General

Water is one of the most important natural resources on earth. Most of the creatures of God which live on the earth require water for their survival. In the past centuries, there had been local or periodical shortage of water resulting in famine and irrigation. In recent centuries, due to the increment in population coupled with economical development, it has made it imperative to use all available water resources in all parts of the world. Hence, safe, economical design and construction of dams to store surplus river water that has pertinent need.

A dam is constructed to intercept runoff and create a reservoir. The reservoir is utilized to regulate runoff that are used for conservation and flood control purposes. Dams may be categorized as: Rigid dams (gravity, masonry, arch, and roller compacted concrete), and embankment dams (earthen, rockfill and concrete faced rockfill dam).

1.2 Historical Development of Rockfill Dam

The concept of a rockfill dam with impervious face dates from California gold rush of the 1860s (Wagmann, 1908). The intuitive use by the miner, of easily available material (rock and timber) and their know-how in rock blasting works led oftenly to the construction of timber face rockfill dams, to store water for the sluicing operation.

Dumped concrete faced rockfill dams became popular in the first half of 20th century, and only few impervious core rockfill dams was built prior to the 1940, (Maranha,1991), leakage due to high fill deformation and opening of the joints in these types of dams has became obvious. Hence this problem diverted the interest of dam engineer towards the earth core rockfill, which became the dominant rockfill dam type for the following 30 years, (Cooke and Arthur, 1988) and (Robin et al., 1992). Figure 1.1 shows the cross section of such dam.

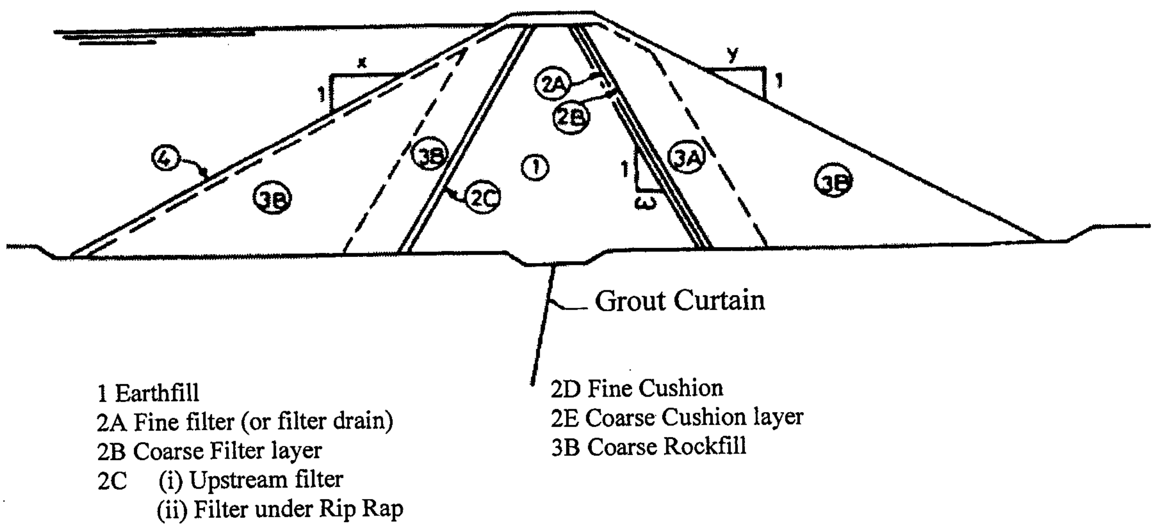

Figure 1.1: Types of Earth and Rockfill Dam with Core. (Robin et al., 1992)

Compaction of rockfill dams started in the 1960s resulting in a much less deformable fill, and more compatible with the needs for an impervious concrete membrane. The leakages has been controlled to very reasonable levels, gradually the concrete faced rockfill dam (CFRD) resumed its place among rockfill dams. In this type of dam the