SAFETY EVALUATION OF BAKUN CONCRETE FACED ROCK-FILL DAM

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ABSTRACT

This study deals with a 2-D plane strain finite element analysis of elastic linear (Hooke's law) and non-linear lastest Duncan-Chang Hyperbolic Model to study the structural response of the dam in respect to the deformation and stresses of Main Dam of Bakun's Concrete face Rockfill Dam (CFRD) project which is currently under construction located in Sarawak, Malaysia as the second highest CFRD in the world when completed. Dead, Birth and Ghost element technique was used to simulate sequences of construction of the dam. The comparison of rigid and flexible foundation on the behaviour of the dam was discussed. In the finite element modeling the concrete slab on the upstream was represented through six-noded element, while the interface characteristic between dam body and concrete slab was modeled using interface element. The maximum settlement and stresses of the cross section was founded and the distribution of them were discussed and tabulated in form of graphs and contours. The effect of reservoir filling loading have gradual effect to the dam response behavior. The computed results by the present method were found to be in good agreement with the comparison of value to the existing dams in the world.

PENILAIAN KESELAMATAN EMPANGAN BATUAN BERPERMUKAAN KONKRIT BAKUN

Oleh

HILTON @ MOHD HILTON BIN AHMAD

ABSTRAK

Kajian ini merangkumi analisis unsur terhingga 2-dimensi terikan dasar linear kenyal (hukum Hooke) dan Model tidak linear Hiperbola Duncan-Chang untuk mengkaji reaksi perlakuan struktur empangan terhadap anjakan dan tegasan. Untuk struktur utama projek Empangan batuan berpemukaan konkrit (CFRD) di mana pada masa ini masih dalam proses pembinaan yang terletak di Sarawak, Malaysia sebagai CFRD yang kedua terbesar di dunia apabila siap kelak. Teknik unsur Dead-Birth-Ghost digunakan untuk memulakan turutan pembinaan empangan ini. Perbandingan antara perlakuan empangan ini dengan asas dan tanpa asas terhadap perlakuan empangan ini juga dibincangkan. Dalam model unsur terhingga, papak konkrit pada sebelah hulu empangan diwakili oleh unsur enam-nod, manakala ciri antara-muka empangan and papak konkrit dimodelkan menggunakan unsur antara-muka. Anjakan dan tegasan maksimum untuk keratan rentas empangan telah diperolehi dan pengagihannya telah dibincangkan dan digambarkan dalam bentuk graf dan kontur. Kesan bebanan daripada tadahan air mempunyai kesan terhadap reaksi perlakuan empangan tersebut. Keputusan yang diperolehi mempunyai persefahaman yang baik dengan perbandingan keputusan daripada empangan yang sedia ada.

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Permission to make photocopies of report /Thesis

I, Hilton @ Mohd Hilton Bin Ahmad declare that the report entitled: "**Safety Evaluation of Bakun Concrete Faced Rockfill Dam**" belongs to me. The content of this report may be used by anyone for the academic purposes of teaching, learning and research only. University Putra Malaysia is permitted to make photocopy of this document for same academic purposes.

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APPROVAL FORM

The project attached hereto entitled, **"Safety Evaluation of Bakun Concrete Faced Rockfill Dam"** prepared and submitted by Hilton @ Mohd Hilton Bin Ahmad in partial fulfillment of the requirements for the Degree of Master of Structural and Construction Engineering is hereby approved.

23/6/06

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INTRODUCTION

Malaysia, which comprises Peninsular Malaysia, Sabah and Sarawak. is located between latitudes 1° and 7° North and longitudes 100° and 119° East. It covers a total land area of over 330,000 km^2. With rapid population growth and accelerating economic development, much of the world's natural resources are being depleted at an unsustainable rate. One of these resources is WATER which requires urgent attention to ensure sustainable use.

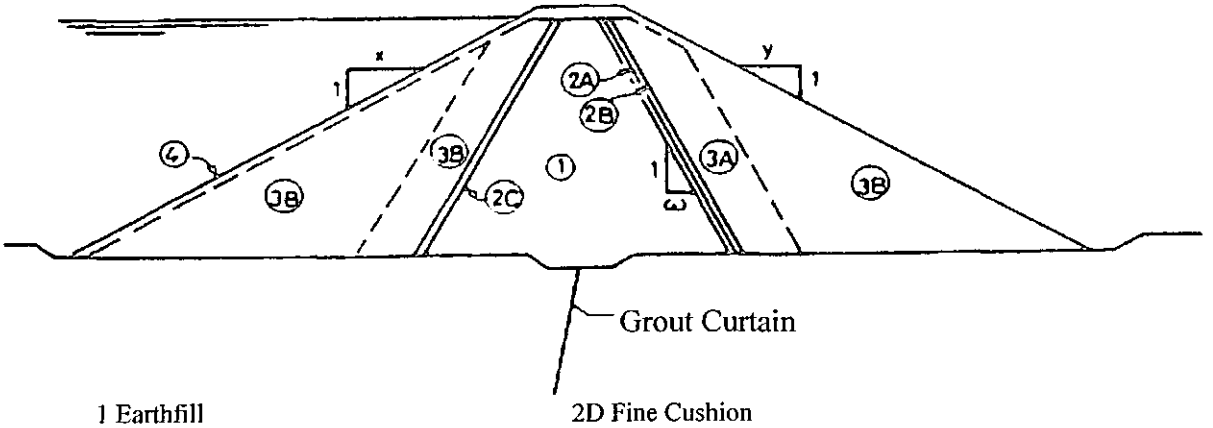
Dams form part of a controlled irrigation system but they also have other roles to play, i.e. flood control, hydroelectric power generation and also as soil conservation. There are a few factors need to be taken care of when designing a dam, i.e. safety, economy, efficiency and appearance. Safety and economy are factors that contradict to each other; however, we may design an economical dam without sacrificing the safety of the dam. In this report, Bakun Dam which is the second biggest Concrete Faced Concrete Dam (CFRD) in the world when completed is analyzed to its safety by using finite element method. Dam structure often store huge quantity of water at great potential energy and if in the case of failure does pose an imminent threat to population and property downstream. There are many cases reported due to dam failure and it cause very severe damages.

Dams are designed to withstand all applied loads, e.g. gravity load, hydrostatic, hydrodynamic pressures etc. The biggest loads on dam are the gravity load due to its massive self weight and also earthquake loads. The accuracy of the estimation of dam safety under static and earthquake (dynamic) and the design work require a good understanding of structural response of dam under both cases. As far as the

design aspect concerns, static load and dynamic load are contradicts as in static we need to design the stiffest structure, however, in dynamic it is required to design the structure most flexible. Therefore, the engineers should be aware of both criteria and fulfills to its optimum dam design.

1.1 Development of Rockfill Dam

In first half of 20th century, most rockfill dam were of loosely dumped quarried rock with some version of core or upstream facing including wooden planking, concrete, or hand-placed rock dry-wall as well as 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 become obvious. From thence up until the 1950's, the design and construction of rockfill dams were a matter of empiricism. Then, dam engineers diverted towards the earth core rockfill for the following 20 years.



1 Earthfill
2A Fine filter (or filter drain)
2B Coarse Filter layer
2C (i) Upstream filter
(ii) Filter under Rip Rap
2D Fine Cushion
2E Coarse Cushion layer
3B Coarse Rockfill

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

The transition to compacted rockfill for both earth-core and concrete-face dams occurred during the period 1955-1965 (Cooke 1984) as shown in Figure 1.2. This transition was possible because of the advent of heavy rollers and was particularly spurred Terzaghi's criticism of dumped rockfill for its excessive compressibility as well as more compatible with the needs for an impervious concrete membrane. Comparison between rates of post-construction at the crest settlement between dumped and compacted rockfill are shown in Table 1.1

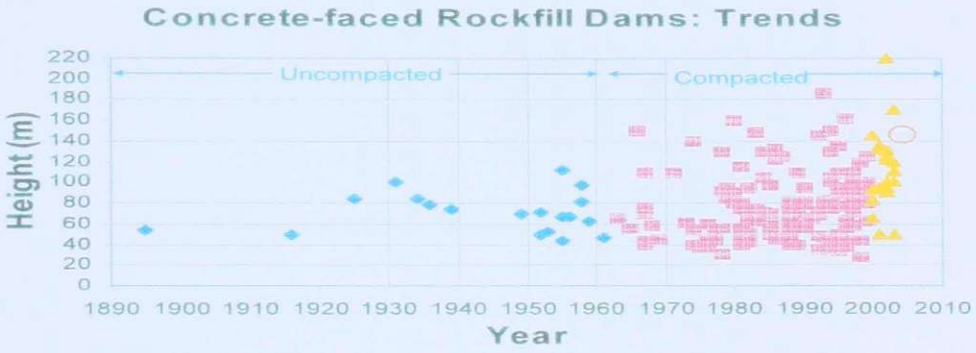


Figure 1.2: Trends in CFRDs over the past years

Table 1.1: Rates of post-construction crest settlement of dumped and compacted rockfills in CFRDs (Sherard and Cooke, 1987)

	Approximate Rate of Crest Settlement for 100m High CFRD (mm/year)		
Type	**After 5 years**	**After 10 years**	**After 30 years**
Compacted Rockfill	3.5	1.5	0.6
Dumped Rockfill	45	30	10

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 foundation requirements being essentially the same as for the central core dam, other attributes such as simpler construction logistics, less