UNIVERSITI PUTRA MALAYSIA

OVERTOPPING RISK AND UNCERTAINTY ANALYSIS OF EMBANKMENT DAMS

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By

EHSAN GOODARZI

Thesis submitted to the school of graduate study, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy.

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DEDICATION

I dedicated this thesis to my parents. I hope that this achievement will complete the dream that they had for me all those many years ago when they choose to give me the best education that I could.

Abstract of thesis presented to the Senate of University Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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EHSAN GOODARZI

October 2010

Chairman: Professor Lee Teang Shui, PhD

Faculty: Engineering

Abstract

The main objectives of this study are the evaluation of overtopping risk in conjunction with uncertainty for two embankment dams in the south of Iran (Fars province) and north of Iran (Mazandaran province). Dams are one of the most significant structures that contribute to the survival of the human race. The main benefits of this structure for human society are; flood controlling, generation of hydro-electric power, and supply water for different purpose such as agriculture, irrigation, recreation, and tourism attraction. Annually, natural disasters like earthquake, flood, drought, and thunders

happen in different parts of the world. Malfunctioning of a dam can result in serious economic damage to the owners, and environmental problems such as pollution, sedimentation in the downstream areas and can also result in the loss of human lives. Iran is one of the ten foremost countries sensitive to the unexpected phenomena and natural disasters. Flooding is one of the most important disasters in Iran and losses during 1951-2000 exceeded more than 11,500 people. So, constructing new flood control structures and assessment safety of existing dams are essential.

There is main gap with regards to apply new statistical tools and techniques for overtopping risk analysis and assessment the safety of dams. Furthermore, considering various events such as wind in conjunction with flood which increase the probability of failure is a crucial task of hydrosystem engineers. Hence, this research presents the application of risk and uncertainty analysis to dam overtopping. A flood frequency analysis of annual maximum discharge was done for the Doroudzan and Meijaran dams applying the General Extreme Value (GEV) probability distribution. Risk of overtopping were calculated for six extreme floods taking into consideration inflow hydrograph, initial water level, discharge coefficient of spillway, and the reservoir geometry as uncertain variables. The reservoir routing technique was used to compute the highest water levels and the Monte Carlo simulation (MCS) and Latin hypercube sampling (LHS) were applied for uncertainty analysis. To consider the effect of wind speed on the overtopping risk, frequency analyses were performed on the wind data and consequently extreme wind speeds, highest wind set-up and wave run-up were calculated. The maximum risk considering the effects of wind speeds in the study was 1.5 to 3.5 times

larger than the risk of overflowing due to only floods using Latin hypercube sampling (LHS) and Monte Carlo simulation (MCS) approaches, respectively. The results of this study show that, initial water level, and inflows to reservoir have significant effects on the overtopping probability of the Doroudzan and Meijaran dams. Overtopping risk increases with increase in magnitude of stated parameters. Trends of computed risks for the Doroudzan dam indicate that calculated probabilities with Latin hypercube sampling were slightly higher than the Monte Carlo simulation, while in the Meijaran dam, there was no any specific trend between the MCS and LHS results.

The major findings and main contributions of this study are; solving the flood model (reservoir routing) in uncertain conditions, estimating wind set-up and wave run up to solve the wind model with considering uncertainties, estimating the probability of failure due to overtopping under different hydrologic conditions, and compare the results based on two applied uncertainty models (MCS and LHS) for two mentioned dams.

Abstrak Tesis Yang Dikemukakan Kepada Senat Universiti Putra Malaysia Sebagai Memenuhi Keperluan Untuk ijazah Doktor Falsafah

ANALISIS RISIKO DAN KETIDAKPASTIAN PARAS TERLAMPAU TINGGI EMPANGAN BENTENG

Oleh

EHSAN GOODARZI

October 2010

Pengerusi: Prof Lee Teang Shui, PhD

Fakulti: Kejuruteraan

Tujuan utama kajian ini ialah penilaian risiko paras terlampau tinggi berkaitan dengan ketakpastian untuk dua empangan tanah terletak di Iran Selatan (daerah Fars) dan di Iran Utara (daerah Mazandaran). Empangan adalah diantara struktur bererti yang menyumbang kepada keadaan terus-hidup manusia. Keuntungan utama struktur ini bagi masyarakat adalah: kawalan banjir, penjanaan kuasa elektrik dan bekalan air untuk tujuan berbeza saperti pertanian, pengairan, rekreasi dan penarikan pelancongan. Setiap tahun, bencana alam seperti gempabumi, banjir, kemarau dan petir berlaku di merata rata tempat di dunia. Empangan pincang tugas boleh menyebabkan kerosakan ekonomi serius kepada pemilik dan masalah alam sekitar saperti pencemaran, pengendapan di kawasan hilir dan juga boleh menyebabkan kehilangan nyawa. Iran adalah diantara sepuluh negara yang peka kepada bencana alam dan fenomenon luar dugaan begitu. Banjir adalah satu malapetaka yang penting di Iran dan pada 1951 – 2000, melebihi 11,500 nyawa

terkorban. Jadi, pembinaan struktur baru untuk mengawal banjir dan penialaian keselamatan empangan yang sedia ujud adalah diperlui.

Terdapat kekurangan dari segi mengaplikasi alat statistic dan teknik analisis risiko terlampau tinggi dan penilaian keselamatan empangan. Tambahan pula, penilaian mengambilkira beberapa peristiwa seperti angin bersama sama banjir akan meningkatkan kebarangkalian kegagalan merupa tugas kritikal jurutera hidrosistem. Jadi, kajian ini mempersembahkan aplikasi risiko dan analisis ketakpastian kepada empangan yang menghadapi paras terlampau tinggi. Satu analisis kekerapan banjir aliran maksimum tahunan telah dibuat untuk empangan Doroudzan dan empangan Meijaran dengan menggunakan taburan kebarangkalian Nilai Ekstrim Umum. Risiko (GEV). Risiko paras terlampau tinggi dikira untuk enam banjir ekstrim dengan mengambilkira hidrograf aliran masuk, paras air awal, angkali aliran alur limpah dan geometri takungan sebagai perubahan takpasti. Teknik penghalaan takungan diguna untuk mengira paras air tertinggi dan simulasi Monte Carlo (MCS) dan pensampelan Latin Hypercube (LHS) diguna untuk analisis ketakpastian. Demi untuk mengambilkira kesan halaju angin terhadap risiko paras terlampau tinggi, analisis kekerapkalian dibuat untuk data angin dan akibatnya, halaju ekstrim angin, kenaikan paras air tertinggi dan panjang gelombang kerana angin dikirakan. Dengan menggunakan pendekatan LHS dan pendekatan MCS, terdapat risiko maksimum dengan ambilkira kesan halaju angin adalah 1.5 ke 3.5 kali lebih besar daripada risiko paras terlampau tinggi sahaja masing masing. Keputusan kajian ini menujukkan bahawa paras air awal serta aliran masuk ke takungan ada kesan bererti terhadap kebarangkalian paras terlampau tinggi bagi empangan empangan Doroudzan

dan Meijaran. Risiko paras terlampau tinggi kian tambah selaras dengan tambahan magnitud parameter tersebut. Risiko dikira untuk empangan Doroudzan menunjukkan kebangkalian dikira dengan LHS lebih tinggi dibandingkan dengan MCS, akan tetapi untuk empangan Meijaran, tidakpastinya bandingan keputusan MCS dan LHS.

Penemuan utama dan sumbangan terpenting kajian ini adalah; menyelesaikan model banjir (penghalaan takungan) didalam keadaan taktentu, penaksiran kenaikan paras air tertinggi dan panjang gelombang kerana angin dengan mengambilkira ketidakpastian, penaksiran kebarangkalian kegagalan disebabkan paras terlampau tinggi dalam keadaan hidrologi berbeza, dan membandingkan keputusan berdasarkan dua model ketidakpastian (MCS dan LHS) bagi dua empangan tersebut.

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I certify that an Examination Committee has met on date of viva voce to conduct the final examination of **Ehsan Goodarzi** on his Doctor of Philosophy entitled "**OVERTOPPING RISK AND UNCERTAINTY ANALYSIS OF EMBANKMENT DAMS**" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the (PhD degree).

Members of the Examination Committee were as follows:

Mohd Amin Mohd Soom

Professor
Engineering
Universiti Putra Malaysia
(Chairman)

Thamer Ahmed Mohamed, PhD

Associate Professor
Engineering
Universiti Putra Malaysia
(Internal Examiner)

Badronnisa Yusuf, PhD

Doctor
Engineering
Universiti Putra Malaysia
(Internal Examiner)

Kwok-wing Chau, PhD

Associate Professor
Engineering
Hong Kong Polytechnic University
(External Examiner)

BUJANG BIN KIM HUAT, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

This thesis was submitted to the Senate of university Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy**.** The members of the Supervisory Committee were as follows:

Lee Teang Shui, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Desa bin Ahmad, PhD
Professor
Faculty Engineering
Universiti Putra Malaysia
(Member)

Name of member 2, PhD
Title: Assoc. Prof. Dr. Abdul Halim Ghazali
Faculty of Engineering
Universiti Putra Malaysia
(Member)

_____
HASANAH MOHD GHAZALI, PhD
Professor
School of Graduate Studies
Universiti Putra Malaysia

Date:

DECLARATION

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

Ehsan Goodarzi

Date: 19/10/2010

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