



UNIVERSITI PUTRA MALAYSIA

***A NUMERICAL TIME INTEGRATION METHOD FOR NONLINEAR
SEISMIC RESPONSE ANALYSIS OF ROLLER-COMPACTED CONCRETE
DAMS***

PARVIZ MORADI POUR

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**A NUMERICAL TIME INTEGRATION METHOD FOR NONLINEAR
SEISMIC RESPONSE ANALYSIS OF ROLLER-COMPACTED CONCRETE
DAMS**

By

PARVIZ MORADI POUR

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
In Fulfillment of the Requirements for the Degree of Master of Science**

September 2010

DEDICATION

To

The memory of my parents

And

All beloved members of my family



Abstract of thesis presented to the senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Master of Science

A NUMERICAL TIME INTEGRATION METHOD FOR NONLINEAR SEISMIC RESPONSE ANALYSIS OF ROLLER-COMPACTED CONCRETE DAMS

By

PARVIZ MORADI POUR

September 2010

Chairman: Associate Professor Jamaluddin Noorzaei, PhD

Faculty: Engineering

Dam is used as a multi-purpose infrastructure for water supply, irrigation, flood control, and hydropower. The application of roller compacted concrete (RCC) technology to dam construction was originated in the United States about three decades ago.

To ensure the safety of life and public property and to preserve the environmental downstream of the dam, comprehensive studies are warranted. The critical issues in this field are thermal and earthquake analysis of the dam-foundation system, which leads to crack prediction in the dam body as well as sliding and debonding at dam foundation interface.

This study deals with the two objectives; to propose a new numerical method and to apply the method for dynamic analysis of the Kinta RCC dam.

The first objective is to propose a new method with higher accuracy and stability as well as less computational cost. The proposed method involves mathematical formulations and general equilibrium equations for structural dynamics. The

acceleration between two consequent time steps was assumed by a second order parabolic curve. Then, Taylor's series were used in mathematical formulations for any response. Finally, mathematical and structural dynamics equations were combined.

The application of the proposed method has been established by a few examples to illustrate the accuracy of the proposed method for analysis of any structure. Based on this objective, the following conclusions can be drawn:

- i) The proposed method is capable of capturing the seismic structural responses of any SDOF and MDOF systems more accurately than Newmark's method.
- ii) The proposed method is more stable than Newmark's method and is able to analyze the structure in fewer numbers of iterations or computation cycles, hence less time-consuming.

The second primary objective deals with the structural response of Kinta RCC dam as one of the two RCC dams in Malaysia.

To achieve this objective, the finite element method has been selected. An existing finite element program for two-dimensional analysis has been modified to include the proposed method in the program. This study is also to improve the physical modeling of plane strain problems such as Kinta RCC dam.

The isoparametric elements have been employed to represent the dam body, foundation sections, and thin layer interface elements. The nonlinearity of the dam body concrete and foundation has been taken into account by employing the crack constitutive model and nonlinear elasto-plastic model respectively. Finally, the finite element model was nonlinearly analyzed under Malaysian seismic excitations using the developed FEM program.

- i) The results show that the yielding of thin layer interface elements occurs before the dam foundation and RCC materials, and it starts by a slipping mode at the interface between foundation and dam body.
- ii) From the seismic fracture analysis of Kinta RCC dam, it was observed that the values of acceleration and stresses of the system are higher than those found by previous researchers. This indicates a fast occurrence of fracture in both thin layer interface elements and dam body.



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

**KAEDAH PENGAMIRAN MASA BERANGKA UNTUK ANALISIS
TINDAKBALAS TAK LELURUS SEISMIK BAGI EMPANGAN KONKRIT
PENGGELEK-TERPADAT**

Oleh

PARVIZ MORADI POUR

September 2010

Pengerusi: Prof. Madya Jamaloddin Noorzaei, PhD

Fakulti: Kejuruteraan

Empangan digunakan sebagai struktur pelbagai guna bagi bekalan air, pengairan, kawalan banjir dan hidrokuasa. Aplikasi teknologi konkrit pengelek terpadat (RCC) ke atas pembinaan empangan mula digunakan di Amerika Syarikat sejak tiga dekad lalu.

Bagi memastikan keselamatan nyawa, harta benda awam dan melindungi alam sekitar di hilir empangan, kajian menyeluruh terhadap infrastruktur tersebut telah diwarankan. Isu yang kritikal dalam bidang ini adalah haba dan analisis gempabumi bagi sistem asas-empangan yang membawa kepada jangkitan keretakan di dalam jasad empangan, gelangar dan nyah-ikatan pada antara muka asas-empangan.

Kajian ini merangkumi objektif berikut: Mengemukakan cadangan kaedah berangka baru dan aplikasi kaedah ini untuk analisis dinamik empangan RCC Kinta.

Objektif pertama adalah untuk mencadangkan kaedah baru dengan ketepatan yang tinggi, kestabilan dan mengurangkan ulangan pengiraan. Kaedah yang dicadangkan melibatkan formulasi matematik dan persamaan seimbang am dalam dinamik struktur.

Pecutan antara dua tempoh masa berturutan ditentukan oleh lengkung parabolik turutan kedua. Kemudian siri Taylor telah digunakan dalam formulasi matematik untuk sebarang tindak balas. Akhirnya persamaan matematik dengan persamaan dinamik struktur dapat digabung.

Aplikasi kaedah yang dicadangkan telah diwujudkan oleh beberapa contoh sistem darjah kebebasan tunggal (SDOF) dan darjah kebebasan pelbagai (MDOF) untuk menggambarkan ketepatan kaedah yang dicadangkan dalam penyelesaian apa-apa jenis struktur.

Berdasarkan objektif ini berikut adalah kesimpulan yang ditemui:

- i) Kaedah yang dicadangkan adalah mampu untuk mengesan tindak balas struktur seismik bagi apa-apa sistem SDOF dan MDOF lebih tepat berbanding Kaedah Newmark.
- ii) Kaedah yang dicadangkan lebih stabil dari kaedah Newmark dan boleh menganalisis struktur pada bilangan yang kurang ulangan atau kitaran pengiraan, dan dengan itu kurang penggunaan masa.

Objektif yang kedua adalah berkenaan tindak balas struktur empangan Kinta RCC sebagai salah satu dari pada dua empangan RCC di Malaysia. Untuk mencapai objektif ini kaedah elemen terhingga telah dipilih. Program elemen terhingga yang ada untuk analisis dua dimensi telah diubahsuai untuk memasukkan kaedah yang dicadangkan ke dalam program. Dalam penyelidikan ini, satu cadangan juga telah dibuat untuk memperbaiki permodelan fizikal masalah ketegangan satah seperti empangan RCC Kinta.

Unsur separameter telah digunakan untuk mewakili empangan, bahagian asas dan unsur antaramuka lapisan nipis. Ketaklurusan konkrit dan asas badan empangan telah diambilkira dengan menggunakan masing-masing model retakan konstitutif dan

model ketaklinearan plastik-elasto. Akhirnya, Ketaklurusan model unsur terhingga telah dianalisis di bawah ujian seismik Malaysia menggunakan kod FEM yang telah dibangunkan.

- i) Keputusan menunjukkan bahawa alahan unsur antaramuka lapisan nipis terjadi sebelum asas empangan dan bahan RCC, dan ia bermula dengan mod gelongsoran pada elemen antaramuka lapisan antara asas dan empangan.
- ii) Daripada analisis seismik empangan RCC Kinta, didapati nilai pecutan dan tegasan adalah lebih tinggi daripada yang telah dilaporkan oleh penyelidik terdahulu. Ini menunjukkan berlakunya kegagalan dalam unsur lapisan antaramuka nipis dan di ikuti oleh kegagalan empangan.

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I certify that an Examination Committee has met on 21 September 2010 to conduct the final examination of Parviz Moradi Pour on his thesis entitled “A Numerical Time Integration Method for Nonlinear Seismic Response Analysis of Roller-Compacted Concrete Dams” in accordance with the Universities and University College Act 1971 and the Constitution of the Universiti Putra Malaysia (PU. (A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

Members of the thesis Examination Committee were as follows:

Ir. Thamer Ahmed Mohamed, PhD

Associate Professor

Faculty of Engineering

Universiti Putra Malaysia

(Chairman)

Ir. Abang Abdullah bin Abang Mohamad Ali, PhD

Professor

Faculty of Engineering

Universiti Putra Malaysia

(Internal Examiner)

Ir. Raizal Saifulnaz Muhammad Rashid, PhD

Assistant Professor

Faculty of Engineering

Universiti Putra Malaysia

(Internal Examiner)

Ir. Abdul Khalim b Abdul Rashid, PhD

Associate Professor

Faculty of Engineering

Universiti Kebangsaan Malaysia

(External Examiner)

SHAMSUDDIN SULAIMAN, PhD

Professor and Deputy Dean

School of Graduate Studies

Universiti Putra Malaysia

Date: 26 November 2010

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted in fulfillment of the requirement for the degree of Master of Science. Members of the Supervisory Committee were as follows:

Ir. Jamaloddin Noorzaei, PhD

Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Ir. Mohd Saleh Jaafar, PhD

Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Ir. Farah Nora Aznieta Binti Abdul Aziz, PhD

Assistant Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

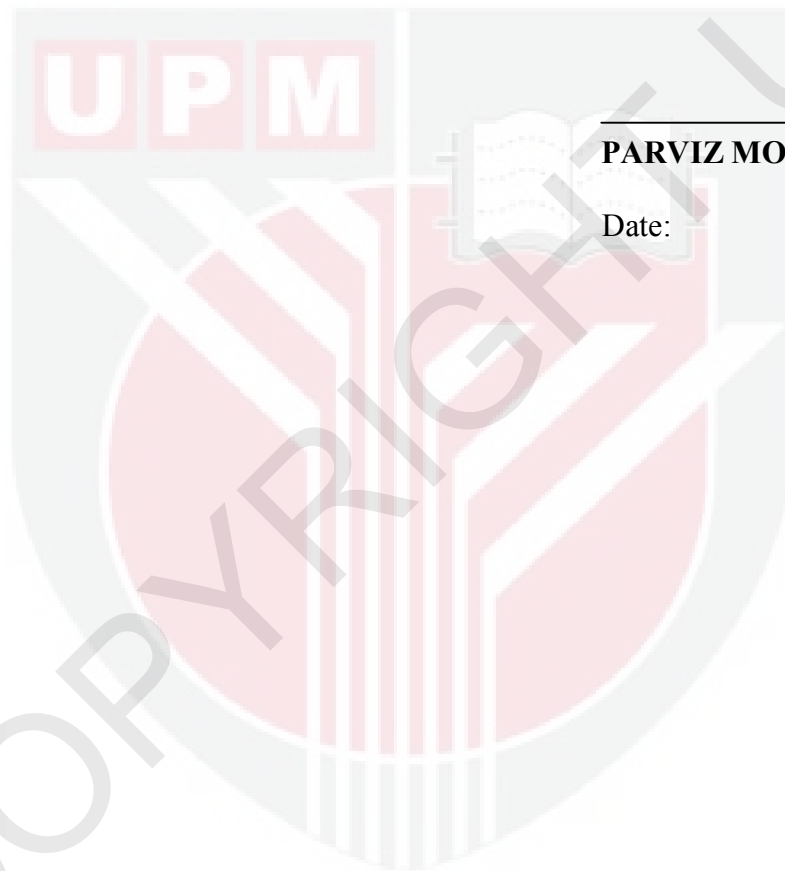
HASANAH MOHD GHAZALI, PhD

Professor and Dean
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 any other institutions.



PARVIZ MORADI POUR

Date:

TABLE OF CONTENTS

	Page
DEDICATION	II
ABSTRACT	III
ABSTRAK	VI
ACKNOWLEDGEMENTS	IX
APPROVAL	X
DECLARATION	XII
LIST OF TABLES	XVI
LIST OF FIGURES	XVII
LIST OF APPENDICES	XXI
LIST OF ABBREVIATIONS	XXII
CHAPTER	
1. INTRODUCTION	1
1.1 General	1
1.2 Failure in gravity dams in past earthquakes	2
1.3 Construction technology in RCC dams	7
1.4 Distribution of RCC dams around the world	8
1.5 Applications of RCC technology	10
1.6 Why roller compacted concrete (RCC) dams?	10
1.7 Loads of RCC dam	12
1.8 Brief review of earlier works	13
1.9 Problem statements	14
1.10 Objectives	15
1.11 Scope and limitation	16
1.12 Layout of thesis	18
2. LITERATURE REVIEW	19
2.1 Introduction	19
2.2 Numerical methods	21
2.3 Structural responses	22
2.4 Evaluation of stability of concrete gravity dams	26
2.4.1 Xiangjiaba dam	27
2.4.2 Three Gorges dam	27
2.5 Crack and failure	31
2.6 Experience of real dams under earthquake excitation	38
2.6.1 Koyna dam	38
2.6.2 Sefid Rud dam	39
2.7 Constitutive relationships in concrete gravity dams	41
2.8 Elasto-plastic constitutive modeling of thin layer element	42
2.9 Failure criteria of concrete	45
2.10 Constitutive models for cracking and crushing	48
2.11 Physical modeling	49
2.12 Available packages for dam analysis	50
2.13 Hazardous seismic potentials of Malaysia	50

2.14	Discussion	50
2.15	Justification of problem to be investigated	52
2.16	Concluding remarks	53
3.	A PROPOSED METHOD OF COMPUTATION FOR SOLUTION OF THE EQUILIBRIUM EQUATIONS OF STRUCTURAL DYNAMICS	55
3.1	Introduction	55
3.2	Methodology	56
3.2.1	Mathematical formulations	57
3.2.2	Combination of mathematical and dynamic equations	58
3.2.3	Transformation of the formulations in matrix notation	58
3.2.4	Verification	58
3.3	Formulation of the proposed method	60
3.3.1	Generation of a system of equations	62
3.3.2	Testing of the linear dependence of the system of equations	63
3.3.3	Successive substitution method	65
3.3.4	Solution of the system of equations	66
3.3.5	Dynamic equations of the proposed method	68
3.4	Computational procedure of the proposed method for structural dynamics problems	72
3.4.1	Initial calculation	72
3.4.2	Calculation for each time step	72
3.5	Comparison of the proposed method and newmark's method	73
3.5.1	Stage I: Mathematical equations	74
3.5.2	Stage II: Structural dynamic equations	76
3.6	Special feature of the proposed method	79
3.7	Comparison of the domain of coefficients β and γ in both methods	79
3.8	Illustrative numerical examples	79
3.8.1	Example 1: A SDOF system without damping	80
3.8.2	Example 2: A MDOF system without damping	87
3.8.3	Example 3: A SDOF system with damping	95
3.9	Parametric studies	100
3.9.1	The effect of Δt	100
3.9.2	The effect of coefficients γ and β	102
3.10	Concluding remarks	104
4.	SEISMIC RESPONSE OF KINTA RCC DAM USING THE PROPOSED METHOD	105
4.1	Introduction	105
4.2	Methodology	106
4.3	Proposed Two-Dimensional finite element modeling (Physical modeling)	109
4.4	Thin layer interface formulation	111
4.4.1	Formulation in local coordinate system	111
4.4.2	Formulation in global coordinate system	116
4.5	Material constitutive modelling	118
4.5.1	Constitutive modeling for failure criteria	119
4.5.2	Failure criteria of thin layer interface element	119

4.6	Stress-strain relationship in plasticity	120
4.7	Host finite element	122
4.7.1	Modification based on the proposed method in Chapter 3	123
4.7.2	Modified time marching computational scheme	125
4.7.3	Modification of the finite element program	130
4.8	Testing and verifications	133
4.8.1	Example 1	133
4.8.2	Example 2	135
4.9	Seismic analysis of Kinta RCC dam	137
4.10	Material properties	139
4.11	Earthquake records	141
4.12	Material properties for nonlinear seismic fracture analysis	141
4.13	Responses of Kinta RCC dam against earthquake excitation	142
4.13.1	Principal Stresses	143
4.13.2	Accelerations	154
4.13.3	Displacements	157
4.14	Safety Evaluation	160
4.15	Concluding Remarks	161
5.	SUMMARY AND CONCLUSION	163
5.1	Summary	163
5.2	conclusions	164
5.2.1	General conclusions	164
5.2.2	Specific conclusions	165
5.3	Recommendation for future researches	167
	REFERENCES	168
	APPENDICES	176
	BIODATA OF STUDENT	198
	LIST OF PUBLICATIONS	199