



**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,  
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**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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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

**FAYDA F. ALOBAIDI**

**October 2005**

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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 permukaan empangan konkrit. Di samping itu, kelakuan sentuhan di



untuk model permukaan 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 dihasilkan ini telah diuji denga, membuat perbandingan antara keputusan kajian ini dengan analisis yang telah dilakukan oleh penyelidik terdahulu.

Aplikasi aturcara 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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## TABLE OF CONTENTS

	<b>Page</b>
ABSTRACT	ii
ABSTRAK	iv
ACKNOWLEDGEMENTS	vi
APPROVAL	vii
DECLARATION	ix
LIST OF TABLES	xiii
LIST OF FIGURES	xiv
<b>CHAPTER</b>	
<b>1 INTRODUCTION</b>	
1.1 General	1.1
1.2 Historical Development of Rockfill Dam	1.1
1.3 Statement of Problem	1.4
1.4 Objective of the Present Study	1.5
1.5 Scope of The Work	1.6
1.6 Layout of The Thesis	1.7
<b>2. LITERATURE REVIEW</b>	
2.1 General	2.1
2.2 Review of Literature Design Practice.	2.2
2.2.1 Evolution	2.2
2.2.2 Dam Zoning	2.4
2.2.3 Fill Cross Section	2.7
2.2.4 Plinth (Toe Slab)	2.9
2.2.5 Concrete Face Slab	2.14
2.2.6 Perimetric Joint Detail	2.17
2.2.7 Crest Detail	2.19
2.3 Numerical Simulation of the Concrete Faced Rockfill Dam	2.22
2.4 Concluding Remarks	2.41
2.4.1 Empirical and Theoretical Design	2.41
2.4.2 Numerical Simulation	2.42
2.5 Justification	2.43
2.5.1 Design of Concrete Face Rockfill Dam.	2.43
2.5.2 Analysis of Concrete Face Rockfill Dam	2.43
<b>3 NONLINEAR COSTITUTIVE NUMERICAL MODELS</b>	
3.1 General	3.1
3.2 Non-linear Stress-Strain model	3.1
3.2.1 Hyperbolic Model Formulation	3.2
3.2.1.1 Extended of Hyperbolic Formulation (Version 1980)	3.7
3.2.1.2 Hyperbolic Model of 1984 Model	3.10



	3.2.2	Modified Secant Model	3.16
	3.2.3	K-G Model	3.17
	3.2.4	Elasto-Plastic and Elasto-viscplastic	3.18
3.3		Interface Constitutive Models	3.18
3.4		Concluded Remarks	3.21
4		<b>FINITE ELEMENT FORMULATION</b>	
	4.1	General	4.1
	4.2	Finite Element Formulation Based on Energy Method	4.1
	4.3	Isoparametric Elements	4.8
	4.3.1	Eight Nodded Isoparametric Elements	4.8
	4.3.2	Six- Nodded Isoparametric Element	4.9
	4.3.3	Infinite Element	4.10
	4.3.4	Interface Element Formulation	4.14
	4.4	Numerical Integration	4.17
	4.5	Nonlinear Solution Algorithm	4.19
	4.5.1	General	4.19
	4.5.1.1	Incremental Procedure (Variable Stiffness Method)	4.20
	4.5.1.2	Iterative Procedure.	4.22
	4.5.1.3	Step-Iterative or Mixed Procedure	4.25
	4.5.2	Sequential Nonlinear Approach	4.25
	4.5.3	Geometrically Nonlinearity	4.28
	4.5.4	Algorithms for Simulation Sequence of Construction	4.28
	4.6	Finite Element Computer Program	4.29
	4.7	Learning Process and Verification	4.30
	4.7.1	Linear Analysis	4.30
	4.7.2	Nonlinear Analysis	4.32
	4.7.2.1	Numerical Example-1 (Embankment)	4.32
	4.7.2.2	Nonlinear Analytical Problem -2 Concrete Strip Footing on Soil	4.34
	4.7.3	Verification of the Interface Element	4.37
	4.7.3.1	Verification of Formulation of Stiffness Matrix	4.37
	4.7.3.2	Numerical Example (I) Fixed End Beam	4.38
	4.7.3.3	Numerical Example (II) Cantilever Beam	4.40
	4.7.4	Verification of the Linear and Nonlinear Solution Algorithm Technique	4.42
	4.8	Concluded Remarks.	4.45
5		<b>FINITE ELEMENT ANALYSIS OF CONCRETE FACED ROCKFILL DAM</b>	5.1
	5.1	General	5.1
	5.2	Analysis of Kavar CFRD	5.1
	5.2.1	Problem Definition	5.1
	5.2.2	Finite Element Modeling	5.3
	5.2.3	Loading	5.3
	5.2.3.1	Simulation of Loading Due to Sequence of Construction	5.5
	5.2.3.2	Reservoir Filling	5.5



5.2.4	Results and Discussion	5.7
5.2.4.1	During the Sequence of Construction	5.8
5.2.4.1.1	Displacements	5.8
5.2.4.1.2	Stresses	5.19
5.2.4.2	Reservoir Filling	5.29
5.2.4.2.1	Displacements	5.29
5.2.4.2.2	Stresses	5.40
5.2.4.2.3	Concrete Slab	5.49
5.3	Bakun Concrete Face Rockfill Dam	5.52
5.3.1	General	5.52
5.3.2	Dam Cross Section	5.54
5.3.3	Different Phase of Schedule of Construction	5.56
5.3.4	Finite Element Modeling.	5.58
5.3.5	Loading	5.60
5.3.5.1	Simulation of sequence of construction.	5.60
5.3.5.2	Simulation of Reservoir filling	5.61
5.3.6	Results and Discussion	5.61
5.3.6.1	Linear Elastic Analysis	5.61
5.3.6.1.1	Displacement	5.62
5.3.6.1.2	Stresses	5.72
5.3.6.2	Nonlinear Analysis	5.85
5.3.6.2.1	During sequence of construction	5.87
5.3.6.2.2	Loading due to reservoir impoundment	5.100
5.3.6	Concluding Remarks	5.110
6	SUMMERY, CONCLUSION AND RECOMMENDATION	
6.1	Summary	6.1
6.2	Conclusion	6.2
6.3	Further Research Work	6.4
	REFERENCES	R.1
	APPENDICES	A.1
	BIODATA OF THE AUTHOR	B.1

## LIST OF TABLES

<b>Table</b>		<b>Page</b>
2.1	Criteria adopted for Concrete Face Membrane Thickness.	2.14
2.2	Results of Yuati Dam.	2.38
2.3	Dams Analyzed by Researchers Using Hyperbolic Model	2.45
4.1	Coordinates and Weights in Gaussian Quadrature Formula	4.19
4.2	Stress Strain Parameters for Problem 1	4.32
4.3	Showing the Stress Strain Parameters for this Problem	4.36
4.4	Values of $K_{mn}$ and $K_{ss}$	4.38
4.5	Values of $K_{mn}$ and $K_{ss}$	4.41
5.1	Material Properties of CFRD Dam	5.2
5.2	Ratio's of Maximum Vertical Displacements in Terms of Height of the Dam	5.63
5.3	Parameters for Duncan's E-B Model	5.86
5.4	Percentage of Maximum Vertical Displacement with respect to Height of Bakun Dam	5.115
5.5	Maximum Horizontal and Vertical Stresses	5.115



## LIST OF FIGURES

Figure	Page
1.1 Types of Earth and Rockfill Dam with Core.	1.2
1.2 Types of Concrete Face Rockfill Dams.	1.3
2.1 Feature of Early Concrete Face Rockfill Dam Design (ICOLD 1989a)	2.3
2.2 Current Practice Design of CFRD constructed o Sound Rockfill on a Strong Rock Foundation. (ICOLD 1989 a)	2.5
2.3 Golillas Dam (Amaya & Marulanda 1985)	2.6
2.4 Crotty Dam (HEC 1988).	2.8
2.5 Segredo Dam. Plinth, typical Cross Section (Maranha. 1991)	2.9
2.6 Comparison of Plinth Design (Cooke, 2000)	2.10
2.7 Toe Slab designs (a) Mangrove Creek Dam, (b) Boondooma Dam (Mackenzie & McDonald 1985, Rogers 1985)	2.11
2.8 Plans and Detail of Plinth at Salvajina Dam (Sierra, et al 1985)	2.12
2.9 Typical perimeter joint detail (Brown 2000)	2.13
2.10 Plinth Detail of Bakun Dam. (Sarawak Hidro Sdn. Bhd. 2003).	2.13
2.11 Antispalling steel in Salvajina Dam (Hacelas & Ramirez, 1985)	2.15
2.12 Joint details for Khao Laem Dam (Robin et al., 1985)	2.16
2.13 Perimeter joint, Foz do Areia dam (Nelson et al., 1985)	2.17
2.14 Salvajino Dam Perimeter and near abutment vertical joints (ICOLD 1989 a)	2.18
2.15 Joint Detail of Antamina Dam. (Alberto et al., 2000)	2.19
2.16 Crest detail adopted for Hydro.Commission of Tasmania Dams HEC (Fitzpatric et al., 1985)	2.20
2.17 Crest details for (a) Galillas Dam, (b) Macaqua Dam. (Amaya and Marulanda 1985, Prusza et al., 1985)	2.20



2.18	Parapet wall (Maranha, 1991)	2.21
2.19	Displacement due to dead weight in standard dam (Clough and Woodward, 1967)	2.22
2.20	Vertical displacement due to dead weight in standard dam in m. (Clough and Woodward, 1967)	2.23
2.21	Cethana Section Showing Discretization (Khalid, 1990)	2.26
2.22	Contours of Vertical Displacement at the End of Construction (Khalid, 1990)	2.27
2.23	Contours of Horizontal Displacement at the End of Construction. (Khalid, 1990)	2.27
2.24	Vertical Stress at end of Construction ( $\text{kN/m}^2$ ), (Khalid, 1990)	2.28
2.25	Vertical Stress after Reservoir Filling ( $\text{kN/m}^2$ ), (Khalid, 1990)	2.28
2.26	Contour of Horizontal Stress at End of Construction ( $\text{kN/m}^2$ ), (Khalid, 1990)	2.28
2.27	Contour of horizontal Stress after Reservoir filling ( $\text{kN/m}^2$ ) (Khalid, 1990)	2.28
2.28	Finite element mesh of Foz do Areia (Saboya, 1993)	2.29
2.29	Settlement beneath dam axis. (Saboya, 1993)	2.29
2.30	Settlement beneath 1 <sup>st</sup> Stage. (Saboya, 1993)	2.29
2.31	Finite Element Mesh for New Melones Dam. (Duncan, 1996)	2.30
2.32	Comparison of Predicated and Measured Cross Valley Movement during Construction for New Malones Dam, (Duncan, 1996)	2.30
2.33	Finite Element Mesh of the Dam Body (Noorzaei, 1999)	2.32
2.34	Vertical Displacement of Central Nodes for 3, 7, 10 Layer Loading, (Noorzaei, 1999)	2.32
2.35	Three-Dimensional Analysis Model. (Kazuo et al., 2000)	2.33
2.36	Three-dimensional Finite Element Discretization of Dam. (Xingzhang et al., 2002)	2.35

2.37	Maximum Cross Section of the Dam (Xingzhang et al., 2002)	2.35
2.38	Contour of Displacements (m). (Xingzhang et al., 2002)	2.37
2.39	Contours of Minor Principal Stresses (MPa) (Xingzheng et al., 2002)	2.38
2.40	Material Zones of Tianshengqia. I. (Zhang et al., 2004)	2.39
2.41	Vertical and Horizontal Displacements at End of Reservoir filling (cm.) (Gao et al., 2001)	2.40
2.42	Major and Minor Principle Stress at end of Reservoir Filling (Mpa) (Gao et al., 2001)	2.42
3.1	Hyperbolic Representation of Stress- Strain (after Kondner, 1963)	3.3
3.2	Linear Representation of the Hyperbolic Stress-Strain Function, (after kondner,1963)	3.4
3.3	Mohr Coulomb Failure Criterions(Noorzaei, 1990)	3.5
3.4	Empirical Equations for Expressing Effects of Confining Pressure, (after Janbu, 1963)	3.6
3.5	Linear Unloading- Reloading Stress-Strain Relationship (Duncan et al., 1984)	3.9
3.6	Comparison between Stress Level and Stress State Criteria for Assignment of Unloading-Reloading Moduli (Duncan et al., 1984)	3.11
3.7	Comparison between Stress Level and Stress State Criteria for Assignment of Unloading-Reloading Moduli (Duncan et al., 1984)	3.12
3.8	Flow Diagram of FEADAM84 Software (Duncan et al., 1984)	3.15
4.1	A General Three-Dimensional Body	4.2
4.2	Eight- Noded Plan Element	4.9
4.3	Six Noded Isoparametric Element	4.10
4.4	Infinite Elements Decay Type in (Noorzaei, 1991)	4.12
4.5	Mapping of Infinite Elements (Battess, 1992)	4.13
4.6	Five Noded Isoparametric Infinite Element (Battess, 1992)	4.14



4.7	Parabolic Interface Element (Noorzaei, 2004)	4.16
4.8	Location of Gaussian Quadrature Point for Two Dimensional Integral (Cook, 2002)	4.19
4.9	Basic Increment Procedure (Singh et al., 1995)	4.21
4.10	Iterative Procedure (Singh et al., 1995)	4.24
4.11	Step Iterative Procedures (Singh et al., 1995)	4.24
4.12	Sequence of Construction Using Birth, Death - Ghost	4.29
4.13	Flowchart of Program	4.31
4.14	Mesh of the Embankment Using 8 Noded Isoparametric Elements	4.33
4.15	Comparisons of the Results of Vertical Displacements	4.33
4.16	Comparison of the Results of Normal Stress $\sigma_y$ as Verification	4.34
4.17	Mesh of Concrete Footing on Soil (Noorzaei et al., 1991)	4.35
4.18	Pressure- Settlement Plot for Central Point of Footing	4.36
4.19	Vertical Stresses Distribution along the Center Line of the Footing for $q = 160 \text{ kN/m}^2$	4.37
4.20	Two Continuums with Interface Element	4.38
4.21	Fixed End Beam (Example 1)	4.39
4.22	Effect of $K_{SS}$ on Vertical Displacement for Fixed End Beam	4.39
4.23	Finite Element Model of a Cantilever Beam with Interface	4.40
4.24	Effect of $K_{SS}$ on Vertical Displacement for Cantilever Beam	4.41
4.25	Effect of Interface at Different Position on Cantilever Beam	4.42
4.26	Vertical Displacements of Para Dam using STRAP Software	4.43
4.27	Vertical Displacements of Para Dam Using Program Code	4.43
4.28	Horizontal and Vertical Displacements of Para Dam	4.44





5.1	Cross Section of Kavar Dam	5.2
5.2	Finite and Infinite Element Discretization of the Kavar dam	5.4
5.3	Sequence of Construction According to Algorithm Technique	5.6
5.4	Loading at the End of Reservoir Filling	5.7
5.5	Vertical Displacements due to Sequence of Construction at El.0.0	5.11
5.6	Vertical Displacements due to Sequence of Construction at El. 26.5	5.12
5.7	Vertical Displacements along the Height of Dam at Centre line	5.13
5.8	Contour of vertical Displacements (mm) at End of Construction	5.14
5.9	Wireframe of Vertical Displacements (mm) at End of Construction	5.15
5.10	Horizontal Displacements due to Sequence of Construction at El. 0.0	5.16
5.11	Contour of Horizontal Displacements (mm) Due to Sequence of construction	5.17
5.12	Wireframe of Horizontal Displacements (mm) at End of Construction	5.18
5.13	Horizontal Normal Stresses (kN/m <sup>2</sup> ) due to Sequence of Construction at Ground Level (El.0.0)	5.22
5.14	Horizontal Stresses $\sigma_x$ (kN/m <sup>2</sup> ) at the End of Construction	5.23
5.15	Vertical Normal Stresses (KN/m <sup>2</sup> ) due to Sequence of Construction at Ground Level (El.0.0)	5.24
5.16	Vertical Stresses ( $\sigma_y$ ) kN/m <sup>2</sup> at the End of Construction	5.25
5.17	Wireframe of $\sigma_y$ (kN/m <sup>2</sup> ) at the End of Construction	5.26
5.18	Variation of Shear Stresses (kN/m <sup>2</sup> ) due to Sequence of Construction at (El.0.0)	5.27
5.19	Shear Stresses $\tau_{xy}$ (kN/m <sup>2</sup> ) at the End of Construction	5.28
5.20	Horizontal Displacements along the Dam Width at the End of Reservoir Filling (El.0.0)	5.31
5.21	Horizontal Displacements along the Upstream of Dam at the End of Reservoir Filling	5.32

5.22	Horizontal Displacements along the Centerline of Dam Height due to Reservoir Filling	5.33
5.23	Contour of Horizontal Displacements (mm) at End of Reservoir Filling	5.34
5.24	Wireframe of Horizontal Displacements (mm) at End of Reservoir Filling	5.35
5.25	Vertical Displacements along the Dam Width at the End of Reservoir Filling (El.0.0)	5.36
5.26	Vertical Displacements along the Centerline of Dam Height due To Reservoir Filling	5.37
5.27	Contour of Vertical Displacements (mm) at End of Reservoir Filling	5.38
5.28	Wireframe of Vertical Displacements (mm) at End of Reservoir Filling	5.39
5.29	Horizontal Stresses $\sigma_x$ (kN/m <sup>2</sup> ) at the End of Construction (EC) and End of Reservoir Filling (RF) at the Ground Level (EL.0.0)	5.42
5.30	Contour of Horizontal Stresses $\sigma_x$ in (kN/m <sup>2</sup> ) at the End of Reservoir Filling	5.43
5.31	Wireframe of Horizontal Stress $\sigma_x$ in (kN/m <sup>2</sup> ) at the End of Reservoir Filling	5.44
5.32	Vertical Stresses $\sigma_y$ (kN/m <sup>2</sup> ) at the End of Construction and End (EC) of Reservoir Filling (RF) at (El.0.0)	5.45
5.33	Contour of Vertical Stresses $\sigma_y$ in (kN/m <sup>2</sup> ) at the End of Reservoir Filling	5.46
5.34	Shear Stresses (Kn/m <sup>2</sup> ) at the End of Construction and End of Reservoir Filling at (El.0.0)	5.47
5.35	Contour of Shear Stresses (kN/m <sup>2</sup> ) at the End of Reservoir Filling	5.48
5.36	Vertical Displacements on Concrete Slab at the End of Reservoir Filling along the Upstream Slope	5.50
5.37	Horizontal Displacements on Concrete Slab at the End of Reservoir Filling along the Upstream Slope	5.50



5.38	Principle Stresses on Concrete Slab along Height of the Dam at End of Reservoir Filling	5.51
5.39	Bakun Dam Location	5.52
5.40	Bakun Layout	5.53
5.41	Bakun Dam Cross Section and Zones	5.54
5.42	Phases of Construction of Bakun Dam	5.57
5.43	Finite Element Meshes	5.59
5.44	Sequence of Construction of Bakun Dam	5.60
5.45	End of Reservoir Filling of Bakun Dam	5.61
5.46	Vertical Displacements at El. 9.4 due to Sequence of Construction	5.64
5.47	Vertical Displacements at El. 29.5 due to Different Sequence of Construction	5.65
5.48	Vertical Displacements at El.52.7 due to Different Sequence of Construction.	5.66
5.49	Vertical Displacements at El. 110.16 due to Sequence of Construction	5.67
5.50	Vertical Displacements at El. 170.0m due to Sequence of Construction	5.68
5.51	Vertical Displacements at the Centreline of the Dam	5.69
5.52	Vertical Settlements due Single Shot Construction	5.70
5.53	Vertical Settlements due Sequence of Construction	5.71
5.54	Normal Stresses $\sigma_x$ at El. 9.4 for Different Stage of Construction	5.75
5.55	Normal Stresses $\sigma_x$ at El. 29.5 for Different Stage of Construction	5.76
5.56	Normal Stresses $\sigma_x$ at El. 52.5 for Different Stage of Construction	5.77
5.57	Stresses $\sigma_x$ at El.110.m due Sequence of Construction	5.78
5.58	Normal Stresses $\sigma_y$ at El. 9.4 due to Sequence of Construction	5.79
5.59	Normal Stresses $\sigma_y$ at El. 29.5 due to Sequence of Construction	5.80



5.60	Normal Stress $\sigma_y$ at El. 52.5 due to Sequence of Construction	5.81
5.61	Stresses $\sigma_y$ at El. 110 due to Sequence of Construction	5.82
5.62	Variation of Normal and Shear Stresses along El. 9.5 due to Progress of Sequence of Construction	5.83
5.63	Contour of Normal Stresses $\sigma_x$ , $\sigma_y$ and $\tau_{xy}$ at the End of Construction	5.84
5.64	Normal Stresses in the Concrete Slab at the End of Construction	5.85
5.65	Contour for vertical Displacement (m) at the End of Construction	5.89
5.66	Vertical Displacement along width of Dam due to Sequence of Construction at El. 110.1	5.90
5.67	Vertical Displacements at the Centerline of Dam due to Sequence of Construction	5.91
5.68	Contour of horizontal Displacement(m) at the End of Construction	5.92
5.69	Contours of Horizontal Stresses ( $\text{kN/m}^2$ ) at End of Construction	5.95
5.70	Contours of Vertical Stresses ( $\text{kN/m}^2$ ) at End of Construction	5.96
5.71	Contours of Shear Stresses ( $\text{kN/m}^2$ ) at End of Construction	5.97
5.72	Contour of Minor Principal Stresses ( $\text{kN/m}^2$ ) at the End of Construction	5.98
5.73	Contour of Major Principal Stresses ( $\text{kN/m}^2$ ) at the End of Construction	5.99
5.74	Horizontal Displacements (m) at the End of Reservoir Filling	5.102
5.75	Vertical Displacements (m) at the End of Reservoir Filling	5.103
5.76	Horizontal Stresses $\sigma_x$ ( $\text{kN/m}^2$ ) at End of Reservoir Filling	5.106
5.77	Vertical Stresses $\sigma_y$ ( $\text{kN/m}^2$ ) at End o Reservoir Filling	5.107
5.78	Minor Principle Stresses ( $\text{kN/m}^2$ ) at End o Reservoir Filling	5.108
5.79	Major Principle Stresses ( $\text{kN/m}^2$ ) at End o Reservoir Filling	5.109



# 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 20<sup>th</sup> 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 become 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.

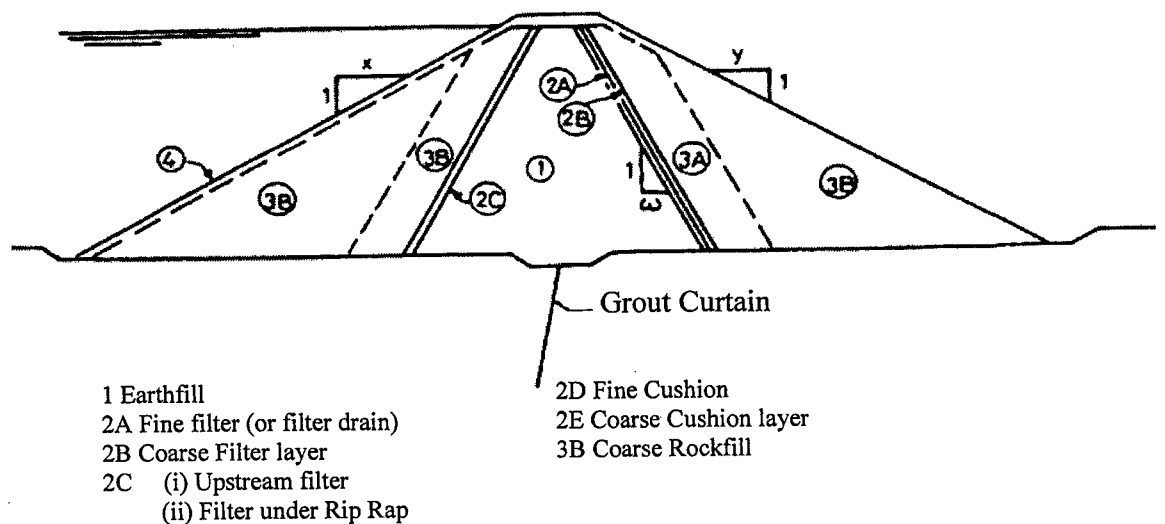


Figure 1.1: Types of Earth and Rockfill Dam with Core. (Robin et al., 1992)

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