

LB/DON/138/07

DCE 23/33

SS

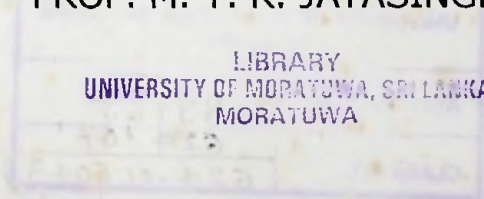
**THE RESPONSE OF CONVENTIONAL STRUCTURES
IN SRI LANKA
TO ADVERSE FORCES OF NATURE**

By

K. S. MANGALA SILVA
(M.Eng.in Structural Eng. Design 2003/2004)

Supervised By

PROF. M. T. R. JAYASINGHE



**THESIS SUBMITTED TO THE DEPARTMENT OF CIVIL
ENGINEERING IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR THE DEGREE OF MASTER OF ENGINEERING IN
STRUCTURAL ENGINEERING DESIGNS**



624 '07'
624-01(043)

89729

Department of Civil Engineering
University of Moratuwa
Sri Lanka

SEPTEMBER 2007

89729

ACKNOWLEDGEMENT

DECLARATION

I, Kuruneruge Samantha Mangala Silva, hereby declare that the content of this thesis is the output of original research work carried out at the Department of Civil Engineering, University of Moratuwa. Whenever others' work is included in this thesis, it is appropriately acknowledged as a reference.



ACKNOWLEDGEMENT

I am immensely grateful to my supervisor, Prof. M.T.R. Jayasinghe, Professor in Civil Engineering at the Department of Civil Engineering for his invaluable guidance and support throughout my research period.

I also thank Dr. Susantha Keragala (Senior lecturer of the Department of Engineering Mathematics University of Peradeniya) for his valuable advice, which helped to make this research a success.

My thanks are also due to all the other lectures at the UOM and UOP for the positive attitude they adopted in promoting this research project.

I wish to acknowledge Architect Piyal Silva, Director/CEO of the Architecture and Building group of ECL my employer, who tolerate me attending to the research works working hours when necessary. His valuable advice on my project is greatly appreciated.

The assistance given my batch-mates and friends who are working at the National Water Supply and Drainage Board are also appreciated.

Finally my thanks are also extended to Rifaadh, Inoka, Sandun, Hashen, Deeva and Uditha and all other colleagues at ECL who assisted and helped me in proof reading of this thesis and giving valuable advice on its formulation and presentation.

Last but not least a special gratitude goes to my parents and Loretta for bearing with me in making this study a success.

ABSTRACT

With the experience of minor earthquakes in deferent areas in Sri Lanka recent times, structural adequacy of existing structures has been questioned. Since a lot of research has already been carried out on buildings in related to their behavior in seismic loads, this research focus on Special structure such as "Kalutara Dagaba", Dagaba at Colombo port and Elevated water towers.

Due to unavailability of required data for detailed analysis of first two structures this study has mainly concentrated on elevated water towers.

Since the "Intze" type is the most common type of the water tower for more than 500m³ capacities, the scope of this study has further reduced to study of "Intze" type water towers.

Since the effect of wind as well as earth quake would be acting horizontally; there is a general belief among the engineers that those structures design to resist wind forces can withstand minor earth quakes as well.

In this back ground, this study has concentrated on the impact of wind and earthquakes on "Intze" type water towers of deferent capacities.

Analysis shows that exiting water towers which have designed for wind loads are not adequately strong for the resisting earthquakes. It is hoped that this study will shed light some structural deficiencies available in existing structures with respect to lateral loads of dynamic nature.

CONTENTS

CHAPTER 1

Introduction

1.1	General	1
1.2	Objectives	3
1.3	Methodology	3
1.4	Main findings	4
1.5	Arrangement of thesis	5

CHAPTER 2

Literature Review

2.1	Introduction	6
2.2	Spring mass model for seismic analysis	6
2.3	Circular and rectangular tanks	8
2.4	Elevated tanks	13
2.5	Response spectrum concept	15

CHAPTER 3

Existing Structures & Mathematical Modeling

3.1	Existing structures	16
3.2	Mathematical Modeling	
3.2.1	Modeling for 6 tanks for tank full, 75%fill, 50%fill and tank empty Conditions	16
3.2.2	Modeling Tanks for Different Heights	17
3.2.3	Modeling Tanks for Different Shaft Thicknesses	17
3.2.4	Modeling Tanks for Different Diameters of Supporting Shaft	17
3.2.5	Modeling Tanks for Different Concrete Grades of Supporting Shaft	17

CHAPTER 4

Analysis of Structures

4.1	Analysis of 6 tanks for tank full, 75% fill, 50% fill and tank empty Conditions	
4.1.1	Analysis for Earthquakes	18
4.1.2	Analysis for Wind loads	19
4.2	Analysis for Different Heights	20
4.3	Analysis for Different Shaft Thicknesses	20
4.4	Analysis for Different Diameters of Supporting Shaft	20
4.5	Analysis for Different Concrete Grades of Supporting Shaft	20
4.6	Dimensions of tanks	21

CHAPTER 5

Results

5.1	Water towers for different percentages of filling	28
5.2	Tanks for different heights	40
5.3	Tanks for different shaft thicknesses	42
5.4	Tanks for different diameters of supporting shaft	44
5.5	Tanks for different concrete grades of supporting shaft	46
5.6	Natural period of vibration for different tanks	47
5.7	Comments on Results	48

CHAPTER 6

Conclusion & Future Works

6.1	Conclusions	48
6.2	Future works	48

References

49

LIST OF TABLES

Table 2.1	Expressions for parameters of spring mass model	10
Table 4.1	S factor for different types of soil	19
Table 5.1.1	225m ³ Tank Base Shear Values	28
Table 5.1.2	225m ³ Moment at Base	29
Table 5.1.3	450m ³ Tank Base Shear Values	30
Table 5.1.4	450m ³ Moment at Base	31
Table 5.1.5	950m ³ Tank Base Shear Values	32
Table 5.1.6	950m ³ Moment at Base	33
Table 5.1.7	1125m ³ Tank Base Shear Values	34
Table 5.1.8	1125m ³ Moment at Base	35
Table 5.1.9	1450m ³ Tank Base Shear Values	36
Table 5.1.10	1450m ³ Moment at Base	37
Table 5.1.11	1600m ³ Tank Base Shear Values	38
Table 5.1.12	1600m ³ Moment at Base	39
Table 5.2.1	Base Shear Values and Base Moment values of 450m ³ and 1450m ³ tanks for different heights	40
Table 5.3.1	Base Shear Values and Base Moment values of 450m ³ and 1450m ³ tanks for different shaft thicknesses	42
Table 5.4.1	Base Shear Values and Base Moment values of 450m ³ and 1450m ³ tanks for different shaft diameters	44
Table 5.5.1	Base Shear Values and Base Moment values of 450m ³ and 1450m ³ tanks for different concrete grades of supporting shaft	46
Table 5.6.1	Natural Period of vibration for different tanks	47

LIST OF FIGURES

Figure 1.1	Collapsed 265m ³ water tower in chobari	1
Figure 1.2	Damaged shaft of Gulaotal water tower in Garha area of Jablpur city	2
Figure 1.3	Flextural tension cracks in shaft of 500m ³ tower in Morbi	2
Figure 2.1	Qualitative description of hydrodynamic pressure distribution on tank wall and base.	7
Figure 2.2	Parameters Of The Spring Mass Model For Circular Tank.	11
Figure 2.3	Parameters Of The Spring Mass Model For Rectangular Tank.	12
Figure 2.4	Two Mass Idealizations for Elevated Tank	14
Figure 4.1	Normalized Response Spectrum	18
Figure 4.2	Cross section of a typical Intze type tank	21
Figure 4.3	Cross section of a 225m ³ Intze type tank	22
Figure 4.4	Cross section of a 450m ³ Intze type tank	23
Figure 4.5	Cross section of a 950m ³ Intze type tank	24
Figure 4.6	Cross section of a 1125m ³ Intze type tank	25
Figure 4.7	Cross section of a 1450m ³ Intze type tank	26
Figure 4.8	Cross section of a 1600m ³ Intze type tank	27
Figure 5.1.1	Base Shear values of 225m ³ tank	28
Figure 5.1.2	Base Shear values of 225m ³ tank	29
Figure 5.1.3	Base Shear values of 450m ³ tank	30
Figure 5.1.4	Base Shear values of 450m ³ tank	31
Figure 5.1.5	Base Shear values of 950m ³ tank	32
Figure 5.1.6	Base Shear values of 950m ³ tank	33
Figure 5.1.7	Base Shear values of 1125m ³ tank	34
Figure 5.1.8	Base Shear values of 1125m ³ tank	35
Figure 5.1.9	Base Shear values of 1450m ³ tank	36
Figure 5.1.10	Base Shear values of 1450m ³ tank	37
Figure 5.1.11	Base Shear values of 1600m ³ tank	38
Figure 5.1.12	Base Shear values of 1600m ³ tank	39
Figure 5.2.1	Base Shear values of 450m ³ tank for different heights	40
Figure 5.2.2	Base Moment values of 450m ³ tank for different heights	40
Figure 5.2.3	Base Shear values of 1450m ³ tank for different heights	41
Figure 5.2.4	Base Moment values of 1450m ³ tank for different heights	41
Figure 5.3.1	Base Shear values of 450m ³ tank for different Shaft Thicknesses	42
Figure 5.3.2	Base Moment values of 450m ³ tank for different Shaft Thicknesses	42
Figure 5.3.3	Base Shear values of 1450m ³ tank for different Shaft Thicknesses	43
Figure 5.3.4	Base Moment values of 1450m ³ tank for different Shaft Thicknesses	43

Figure 5.4.1	Base Shear values of 450m ³ tank for different Shaft Diameters	44
Figure 5.4.2	Base Moment values of 450m ³ tank for different Shaft Diameters	44
Figure 5.4.3	Base Shear values of 1450m ³ tank for different Shaft Diameters	45
Figure 5.4.4	Base Moment values of 1450m ³ tank for different Shaft Diameters	45
Figure 5.5.1	Base Shear values of 1450m ³ tank for different concrete grades of supporting shaft	46
Figure 5.5.2	Base Moment values of 1450m ³ tank for different concrete grades of supporting shaft	46

LIST OF ANNEXTURES

- Annexure 1 Modeling and Analysis of Water towers for different Percentages of Filling
- Annexure 2 Analysis of Water towers for Wind Loads
- Annexure 3 Modeling and Analysis of Water towers for different Heights
- Annexure 4 Modeling and Analysis of Water towers for different Shaft Thicknesses
- Annexure 5 Modeling and Analysis of Water towers for different Diameters of Supporting Shaft
- Annexure 6 Modeling and Analysis of Water towers for different Concrete Grades of Supporting Shaft