SIZING OF REINFORCED CONCRETE STRUCTURAL MEMBERS BASED ON SRI LANKAN DESIGN DATA

Konara Mudiyanselage Roshanthi Niluka Konara

(118615M)

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Dissertation submitted in partial fulfillment of the requirements for the Master of Engineering Degree in Structural Engineering Design

Department of Civil Engineering

University of Moratuwa

Sri Lanka

November 2014

DECLARATION

Declaration of the candidate

"I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text".

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my thesis, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Signature: ..... Date:

Declaration of the supervisor

The above candidate has carried out research for the Masters thesis under my supervision.

Signature of the supervisor: ..... Date:

Sizing of Reinforced Concrete Structural Members Based on Sri Lankan Design Data

Abstract

The majority of building structures in Sri Lanka, are of reinforced concrete. Often it is required to estimate structural member sizes at the initial stage of a building construction project for load evaluation, cost estimation and reinforcement design.

For member dimension estimation, theoretical knowledge alone is inadequate as there are some practical issues also to be addressed. This study proposes reinforced concrete member sizes for future projects based on design data of past low to medium rise buildings in Sri Lanka.

Standards available for member size estimation, difficulties encountered by the designers while following available standards, gaps in existing sources, and applicability to local conditions are discussed. Structural and architectural drawings of twenty one buildings from two to thirteen storeys were used to extract design details related to slabs, staircases, beams, columns and footings elements. Data gathered for each element type are used to interpret relationships between member dimensions and design parameters.

Artificial Neural Networks (ANN) is an artificial intelligence technique for recognizing patterns among data that are difficult to represent algorithmically. This study also explores the potential of using Sri Lankan design data from past buildings in Artificial Neural Network models for predicting reinforced concrete member sizes.

Recommended structural member sizes are presented in graphs and tables, and compared with the ANN model results. Finally the member sizes recommended by the study are compared with the sizes derived according to the available literature.

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Key Words: Low to medium rise Buildings, Reinforced Concrete, Structural Member sizes, Artificial Neural Networks

ACKNOWLEDGEMENT

First of all I would like to express gratitude to my supervisor Prof. W.P.S. Dias for introducing me to this topic and giving earnest support by reviewing and commenting on the work throughout the study. I would also like to thank staff of the Department of Civil Engineering at University of Moratuwa for their support and guidance.

I'm indebted to my employer, Central Engineering Consultancy Bureau (CECB), for allowing me to use the structural and architectural drawings of buildings for the research. I would like to thank Drawing Officer, (Ms) Malkanthi Rajapaksha and draughtsman staff of CECB for helping me to find drawings of buildings which were prepared several years ago. I'm also thankful to my colleagues and staff for helping me to find necessary information and encouraging me throughout.

I also would like to thank my family, who has supported and encouraged me throughout the entire process.

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

TABLE OF CONTENTS

Declaration		i
Abstract		ii
Acknowledgement		iii
Table of Content		iv
List of Figures		vi
List of Tables		viii
List of Abbreviations		xi
List of Appendices		xii
1.	**Introduction**	**01**
	1.1 Background	01
	1.2 Objectives	02
	1.3 Scope and Limitations of study	02
	1.4 Outline of the Thesis	03
2.	**Literature Review**	**04**
	2.1 Existing Guidelines for Initial Sizing	04
	2.2 Use of Artificial Neural Networks (ANN) for Element Sizing	14
3.	**Methodology**	**21**
	3.1 Data Collection	21
	3.2 Analysis of Data	24
	3.2.1 Graphical Interpretation	24

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

3.2.2 Artificial Neural Networks (ANN) and Multiple Regression (MR) Models 25

3.3 Comparing graphically interpreted data with ANN model results 29

3.4 Comparing member sizes with values derived from literature 30

4. Results & Discussion 31

4.1 Slabs 31

4.1.1 One-way slabs 31

4.1.2 Two-way slabs 33

4.2 Staircases 40

4.3 Beams 44

4.4 Columns 49

4.5 Pad Footings 55

4.5.1 Footing Area 55

4.5.2 Footing Depth 59

5. Conclusions & Recommendations 63

Reference List

Annex A: List of buildings, architectural and structural drawings

Annex B: Structural elements data

Annex C: Load calculations

Annex D: Training, testing data sets and results of ANN and MR Models

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF FIGURES

		Page
Figure 2.1	Example showing how most economic sizes were identified (Goodchild,1997)	07
Figure 2.2	Slab Depth vs. Span Chart for One-way and Two-way Solid Slabs (Goodchild,1997)	08
Figure 2.3	Waist Thickness vs. Span Chart for Staircases (Goodchild,1997)	09
Figure 2.4	Depth vs. Span Chart for Rectangular beams of width 300mm, Multi Spans (Goodchild,1997)	09
Figure 2.5	Size vs. Ultimate Axial Load Chart for Internal Columns (Goodchild,1997)	10
Figure 2.6	Graph of Column Area X Concrete Grade vs Number of Floor X Grid Size (Dharmawardana,2003)	13
Figure 2.7	Components of a Neural Network	14
Figure 3.1	Variables shown on a typical floor plan	23
Figure 3.2	Structural Elements Cross Sectional Dimensions	24
Figure 4.1	Graph of concrete compressive strength X column cross sectional area vs tributary area X number of RC floors	50
Figure 4.2	Graph of column cross sectional area vs column design ultimate load modified as per the Manual (Grade 25 concrete)	54
Figure 4.3	Graph of soil bearing capacity x footing area vs tributary area x Number of RC floors	56

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Page

Figure 4.4 Graph of footing depth^2 vs tributary area x Number of RC floors 60

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF TABLES

		Page
Table 2.1	Span/Effective Depth Ratios for Initial Design of Slabs (Manual, 1985)	04
Table 2.2	Span/Effective Depth Ratios for Initial Design of Beams (Manual, 1985)	05
Table 2.3	Ultimate Loads for Stocky Columns (Manual, 1985)	06
Table 2.4	Sizes of Structural Elements (Orton, 1988)	12
Table 2.5	Results of significance testing for the column sizing problem (Dias & Padukka, 2005)	16
Table 2.6	Prediction results for the column sizing problem (Dias & Padukka, 2005)	17
Table 2.7	Details of Neural Networks Used for Simply Supported Beam Design (Hadi, 2002)	19
Table 3.1	Recorded data for each type of structural element	22
Table 3.2	Characteristics of ANN Models for Structural Element Sizing	28
Table 4.1	One-way Slab Thicknesses	31
Table 4.2	Comparison of overall slabs depths obtained from Reference[1] with the values recommended by the study – One-way slabs	32
Table 4.3	Observed Two-way slab thicknesses	33
Table 4.4	Recommended Two-way slab thicknesses	34

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Page

Table 4.5 Two way slab thicknesses – Summary of ANN & MR model analysis 36

Table 4.6 Span/effective depth ratios for two-way slabs according to Reference[1] 37

Table 4.7 Effective depths for two-way slabs according to Reference[1] 37

Table 4.8 Comparison of overall slabs depths obtained from Reference[1] with the values recommended by the study – Two-way slabs 38

Table 4.9 Observed staircases waist thicknesses in mm 40

Table 4.10 Staircases waist thicknesses – Summary of ANN & MR model analysis 41

Table 4.11 Comparison of Staircases waist thicknesses obtained from Graphical and ANN analysis 42

Table 4.12 Recommended staircases waist thicknesses in mm 43

Table 4.13 Comparison of staircases waist thicknesses obtained from Reference[1] with the values recommended by the study 43

Table 4.14 Observed beam depths in mm 44

Table 4.15 Recommended beam depths in mm 45

Table 4.16 Beam sizing – Summary of ANN & MR model analysis 46

Table 4.17 Comparison of beam depths obtained from Reference[1] with the values recommended by the study 48

Table 4.18 Column sizing – Summary of ANN & MR model analysis 51

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

Page

Table 4.19 Comparison of column cross sectional area results - ANN and Graph 52

Table 4.20 Footing area – Summary of ANN & MR model analysis 57

Table 4.21 Footing depth – Summary of ANN & MR model analysis 61

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF ABBREVIATIONS

Abbreviation	Description
A	Tributary Area
ANN	Artificial Neural Network
b	Beam or column width
D	Depth of footing
f_{cu}	Compressive strength of concrete
h	Slab thickness / beam depth or column depth
L	Length of footing
l	Span
l_x	Shorter Span
l_y	Longer Span
l_x/l_y	Ratio of spans
MAE	Mean absolute error
MR	Multiple regression
RSTD	Standard deviation of ratios
|1 – RAVG |	Deviation of average ratio from unity

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk

LIST OF APPENDICES

Appendix	Description	Page
Appendix A	List of buildings, architectural and structural drawings	65
Appendix B	Structural elements data	175
Appendix C	Load calculations	186
Appendix D	Training, testing data sets and results of ANN and MR Models	241

University of Moratuwa, Sri Lanka.
Electronic Theses & Dissertations
www.lib.mrt.ac.lk