TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>CHAPTER NO.</th>
<th>TITLE</th>
<th>PAGE NO.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td></td>
<td>vi</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td></td>
<td>xvii</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td></td>
<td>xix</td>
</tr>
<tr>
<td>LIST OF SYMBOLS AND ABBREVIATIONS</td>
<td></td>
<td>xxv</td>
</tr>
<tr>
<td>1</td>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1</td>
<td>PREAMBLE</td>
<td>1</td>
</tr>
<tr>
<td>1.2</td>
<td>RESEARCH IN INDIA</td>
<td>2</td>
</tr>
<tr>
<td>1.3</td>
<td>GENERAL</td>
<td>3</td>
</tr>
<tr>
<td>1.3.1</td>
<td>Composite action between Steel and Concrete</td>
<td>3</td>
</tr>
<tr>
<td>1.3.2</td>
<td>Local Buckling of Steel tube</td>
<td>4</td>
</tr>
<tr>
<td>1.3.3</td>
<td>Cross-sectional Shape</td>
<td>4</td>
</tr>
<tr>
<td>1.3.4</td>
<td>Slenderness Ratio of Column</td>
<td>4</td>
</tr>
<tr>
<td>1.3.5</td>
<td>Confinement of Concrete</td>
<td>5</td>
</tr>
<tr>
<td>1.3.6</td>
<td>Flat width/ Diameter to thickness ratio of Column</td>
<td>6</td>
</tr>
<tr>
<td>1.3.7</td>
<td>Concrete Core Strength</td>
<td>6</td>
</tr>
<tr>
<td>1.4</td>
<td>NEED FOR THE STUDY</td>
<td>6</td>
</tr>
<tr>
<td>1.5</td>
<td>OBJECTIVE AND SCOPE OF THE STUDY</td>
<td>7</td>
</tr>
<tr>
<td>1.6</td>
<td>OUTLINE OF THE THESIS</td>
<td>9</td>
</tr>
</tbody>
</table>
# LITERATURE REVIEW

2.1 PREAMBLE 10

2.2 RESEARCH IN INDIA 10

2.3 ULTIMATE STRENGTH 12

2.4 CONFINEMENT OF CONCRETE 15

2.5 USE OF CONCRETE OF VARIABLE STRENGTHS 18

2.6 DUCTILITY 20

2.7 SUMMARY 20

# CODAL PROVISIONS AND DESIGN

3.1 PREAMBLE 22

3.2 AXIAL COMPRESSIVE STRENGTH OF FILLED COLUMNS 22

3.2.1 Eurocode 4-1994 22

3.2.2 ACI 318-1999 24

3.2.3 AISC-LRFD-1999/AISC-2005 26

3.2.3.1 AISC-LRFD-1999 27

3.2.3.2 AISC-2005 27

3.2.4 AS 3600-1994 / AS 4100-1998 28

3.2.5 Summary 28

3.3 LOCAL BUCKLING OF STEEL TUBE 29

3.3.1 Eurocode 4-1994 29

3.3.2 ACI 318-1999 29

3.3.3 AISC-LRFD-1999/AISC-2005 30

3.3.4 Summary 30

3.4 SLENDERNESS LIMITS 30

3.4.1 Eurocode 4-1994 30

3.4.2 ACI 318-1999 31
3.4.3 Summary 31
3.5 CONFINEMENT OF CONCRETE 31
3.5.1 Eurocode 4-1994 33
3.5.2 AISC-2005 33
3.5.3 Summary 33
3.6 STEEL CONTRIBUTION RATIO 34
3.6.1 Eurocode 4-1994 34
3.6.2 AISC-LRFD-1999/AISC-2005 34
3.6.3 Summary 34
3.7 DESIGN METHODS SUGGESTED BY PREVIOUS RESEARCHERS 35
3.7.1 Circular columns 35
3.7.2 Square columns 35
3.7.3 Summary 36

4 EXPERIMENTAL INVESTIGATION 37
4.1 PREAMBLE 37
4.2 TEST PROGRAM 37
4.2.1 Phase I 37
4.2.2 Phase II 41
4.2.3 Phase III 41
4.3 MATERIALS USED 41
4.3.1 Steel 42
4.3.2 Concrete 42
4.4 TEST ARRANGEMENT 44
4.5 PREPARATION OF TEST SPECIMENS 44
4.5.1 Casting of Column Specimens 45
4.6 CURING 45
4.7 TESTING OF COLUMN SPECIMENS 52
4.8 SUMMARY 52
5 RESULTS AND DISCUSSION

5.1 PREAMBLE

5.2 TEST RESULTS

5.2.1 Test on Columns of Varying Shape

5.2.1.1 Ultimate Strength

5.2.1.2 Effect of Slenderness Ratio

5.2.1.3 Effect of Concrete Core Strength

5.2.1.4 Effect of Infill

5.2.1.5 Load versus Axial Strain Behaviour

5.2.1.6 Ductility

5.2.1.7 Failure modes

5.2.2 Test on Circular Columns

5.2.2.1 Ultimate Strength

5.2.2.2 Effect of Slenderness Ratio

5.2.2.3 Effect of Infill

5.2.2.4 Load versus Axial Strain Behaviour

5.2.2.5 Ductility

5.2.2.6 Failure modes

5.2.3 Test on Circular Columns of Constant Slenderness

5.2.3.1 Ultimate Strength

5.2.3.2 Effect of Diameter to thickness ratio

5.2.3.3 Effect of Infill

5.2.3.4 Load versus Axial Deformation Behaviour

5.2.3.5 Axial Stiffness

5.2.3.6 Failure modes

5.2.4 Summary
5.3 COMPARISON OF EXPERIMENTAL AND PREDICTED STRENGTH

5.3.1 Square columns

5.3.1.1 Experimental and Eurocode 4-1994 Strengths

5.3.1.2 Experimental and ACI318-1999 and AS3600-1994/AS4100-1998 Strengths

5.3.1.3 Experimental and AISC-2005 Strengths

5.3.1.4 Experimental and AISC-LRFD-1999 Strengths

5.3.1.5 Experimental Strengths and Strengths as per Equation suggested by Muhammad et al.

5.3.2 Circular columns

5.3.2.1 Experimental and Eurocode4-1994 Strengths

5.3.2.2 Experimental and ACI318-1999 and AS3600-1994/AS4100-1998 Strengths

5.3.2.3 Experimental and AISC-2005 Strengths

5.3.2.4 Experimental and AISC-LRFD-1999 Strengths

5.3.2.5 Experimental Strengths and Strengths as per Equation suggested by Giakoumelis and Lam

5.3.3 Hollow columns

5.3.4 Summary
5.4 EFFECT OF CONCRETE CORE STRENGTH ON STRENGTH PREDICTIONS 115

5.5 EFFECT OF CROSS-SECTIONAL SHAPE ON STRENGTH PREDICTIONS 116

5.6 EFFECT OF SLENDERNESS RATIO ON STRENGTH PREDICTIONS 116
  5.6.1 Square Columns 116
  5.6.2 Circular Columns 125
  5.6.3 Summary 131

5.7 EFFECT OF FLAT WIDTH/ DIAMETER TO THICKNESS RATIO ON STRENGTH PREDICTIONS 133
  5.7.1 Square Columns 133
  5.7.2 Circular columns 138
  5.7.3 Summary 141

5.8 EFFECT OF CONFINEMENT OF CONCRETE 142
  5.8.1 Effect of Slenderness Ratio 144
  5.8.2 Effect of Diameter to thickness Ratio 144
  5.8.3 Effect of Concrete Core strength 144
  5.8.4 Summary 146

5.9 PROPOSED EQUATION 146

5.10 BUCKLING CURVE 154

5.11 SUMMARY 154

6 SUMMARY AND CONCLUSIONS 157

6.1 PREAMBLE 157
6.2 BEHAVIOUR OF HOLLOW AND CONCRETE INFILLED STEEL TUBULAR COLUMNS 158
6.3 FAILURE MODES 160
6.4 PREDICTIONS AS PER CODES AND DESIGN METHODS 161
6.5 CONFINEMENT OF CONCRETE 162
6.6 PROPOSED EQUATION 162
6.7 BUCKLING CURVE 163
6.8 CONCLUSIONS 163
6.9 SCOPE FOR FURTHER WORK 166

REFERENCES 167
APPENDIX 172
LIST OF PUBLICATIONS 178
VITAE 180