ENGINEERING PROPERTIES OF POLYSTYRENE AGGREGATE CONCRETE

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Submitted for the Degree of Doctor of Philosophy

Faculty of Engineering
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1998
CERTIFICATE

I certify that this thesis has not already been submitted for any degree and is not being submitted as part of candidature for any other degree.

I also certify that the thesis has been written by me and that any help that I have received in preparing this thesis, and all sources used, have been acknowledged in this thesis.

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ABSTRACT

The project reported in this thesis was concerned with the utilization of recycled polystyrene granulates as lightweight aggregate for use in concrete. A manufacturing process for the conversion of polystyrene waste from the packaging industry into chemically coated expanded polystyrene aggregate was developed by Building Systems Technology (BST) Pty. Ltd. When the treated polystyrene aggregates are incorporated into fresh mortar or concrete they are uniformly and evenly distributed in the cement paste or the mortar matrix.

The polystyrene aggregate produced by BST was used to establish the workability, strength, deformation, bond strength, and the functional properties of the concrete. The properties of the concretes made with the polystyrene aggregate were compared with concretes made with normal weight aggregates of equivalent mix proportions using General Purpose Portland (Type GP) cement.

It was found that it is generally feasible to manufacture structural grade lightweight concrete from treated recycled polystyrene aggregate. No reduction was observed in the compressive and tensile strengths, and the modulus of elasticity of concretes made with the polystyrene aggregate, and cured in water over a period of about one year. The maximum cylinder compressive strength of concrete made with the treated polystyrene aggregate satisfied the strength requirement of medium strength structural reinforced concrete.

This investigation has shown that structural grade polystyrene aggregate concrete having saturated surface-dry density of 1800 kg/m³ to 2400 kg/m³ can be produced with cylinder compressive strength up to 32 MPa. The test results have shown that, for a stress/strength ratio of 30% of the 28-day cylinder compressive strength, the creep strain of polystyrene aggregate concrete compares well with concrete made with normal weight aggregates. The functional properties such as impact resistance and freezing and thawing durability of concrete is improved when polystyrene aggregate is incorporated.

From the conclusions derived, design recommendations are suggested. Limitations of the investigation and suggestions for future work are presented.
ACKNOWLEDGMENTS

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Finally to family and friends the author acknowledges their patience and encouragement, in particular, Esther Dedei Armah who assisted with some preparation and testing, and typing of the manuscript.
DEDICATION

This work is dedicated to the memory of my father SAMUEL DOKU SABAA.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>i</td>
</tr>
<tr>
<td>ACKNOWLEDGMENT</td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xiv</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xxvii</td>
</tr>
<tr>
<td>LIST OF PLATES</td>
<td>xxxii</td>
</tr>
<tr>
<td>NOTATIONS</td>
<td>xxxiii</td>
</tr>
<tr>
<td>ABBREVIATIONS</td>
<td>xxxiv</td>
</tr>
<tr>
<td>CHAPTER 1 INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>1.1 General introduction</td>
<td>1</td>
</tr>
<tr>
<td>1.2 Purpose and scope</td>
<td>2</td>
</tr>
<tr>
<td>CHAPTER 2 REVIEW OF PREVIOUS INVESTIGATION INTO POLYSTYRENE AGGREGATE CONCRETE</td>
<td>5</td>
</tr>
<tr>
<td>2.1 Introduction</td>
<td>5</td>
</tr>
<tr>
<td>2.2 Expanded polystyrene in concrete</td>
<td>6</td>
</tr>
<tr>
<td>2.2.1 Coated polystyrene beads in concrete</td>
<td>6</td>
</tr>
<tr>
<td>2.2.2 Waste polystyrene chips in concrete</td>
<td>8</td>
</tr>
<tr>
<td>2.2.3 Uncoated polystyrene beads in concrete</td>
<td>8</td>
</tr>
<tr>
<td>2.3 Applications of polystyrene concrete</td>
<td>9</td>
</tr>
<tr>
<td>2.3.1 Concrete block making</td>
<td>9</td>
</tr>
<tr>
<td>2.3.2 Structural applications</td>
<td>9</td>
</tr>
<tr>
<td>2.3.3 Other applications</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER 3 EXPERIMENTAL PROGRAMME</td>
<td>11</td>
</tr>
<tr>
<td>3.1 Scope of experimental investigation</td>
<td>11</td>
</tr>
<tr>
<td>3.2 Details of concrete materials</td>
<td>11</td>
</tr>
<tr>
<td>3.2.1 Portland cement</td>
<td>11</td>
</tr>
</tbody>
</table>
3.2.2 Aggregates

3.3 Details of Concrete Mixes

3.4 Preparation of test specimens for hardened concrete properties study
   3.4.1 Mixing procedure
   3.4.2 Concrete specimen for strength and creep studies
   3.4.3 Concrete prisms for shrinkage and durability studies
   3.4.4 Concrete specimens for bond strength studies
   3.4.5 Impact resistance test specimens

3.5 Apparatus
   3.5.1 Compression creep testing rigs
   3.5.2 Impact strength testing equipment
   3.5.3 Pulse velocity measurement apparatus
   3.5.4 Resonant frequency apparatus
   3.5.5 Ancillary equipment

3.6 Experimental investigation
   3.6.1 Determination of the strength properties of polystyrene aggregate concrete
   3.6.2 Deformations of polystyrene aggregate concrete
   3.6.3 Creep of polystyrene aggregate concrete in compression
   3.6.4 Drying shrinkage of polystyrene aggregate concrete
   3.6.5 Bond development with reinforcing steel studies
   3.6.6 Impact resistance of polystyrene aggregate concrete
   3.6.7 Freeze-thaw resistance of polystyrene aggregate concrete

3.7 General comments

CHAPTER 4 PROPERTIES OF FRESH POLYSTYRENE AGGREGATE CONCRETE

4.1 Workability of concrete
   4.1.1 Introduction
4.1.2 Factors influencing concrete workability 42
4.1.2.1 Influence of type and property of aggregate on workability 43
4.1.2.2 Influence of mix proportions on workability 43
4.1.2.3 Influence of time and temperature on workability 44
4.1.3 Workability of lightweight aggregate concrete 45
4.1.3.1 Measurement of lightweight aggregate concrete workability 46

4.2 Workability of polystyrene aggregate concrete 47
4.2.1 Evaluation of the DIN Compaction Test 47
4.2.1.1 Effect of size of compaction test container 47
4.2.1.2 Effect of method of compaction on compaction index 51
4.2.1.3 Optimising compaction by ramming 54
4.2.2 Effect of mix composition on PAC workability 58
4.2.2.1 Effect of polystyrene aggregate content on workability 58
4.2.2.2 Influence of unit weight on workability 60
4.2.2.3 Effect of fine aggregate content on workability 63
4.2.2.4 Effect of aggregate grading on workability 65
4.2.3 Sensitivity of the compaction test to aggregate grading 68
4.2.4 Sensitivity of the compaction test to binder type 68
4.2.5 Classification of workability of PAC 69
4.2.5.1 Visual observation and classification of workability 71
4.2.5.2 Relating air bubble escape time and visual observation 73
4.2.6 Comparison of workability tests 75
4.2.6.1 Slump of PAC compared to that of reference concrete 79
4.2.6.2 Relation between compaction test and slump test 79
4.2.7 Variability and repeatability of DIN compaction test 81

4.3 Unit weight of fresh PAC 85
4.3.1 Relation between PA replacement levels and unit weight 85
4.3.2 Relation between PA addition levels and unit weight 87
4.3.3 Statistical significance of factors influencing unit weight 91
4.3.3.1 The significance of the influence of cement content on unit weight 92
4.3.3.2 The significance of the influence of water/cement ratio on unit weight 97
4.3.3.3 The significance of the influence of method of PA incorporation on unit weight 100
4.3.3.4 The significance of the influence of type of reference mix on unit weight 100
4.3.4 Regression model for predicting unit weight of PAC with normal weight coarse aggregate

4.3.5 Regression model for predicting unit weight of PAC without normal weight coarse aggregate

4.3.6 Prediction intervals

4.3.7 Simplified regression models

4.4 Concluding remarks

4.4.1 General

4.4.2 Conclusions

CHAPTER 5 STRENGTH AND ELASTIC DEFORMATION OF POLYSTYRENE AGGREGATE CONCRETE

5.1 Introduction

5.2 Theoretical principles

5.2.1 Concrete as a composite material

5.2.2 Mathematical models for modulus of concrete

5.2.3 The influence of aggregate type on the strength of concrete

5.3 Strength of polystyrene aggregate concrete

5.3.1 Compressive strength

5.3.1.1 Influence of concrete density on compressive strength

5.3.1.2 Effect of age on compressive strength

5.3.2 Prediction of compressive strength

5.3.2.1 Limiting compressive strength

5.3.3 Effect of specimen shape on compressive strength

5.3.4 Tensile strength of concrete

5.3.4.1 Influence of concrete density on indirect tensile strength

5.3.4.2 Relation between concrete density and indirect tensile strength

5.3.4.3 Comparison of relative indirect tensile strength with relative compressive strength

5.3.5 Relation between indirect tensile strength and cylinder compressive strength

5.3.6 Relation between indirect tensile strength and cube compressive strength
5.3.7 Relation between flexural strength and compressive strength 172
5.3.8 Theoretical prediction of compressive strength 174

5.4 Elastic deformation in compression 179
5.4.1 Stress-Strain relation of PAC 179
5.4.1.1 Strain at peak stress 183
5.4.1.2 Equation for stress-strain relation for PAC 186
5.4.2 Modulus of elasticity 189
5.4.2.1 Expressions relating modulus of elasticity and compressive strength 193
5.4.2.2 Relation between the moduli for PAC and reference concrete 199
5.4.2.3 Expressions relating modulus of elasticity to strength and density 199
5.4.2.4 Relation between static and dynamic modulus of elasticity 205
5.4.3 Poisson’s ratio of PAC 207
5.4.4 Theoretical estimation of the modulus of elasticity 213

5.5 Conclusions 218

CHAPTER 6 TIME-DEPENDENT DEFORMATIONS OF PAC 220

6.1 Introduction 220

6.2 Theoretical principle 220
6.2.1 The influence of aggregate on the shrinkage and creep of concrete 221

6.3 Shrinkage of polystyrene aggregate concrete 223
6.3.1 Influence of polystyrene aggregate content on drying shrinkage 223
6.3.2 Relation between aggregate content and drying shrinkage 227
6.3.3 Influence of water/cement ratio and aggregate/cement ratio 230
6.3.4 Influence of initial curing duration on shrinkage of PAC 234
6.3.5 Effect of drying condition on shrinkage 239
6.3.6 Ultimate shrinkage of PAC 241
6.3.6.1 Shrinkage-time relation 241
6.3.6.2 Effect of density on ultimate shrinkage 242
6.3.7 Swelling of preshrunk concrete: reversible shrinkage 247
6.3.8 Shrinkage of PAC compared with other lightweight concretes 251

viii
6.4 Creep of polystyrene aggregate concrete
   6.4.1 Instantaneous strain on loading
   6.4.2 Creep rate
   6.4.3 Total creep strain of PAC and lightweight aggregate concrete
   6.4.3.1 Creep of PAC
   6.4.3.2 Comparison of creep of PAC with LWAC
   6.4.4 Influence of cement paste on creep of PAC
   6.4.5 Influence of strength of concrete on creep of PAC
   6.4.6 Influence of PA aggregate content on creep of PAC
   6.4.7 Influence of the age at the time of loading on PAC creep
   6.4.8 Influence of curing and storage conditions on creep of PAC
   6.4.9 Prediction of long-term creep
   6.4.9.1 Prediction of long-term creep from experimental data
   6.4.9.2 Ultimate creep
   6.4.9.3 Time to achieve half ultimate creep
   6.4.10 Creep coefficient

6.5 Creep recovery of PAC
   6.5.1 Components of creep recovery
   6.5.2 Creep recovery of PAC in relation to density
   6.5.3 Irrecoverable creep
   6.5.4 Effect of age of concrete at loading on creep recovery

6.6 Prediction of creep and shrinkage from strength, mix composition
and environmental conditions
   6.6.1 Creep and shrinkage prediction by ACI-209R-82
   6.6.2 Creep and shrinkage prediction by CEB-FIP MC 90

6.7 Conclusions

CHAPTER 7  BOND PERFORMANCE OF POLYSTYRENE
AGGREGATE CONCRETE

7.1 Introduction
   7.1.1 Bond mechanism
   7.1.2 Types of bond failure
7.2 Research into bond strength

7.3 Lightweight concrete bond strength research

7.4 Bond measurement: requirement in codes and standards
   7.4.1 BS 4449 method
   7.4.2 RILEM method
   7.4.3 ASTM method
   7.4.4 British Concrete Association method

7.5 Bond strength of polystyrene aggregate concrete
   7.5.1 Failure patterns of pull-out specimens
   7.5.2 Bond performance in relation to concrete strength
   7.5.2.1 Relation between bond and tensile strengths
   7.5.3 Effect of concrete density on bond strength
   7.5.3.1 Bond performance on the basis of slip
   7.5.4 Effect of bar direction in relation to casting direction on bond strength
   7.5.5 Bond performance as a function of concrete cast below bar
   7.5.6 Development length for bar yield strength
   7.5.6.1 Development length-compressive strength relation
   7.5.6.2 Ratio of pull-out test development length to calculated development length

7.6 Conclusions

CHAPTER 8 FUNCTIONAL PROPERTIES OF POLYSTYRENE AGGREGATE CONCRETE

8.1 Introduction

8.2 Mechanics of frost action on hardened concrete
   8.2.1 Coarse aggregate response to frost action
   8.2.2 Factors controlling frost resistance of concrete
   8.2.2.1 Air entrainment
   8.2.2.2 Water/cement ratio
   8.2.3 Lightweight concrete resistance to freezing and thawing
8.2.4 Effect of microspheres on freeze-thaw durability 351
8.2.5 Freeze-thaw test procedures and interpretation 351
8.2.5.1 Merits of standard freezing and thawing tests 352
8.2.5.2 Test method for freeze-thaw investigation 353

8.3 Impact resistance of concrete 353
8.3.1 Requirements of an efficient energy-absorbing material 354
8.3.2 Spring-mass model: hard impact 356
8.3.3 Measurement and characterization of impact resistance 358
8.3.4 Impact testing apparatus 359

8.4 Resistance of PAC to repeated freezing and thawing cycles 361
8.4.1 Properties of fresh concrete 361
8.4.2 Frost response of PAC with normal weight coarse aggregate 361
8.4.2.1 Effect of mix composition on frost resistance 365
8.4.2.2 Effect of freezing and thawing on length and weight changes 367
8.4.2.3 Effect of the density on resistance to freezing and thawing 369
8.4.2.4 Frost responds of PAC without normal weight coarse aggregate 373

8.5 Impact resistance of polystyrene aggregate concrete 380
8.5.1 Selection of drop weight 380
8.5.2 Mode of failure under repeated impact 380
8.5.3 Repeatability of test results 383
8.5.4 Relation between impact strength and mix composition 383
8.5.5 Effect of polystyrene aggregate content on impact strength 388
8.5.6 Effect of curing condition on impact strength 390
8.5.7 Effect of curing duration on impact resistance 393
8.5.8 Method of PA inclusion on the impact resistance of concrete 395
8.5.9 Impact resistance of plain PAC compared with fibre reinforced PAC 399

8.6 Conclusions 403

CHAPTER 9 MIX DESIGN OF POLYSTYRENE AGGREGATE CONCRETE 405

9.1 Principle of proposed method 405
9.1.1 Scope of proposed method 405
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.1.2</td>
<td>The mix design process</td>
<td>406</td>
</tr>
<tr>
<td>9.2</td>
<td><strong>Relation between the mix constituents and concrete properties</strong></td>
<td>407</td>
</tr>
<tr>
<td>9.2.1</td>
<td>Polystyrene aggregate concrete strength and density relation</td>
<td>407</td>
</tr>
<tr>
<td>9.2.2</td>
<td>Relation between types of polystyrene aggregate and compressive strength</td>
<td>410</td>
</tr>
<tr>
<td>9.2.3</td>
<td>Cement content-strength and water/cement ratio-strength relations</td>
<td>410</td>
</tr>
<tr>
<td>9.2.4</td>
<td>Variability of the strength of polystyrene aggregate concrete</td>
<td>412</td>
</tr>
<tr>
<td>9.2.5</td>
<td>Water content and workability</td>
<td>413</td>
</tr>
<tr>
<td>9.2.6</td>
<td>Estimation of polystyrene aggregate content</td>
<td>413</td>
</tr>
<tr>
<td>9.3</td>
<td><strong>Mix design calculations</strong></td>
<td>421</td>
</tr>
<tr>
<td>9.3.1</td>
<td>Design of reference concrete</td>
<td>421</td>
</tr>
<tr>
<td>9.3.2</td>
<td>PAC mix design based on data obtained in this study</td>
<td>421</td>
</tr>
<tr>
<td>9.3.2.1</td>
<td>Alternate method to design reference mix</td>
<td>422</td>
</tr>
<tr>
<td>9.4</td>
<td><strong>Trial batch adjustment</strong></td>
<td>423</td>
</tr>
<tr>
<td>9.4.1</td>
<td>Adjustment for unit weight</td>
<td>423</td>
</tr>
<tr>
<td>9.4.2</td>
<td>Adjustment for strength</td>
<td>427</td>
</tr>
<tr>
<td>9.5</td>
<td><strong>Design of polystyrene aggregate concrete without normal weight</strong></td>
<td>428</td>
</tr>
<tr>
<td></td>
<td>coarse aggregate</td>
<td></td>
</tr>
<tr>
<td>9.6</td>
<td><strong>Examples of polystyrene aggregate concrete mix design</strong></td>
<td>430</td>
</tr>
<tr>
<td>9.6.1</td>
<td>Specification of required structural polystyrene aggregate concrete</td>
<td>430</td>
</tr>
<tr>
<td>9.6.2</td>
<td>Procedure of mix design</td>
<td>430</td>
</tr>
<tr>
<td>9.6.2.1</td>
<td>Determination if specified strength and unit weight can be achieved</td>
<td>430</td>
</tr>
<tr>
<td>9.6.2.2</td>
<td>Proportioning of reference mix</td>
<td>430</td>
</tr>
<tr>
<td>9.6.2.3</td>
<td>Determination of polystyrene aggregate content</td>
<td>432</td>
</tr>
<tr>
<td>9.6.3</td>
<td>Adjusting trial mix for density</td>
<td>433</td>
</tr>
<tr>
<td>9.6.3.1</td>
<td>Polystyrene aggregate content adjustment</td>
<td>433</td>
</tr>
<tr>
<td>9.6.3.2</td>
<td>Normal weight coarse aggregate adjustment</td>
<td>434</td>
</tr>
<tr>
<td>9.6.3.3</td>
<td>Adjusting trial mix for strength</td>
<td>434</td>
</tr>
</tbody>
</table>
CHAPTER 10  CONCLUSIONS AND RECOMMENDATIONS  435

10.1  Introduction  435
10.2  Limitation of present work  435
10.3  Conclusions  436
   10.3.1  Properties of fresh concrete made with polystyrene aggregate  437
   10.3.2  Properties of hardened concrete made with polystyrene aggregate  437
10.4  Design recommendations  440
10.5  Recommendations for further work  441

REFERENCES  442

APPENDICES
   A  Statistical Methods  456
   B  Mix proportions of all mixes used for workability and unit weight study  471
   C  Regression analysis of unit weight - Tabulated Values  521
   D  Workability test results  526
### LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Samples of expanded polystyrene aggregates</td>
<td>14</td>
</tr>
<tr>
<td>3.2</td>
<td>Test specimen for the study of bond strength according to ASTM C234</td>
<td>24</td>
</tr>
<tr>
<td>3.3</td>
<td>Test specimen for the bond strength study: modified version of RILEM RC 6.1 pull-out test specimens</td>
<td>24</td>
</tr>
<tr>
<td>3.4</td>
<td>Set-up of creep rig used for the creep investigation</td>
<td>26</td>
</tr>
<tr>
<td>3.5</td>
<td>Impact strength test equipment</td>
<td>29</td>
</tr>
<tr>
<td>3.6</td>
<td>Compressometer arrangement</td>
<td>31</td>
</tr>
<tr>
<td>3.7</td>
<td>Profile of reinforcing bar: maximum average spacing 14.0 mm; maximum gap 7.9 mm; minimum average height 1.0 mm; AS 1302 grade 410Y</td>
<td>36</td>
</tr>
<tr>
<td>3.8</td>
<td>Set-up of bond strength test according to ASTM C 234</td>
<td>38</td>
</tr>
<tr>
<td>3.9</td>
<td>Set-up for bond strength test according to modified RILEM CR 6</td>
<td>38</td>
</tr>
<tr>
<td>4.1</td>
<td>Relation between compaction index and water/cement ratio for polystyrene aggregate concrete: unit weight = 1600 kg/m³</td>
<td>48</td>
</tr>
<tr>
<td>4.2</td>
<td>Relation between compaction index and water/cement ratio for polystyrene aggregate concrete: unit weight = 1800 kg/m³</td>
<td>48</td>
</tr>
<tr>
<td>4.3</td>
<td>Effect of diameter of test container on loose unit weight of polystyrene aggregate concrete having different water/cement ratios</td>
<td>50</td>
</tr>
<tr>
<td>4.4</td>
<td>Influence of the method of compaction on the unit weight: concrete density = 1650 kg/m³</td>
<td>52</td>
</tr>
<tr>
<td>4.5</td>
<td>Influence of the method of compaction on the unit weight: concrete density = 1800 kg/m³</td>
<td>52</td>
</tr>
<tr>
<td>4.6a</td>
<td>Relation between height change and number of blows of ramming: rammer size = 16 mm diameter; unit weight of concrete = 1650 kg/m³.</td>
<td>55</td>
</tr>
<tr>
<td>4.6b</td>
<td>Relation between height change and number of blows of ramming: rammer size = 16 mm diameter; unit weight of concrete = 1800 kg/m³</td>
<td>55</td>
</tr>
<tr>
<td>4.6c</td>
<td>Relation between height change and number of blows of ramming: rammer size = 45 mm diameter; unit weight of concrete = 1650 kg/m³</td>
<td>56</td>
</tr>
</tbody>
</table>
4.6d  Relation between height change and number of blows of ramming: rammer size = 45 mm diameter; unit weight of concrete = 1800 kg/m³

4.6e  Relation between height change and number of blows of ramming: rammer size = 65 mm diameter; unit weight of concrete = 1650 kg/m³

4.6f  Relation between height change and number of blows of ramming: rammer size = 65 mm diameter; unit weight of concrete = 1800 kg/m³

4.7  Relation between compaction index and water/cement ratio (cement content calculated at water/cement ratio of 0.40)

4.8  Relation between the slump and water/cement ratio (cement content calculated at water/cement ratio of 0.40)

4.9a  Relation between the compaction index and water/cement ratio, for mixes of similar cement paste content

4.9b  Relation between the slump of polystyrene aggregate concrete and water/cement ratio, for mixes of similar cement paste content

4.10  Combined aggregate grading for polystyrene aggregate concrete having varying fine to coarse aggregate ratio: unit weight 1800 kg/m³

4.11  Effect of fine aggregate content on workability

4.12  Combined aggregate grading of polystyrene aggregate concrete having varying percentage fines: nominal unit weight 1800 kg/m³

4.13  Effect of aggregate grading and cement paste content on the workability: unit weight 1800 kg/m³

4.14  Relation between level of fly ash replacement and workability as measured by DIN compaction test and slump test: nominal concrete density = 1800 kg/m³; water/cement ratio of 0.35

4.15  Relation between compaction index and compacting effort for concrete with maximum aggregate size of 32 mm.

4.16  Relation between workability as determined by visual observation and compaction test

4.17  Relation between air bubble escape time, compaction index and visually determined workability

4.18  General pattern of relations between the slump, Vebe and DIN compaction tests for polystyrene aggregate concrete mixes of different unit weights and aggregate/cement ratios (by volume)
4.19 General pattern of relations between the slump, Vebe and compacting factor tests for polystyrene aggregate concrete mixes of different unit weights and aggregate/cement ratios (by volume).

4.20 Ratio of slump of PAC to slump of reference concrete

4.21 Relation between compaction index and slump: volume of paste calculated at w/c = 0.40

4.22 Loss of workability with time (with remixing): unit weight of PAC = 1800 kg/m³; w/c = 0.40.

4.23 Relation between relative unit weight and percentage level of coarse aggregate replacement with polystyrene aggregate

4.24 Regression of relative unit weight on level of coarse aggregate replacement with polystyrene aggregate

4.25 Relation between relative unit weight and percentage level of polystyrene aggregate added per unit volume of concrete, with increased water content

4.26 Relation between relative unit weight and percentage level of polystyrene aggregate added per unit volume of concrete, with superplasticizer added

4.27 Comparison of the method of PA incorporation into reference concrete

4.28 Regression of relative unit weight on polystyrene aggregate content

4.29 Relation between measured unit weight and calculated unit weight for concretes having different cement contents

4.30 Relation between measured unit weight and calculated unit weight for concretes having different water/cement ratio

4.31 Influence of the method of polystyrene aggregate incorporation on the unit weight of polystyrene aggregate concrete

4.32 Regression of measured unit weight on calculated unit weight for PAC with concrete and mortar reference mixes

4.33 Regression of measured unit weight on calculated unit weight for polystyrene aggregate concrete with normal weight coarse aggregate

4.34 Diagnostic plot of standardized residuals versus predicted unit weight for PAC with normal weight coarse aggregate

4.35 Regression of measured unit weight on calculated unit weight for PAC without normal weight coarse aggregate
4.36 Diagnostic plot of standardized residuals versus predicted unit weight for PAC without normal weight coarse aggregate

4.37 Estimated line of regression for measured unit weight on calculated unit weight and confidence and prediction limit intervals for PAC with normal weight coarse aggregate: $\alpha = 0.05$.

4.38 Estimated line of regression for measured unit weight on calculated unit weight and confidence and prediction limit intervals for PAC without normal weight coarse aggregate: $\alpha = 0.05$

5.1 Parallel and series models of concrete

5.2 Influence of polystyrene aggregate volume fraction (PAC-Addition) on relative density and relative strength

5.3 Influence of polystyrene aggregate volume fraction (PAC-Replacement) on relative density and relative strength

5.4 Influence of reference mix composition on 28-day compressive strength (PAC-Addition)

5.5 Influence of reference mix composition on 28-day compressive strength (PAC-Replacement)

5.6 Relation between void and air content and relative unit weight

5.7 Effect of method of polystyrene aggregate inclusion on the relation between relative strength and relative density of 7-day PAC

5.8 Effect of method of polystyrene aggregate inclusion on the relation between relative strength and relative density of 28-day PAC

5.9 Effect of specimen shape on the relation between relative strength and relative density

5.10 Comparison of PAC and incompletely compacted normal weight concrete

5.11 Effect of method of PA inclusion on the relative cube strength-density relationship for PAC (mortar reference mix)

5.12 Typical relation between compressive strength and age of PAC: Mixes 16CA0, 16CA1, 16CA2, 16CA3, and 16CA4; cement content = 420 kg/m³; w/c = 0.55; aggregate/cement = 4.02

5.13 Typical relation between compressive strength and age of PAC without NWCA: Mixes 3MR0 to 3MR70
5.14 Relative gain of strength with time in concretes with different densities (mixes 19CA0, 19CA1, 19CA2, 19CA3, and 19CA4) 152
5.15 Influence of concrete density on short-term strength development 152
5.16 Different factors influencing strength of lightweight aggregate concrete 156
5.17 Increase of the 28-day compressive strength as a function of the cement content 158
5.18 Relationship between cylinder and cube compressive strength 160
5.19 Relation between relative indirect tensile strength with concrete density for different mix composition; PAC-Addition 164
5.20 Relation between relative indirect tensile strength with concrete density for different mix composition; PAC-Replacement. 164
5.21 Variation of indirect tensile strength with density for 28-day and 91-day concrete 165
5.22 Relation between 28-day relative indirect tensile strength and relative density 165
5.23 Relation between indirect tensile strength and cylinder compressive strength 170
5.24 Relation between indirect tensile strength and cube compressive strength for PAC 173
5.25 Relation between flexural tensile strength and cube compressive strength of moist cured PAC 173
5.26 Comparison of experimental strength with predicted strengths based on Bache's model for PAC-Addition with NWCA 177
5.27 Comparison of PAC experimental strengths with strengths of PAC without NWCA predicted from relative density and strength of reference mortar 177
5.28a Typical stress-strain relation in compression for PACs with NWCA and corresponding reference concrete: mixes 20CA0, 20CA1, 20CA2, 20CA3, and 20CA4. 180
5.28b Typical relation between stress/strength and strain for PACs with NWCA and corresponding reference concrete: mixes 20CA0, 20CA1, 20CA2, 20CA3, and 20CA4 180
5.29a Typical stress-strain relation in compression for PACs without NWCA and corresponding reference mix: mixes 1MA0, 1MA1, 1MA2, 1MA3, and 1MA4 181
5.29b Typical relation between stress/strength and strain for PACs with NWCA and corresponding reference concrete: mixes 1MA0, 1MA1, 1MA2, 1MA3, and 1MA4

5.30 Comparison of stress-strain relation in compression for PAC containing NWCA with that for NWC of similar compressive strength

5.31 Comparison of stress-strain relation for PACs containing NWCA with that for PAC without NWCA having similar compressive strength.

5.32 Variation of strain at peak stress with concrete strength

5.33 Variation of strain at peak stress with concrete density

5.34a Comparison of stress-strain formulae (Eqns. 5.40 and 5.41) for ascending branch of stress-strain curve for PAC and NWC: composition of reference mix; cement content = 422 kg/m3, aggregate/cement ratio = 4.02, and w/c = 0.55)

5.34b Comparison of stress-strain formulae (Eqns. 5.42 and 5.43) for ascending branch of stress-strain curve for PAC and NWC: composition of reference mix; cement content = 422 kg/m3, aggregate/cement ratio = 4.02, and w/c = 0.55)

5.35 Comparison of predicted boundary conditions of fitted stress/strength ratio-strain curves with experimental results

5.36 Variation of Static modulus with strength for PAC having different mix composition

5.37 Variation of static modulus of elasticity with cylinder compressive strength for PAC: regression curve fitted to all data regardless of specimen age

5.38 Variation of dynamic modulus of elasticity with cylinder compressive strength for PAC: regression curve fitted to all data regardless of specimen age

5.39 Linear regression relation between static modulus of elasticity and compressive strength: all ages

5.40 Variation of static modulus of elasticity with the density of concrete: reference concretes; 16CA0, 17CA0, 18CA0, 19CA0, and 20CA0

5.41 Regression of relative static chord modulus of elasticity on relative density of PAC at 28 days

5.42 Regression of relative dynamic modulus of elasticity on relative density of PAC at 28 days
5.43 Relation between 28-day predicted and measured moduli of elasticity for PAC

5.44 Relation between 28-day static and dynamic moduli of elasticity

5.45 Poisson's ratio as a function of compressive strength: mean value based on all data show

5.46 Poisson's ratio as a function of concrete density: mean value based on all data show

5.47 Poisson's ratio as a function of modulus of elasticity: mean value based on all data show

5.48 Influence of volumetric proportion of PAC on static chord modulus of PAC-Addition as estimated by various methods: cement content = 598 kg/m³

5.49 Influence of volumetric proportion of PAC on static chord modulus of PAC-Addition as estimated by various methods: cement content = 422 kg/m³

5.50 Influence of volumetric proportion of PAC on static chord modulus of PAC-Addition as estimated by various methods: cement content = 422 kg/m³

5.51 Influence of volumetric proportion of PAC on static chord modulus of PAC (mortar reference mix) as estimated by various methods

6.1 Shrinkage of concretes of fixed paste content but with varying proportion of coarse normal weight aggregate and polystyrene aggregate: cement content = 450 kg/m³; water/cement ratio = 0.40

6.2 Shrinkage of concretes of fixed paste content but with varying proportion of coarse normal weight aggregate and polystyrene aggregate: cement content = 545 kg/m³; water/cement ratio = 0.40

6.3 Influence of concrete density on the rate of drying shrinkage strain development with time (expressed as the ratio of shrinkage at a given time to shrinkage at 520 days): w/c = 0.40

6.4 Influence of mix composition on shrinkage strain development (expressed as the average ratio of shrinkage at a given time to shrinkage at 520 days for PACs and reference concrete of the same mix proportions)
6.5 Relation between logarithm of shrinkage after 520 days of drying and polystyrene aggregate content: a/c = total aggregate/cement ratio; w/c = water/cement ratio; unit of shrinkage $1 \times 10^{-6}$

6.6 Influence of polystyrene aggregate content in concrete (by volume) on the ratio of PAC shrinkage to reference concrete shrinkage (relative shrinkage)

6.7 Influence of water/cement ratio and polystyrene aggregate content on PAC shrinkage: drying time = 520 days

6.8 Relation between drying shrinkage after 240 days and dynamic modulus of elasticity of concrete at 28 days

6.9 Relation between shrinkage and drying time for PAC moist cured for 7 and 30 days: PA content = 9.7% (by volume); nominal concrete density = 2000 kg/m$^3$

6.10 Relation between shrinkage and drying time for PAC moist cured for 7 and 30 days: PA content = 16.2% (by volume); nominal concrete density = 1800 kg/m$^3$

6.11 Relation between drying shrinkage and time for PAC stored at 50% and 75% relative humidity

6.12 Influence of mix composition on the ultimate drying shrinkage

6.13 Variation of ultimate drying shrinkage with density of concrete

6.14 Relation between relative ultimate shrinkage and relative concrete density

6.15 Variation of the coefficient, $k$ (Eqn. 6.8) with drying time

6.16 Typical behaviour of PAC and NWC on drying and rewetting

6.17 Effect of concrete density on drying shrinkage and irreversible shrinkage: drying time = 520 days; rewetting time 177 days

6.18 Influence of concrete density on specific creep: aggregate/cement ratio = 2.89

6.19 Influence of concrete density on specific creep: aggregate/cement ratio = 3.94

6.20 Creep of PAC stored at 50% relative humidity: cement content 545 kg/m$^3$; age at application of load = 28 days; stress/strength ratio = 0.3

6.21 Creep of PAC stored at 50% relative humidity: cement content 425 kg/m$^3$; age at application of load = 28 days; stress/strength ratio = 0.3

6.22 Relation between logarithm of specific creep after 28, 56, and 150 days under load and polystyrene aggregate content
6.23 Influence of age at application of load on creep of PAC after 150 days under load
6.24 Comparison of the specific creep of PAC load at the ages of 28 days and 410 days
6.25 Influence of age at loading on the rate of creep for the first few days under load
6.26 Influence of curing and storage conditions on specific creep: aggregate/cement ratio = 2.89
6.27 Influence of curing and storage conditions on specific creep: aggregate/cement ratio = 3.94
6.28 Determination of constants of creep prediction expression: cement content = 545 kg/m³; water content = 230 kg/m³
6.29 Determination of constants of creep prediction expression: cement content = 425 kg/m³; water content = 220 kg/m³
6.30 Comparison of predicted creep strain to observed creep strain for various times under load
6.31 Development of creep coefficient with time under load: cement content = 545 kg/m³; water content = 230 kg/m³
6.32 Development of creep coefficient with time under load: cement content = 425 kg/m³; water content = 220 kg/m³
6.33 Variation of creep coefficient with concrete density (SSD)
6.34 Creep and creep recovery of PAC and reference concrete: compressive strength of reference concrete = 58.8 MPa
6.35 Creep and creep recovery of PAC and reference concrete: compressive strength of reference concrete = 43.0 MPa
6.36 Influence of density of concrete on creep and creep recovery
6.37 Influence of age of concrete at the time of loading on creep recovery of PAC

7.1 Relation between bond and compressive strengths: vertical bars
7.2 Relation between bond and compressive strengths: horizontal bars
7.3 Relation between bond and tensile strengths
7.4 Comparison Eqn. (7.1) and (7.1a): vertically embedded reinforcement
7.5 Comparison of Eqn. (7.2) and (7.2a): horizontally embedded reinforcement
7.6 Relation between relative bond strength and relative density for vertical and horizontal bars
7.7 Bond stress at various slips at loaded end of bar
7.8 Relation between slip at the loaded end and bond stress of vertically embedded bars: cement content = 425 kg/m³; water content = 220 kg/m³.
7.9 Relation between slip at the loaded end and bond stress of vertically embedded bars: cement content = 545 kg/m³; water content = 230 kg/m³.
7.10 Relation between development length and compressive strength based on pull-out test: vertical bars
7.11 Relation between development length and compressive strength based on pull-out test: horizontal bars
7.12 Ratio of test development length to calculated development length: vertical bars
7.13 Ratio of test development length to calculated development length: horizontal bars

8.1 Response of saturated cement paste to freezing and thawing both with and without entrained air
8.2 Hard and soft impact
8.3 Load-deformation response for an ideal energy absorbing material
8.4 Simple mechanical model for two-mass system
8.5 Single mass model
8.6 Variation of dynamic modulus of elasticity of PACs subjected to freezing and thawing as a function of cement content and testing procedure
8.7 Variation of ultrasonic pulse velocity of PACs subjected to freezing and thawing as a function of cement content and testing procedure
8.8 Variation of shrinkage of PACs subjected to freezing and thawing as a function of cement content and testing procedure
8.9 Variations density of PACs subjected to freezing and thawing as a function of cement content and testing procedure
8.10 Increase in dynamic modulus of elasticity of PAC subjected to freezing and thawing as a function of density and cement content
8.11 Increase in ultrasonic pulse velocity of PAC subjected to freezing and thawing as a function of density and cement content

8.12 Influence of density and cement content on relative dynamic modulus of elasticity of PAC subjected to freezing and thawing

8.13 Influence of density and cement content on relative pulse velocity of PAC subjected to freezing and thawing

8.14 Influence of density and cement content on variation of shrinkage of PAC subjected to freezing and thawing

8.15 Influence of concrete density and cement content on variation of density of PAC subjected to freezing and thawing

8.16 Comparison of variation of dynamic modulus of elasticity of PAC-Addition and PAC-Replacement (without normal weight coarse aggregate) subjected to freezing and thawing with reference mortar with and without air entrainment

8.17 Comparison of variation of pulse velocity of PAC-Addition and PAC-Replacement (without normal weight coarse aggregate) subjected to freezing and thawing with reference mortar with and without air entrainment

8.18 Comparison of freeze-thaw resistance of PAC-Addition (without normal weight coarse aggregate) with reference mortar with and without air entrainment

8.19 Comparison of freeze-thaw resistance of PAC-Replacement (without normal weight coarse aggregate) with reference mortar with and without air entrainment

8.20 Comparison of length change of PAC-Replacement (without normal weight coarse aggregate) subjected to freezing and thawing with reference mortar with and without air entrainment

8.21 Change in volume of frost-resistant and vulnerable concretes on cooling

8.22 Comparison of the spread of number of blows required for failure for 4.56 kg and 3.1 kg hammers

8.23 Effect of changes in cement content on impact strength of PAC

8.24 Relation between concrete density of plain PAC and number of blows to caused first crack and the depth of penetration after first crack

8.25 Effect of curing conditions on impact strength of plain PAC

8.26 Effect of curing conditions on impact strength of fibre reinforced PAC
8.27 Effect of prolonged curing on the impact resistance of plain PAC 394
8.28 Effect of prolonged curing on the impact resistance of fibre reinforced PAC 394
8.29 Effect of replacing sand of a reference mortar with PA on impact properties 397
8.30 Effect of the addition of PA to a mortar reference concrete on impact properties 397
8.31 Comparison of impact strength of plain PAC with fibre reinforced PAC: cement content = 425 kg/m³; 28 days water cured 401
8.32 Comparison of impact strength of plain PAC with fibre reinforced PAC: cement content = 370 kg/m³; 28 days water cured 401
8.33 Comparison of depth of penetration after first crack of plain PAC with fibre reinforced PAC 402

9.1 28-day cylinder compressive strength in relation to the unit weight of fresh polystyrene aggregate concrete for various reference concrete strengths. 409
9.2 Relation between relative cylinder strength and relative unit weight 409
9.3 Relation between the compressive strengths of polystyrene aggregate concrete containing standard and premium grades aggregates 411
9.4 Relation between cement content and 28-day compressive strength 414
9.5 Relation between water/cement ratio and 28-day compressive strength 414
9.6 Relationship between standard deviation and compressive strength 415
9.7 Relation between the compaction index and the water content 417
9.8 Void and air content in relation to relative unit weight of polystyrene aggregate concrete 420
9.9 Examples of the process for adjusting polystyrene aggregate content using the results of a trial mix 424
9.10 Illustration of the process of polystyrene aggregate content adjustment 426
9.11 Relation between 28-day cylinder compressive strength and unit weight of polystyrene aggregate concrete without normal weight coarse aggregate

9.12 Void and air contents per unit volume of concrete in relation to relative unit weight of polystyrene aggregate concrete without normal weight coarse aggregate
### LIST OF TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Properties of polystyrene concrete</td>
<td>7</td>
</tr>
<tr>
<td>3.1</td>
<td>Composition of KANDOS brand, Type GP Portland Cement.</td>
<td>12</td>
</tr>
<tr>
<td>3.2</td>
<td>Mix proportion of PAC-Replacement with normal weight coarse aggregate</td>
<td>16</td>
</tr>
<tr>
<td>3.3</td>
<td>Mix proportion of PAC-Addition with normal weight coarse aggregate</td>
<td>19</td>
</tr>
<tr>
<td>3.4</td>
<td>Mix proportion of PAC without normal weight coarse aggregate</td>
<td>20</td>
</tr>
<tr>
<td>4.1</td>
<td>Summary of single-factor analysis of variance (ANOVA) of the effect of diameter of test container on compaction index</td>
<td>50</td>
</tr>
<tr>
<td>4.2</td>
<td>Summary of analysis of variance (ANOVA) for the effect of method of compaction on the compaction test</td>
<td>53</td>
</tr>
<tr>
<td>4.3</td>
<td>Mix proportions of polystyrene aggregate concrete of similar paste content (water/cement ratio = 0.40)</td>
<td>61</td>
</tr>
<tr>
<td>4.4</td>
<td>Apparent workability ranges for polystyrene aggregate concrete based on the compaction test, air bubble escape time and visual judgement.</td>
<td>76</td>
</tr>
<tr>
<td>4.5</td>
<td>Description of workability and magnitude of slump of PAC compared with that of normal weight concrete</td>
<td>82</td>
</tr>
<tr>
<td>4.6</td>
<td>Repeatability of the DIN compaction test</td>
<td>84</td>
</tr>
<tr>
<td>4.7</td>
<td>Descriptive statistics of repeatability test results</td>
<td>84</td>
</tr>
<tr>
<td>4.8</td>
<td>Unit weights for concretes having different cement contents</td>
<td>93</td>
</tr>
<tr>
<td>4.9</td>
<td>Difference between calculate and measured unit weights</td>
<td>93</td>
</tr>
<tr>
<td>4.10</td>
<td>Sums of Squares and Cross-Products for concretes having different cement contents</td>
<td>95</td>
</tr>
<tr>
<td>4.11</td>
<td>Analysis of Covariance for the effect of cement content</td>
<td>95</td>
</tr>
<tr>
<td>4.12</td>
<td>Analysis of covariance for the effect of water/cement ratio on the unit weight of polystyrene aggregate concrete</td>
<td>101</td>
</tr>
<tr>
<td>4.13</td>
<td>Comparison of lines of regression for concretes with polystyrene aggregate replacement and addition</td>
<td>104</td>
</tr>
<tr>
<td>4.14</td>
<td>Summary of analysis of covariance for the comparison of lines of regression for polystyrene aggregate concretes with concrete and mortar reference mixes</td>
<td>107</td>
</tr>
</tbody>
</table>

xxvii
<table>
<thead>
<tr>
<th>Section</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.15</td>
<td>Regression of measured unit weight on calculated unit weight and analysis of variance for PAC with normal weight coarse aggregate</td>
</tr>
<tr>
<td>4.16</td>
<td>Regression of measured unit weight on calculated unit weight and analysis of variance for PAC without normal weight coarse aggregate</td>
</tr>
<tr>
<td>4.17</td>
<td>Error associated with using simplified equations of regression for measured unit weight on calculated unit weight</td>
</tr>
<tr>
<td>5.1</td>
<td>Properties of hardened PAC-Addition at the age of 28 days</td>
</tr>
<tr>
<td>5.2</td>
<td>Properties of hardened PAC-Replacement at the age of 28 days</td>
</tr>
<tr>
<td>5.3</td>
<td>28-day Properties of hardened PAC not containing coarse normal weight aggregate (mortar reference mix)</td>
</tr>
<tr>
<td>5.4</td>
<td>28-day compressive strength and density of PAC-Addition compared to corresponding reference concrete</td>
</tr>
<tr>
<td>5.5</td>
<td>28-day compressive strength and density of PAC-Replacement compared to corresponding reference concrete</td>
</tr>
<tr>
<td>5.6</td>
<td>28-day compressive strength and density of PAC (mortar reference mixes) compared to corresponding reference concrete</td>
</tr>
<tr>
<td>5.7</td>
<td>Regression equation connecting relative strength and relative density</td>
</tr>
<tr>
<td>5.8</td>
<td>Relative gain of compressive strength (PAC-Addition with NWCA)</td>
</tr>
<tr>
<td>5.9</td>
<td>Relative gain of strength (PAC-Replacement with NWCA)</td>
</tr>
<tr>
<td>5.10</td>
<td>Relative gain of strength (PAC-Replacement without NWCA)</td>
</tr>
<tr>
<td>5.11</td>
<td>Regression equation relating compressive strength (MPa) and age (days) for PAC with NWCA</td>
</tr>
<tr>
<td>5.12</td>
<td>Regression equation connecting compressive strength (MPa) and age (days) for PAC without NWCA</td>
</tr>
<tr>
<td>5.13</td>
<td>Indirect tensile strength of PAC-Addition compared with corresponding reference concrete at the age of 28 days</td>
</tr>
<tr>
<td>5.14</td>
<td>Indirect tensile strength of PAC-Replacement compared with corresponding reference concrete at the age of 28 days</td>
</tr>
<tr>
<td>5.15</td>
<td>Regression equation connecting relative indirect tensile strength and relative density of PAC</td>
</tr>
<tr>
<td>5.16</td>
<td>28-day relative compressive strength compared with 28-day relative indirect tensile strength</td>
</tr>
<tr>
<td>Page</td>
<td>Section</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
</tr>
<tr>
<td>5.17</td>
<td>Empirical constants for expressions relating indirect tensile strength to compressive strength</td>
</tr>
<tr>
<td>5.18</td>
<td>Comparison of experimental and theoretical 28-day compressive strength of PAC-Addition</td>
</tr>
<tr>
<td>5.19</td>
<td>Comparison of experimental and theoretical compressive strength of PAC-Replacement</td>
</tr>
<tr>
<td>5.20</td>
<td>Modulus of elasticity of concretes of similar compressive strength</td>
</tr>
<tr>
<td>5.21</td>
<td>Comparison of formulae for stress-strain curve of concrete</td>
</tr>
<tr>
<td>5.22</td>
<td>Comparison of predicted and experimental strain and modulus of elasticity</td>
</tr>
<tr>
<td>5.23</td>
<td>Influence of aggregate content on static and dynamic moduli of PAC of comparable compressive strength</td>
</tr>
<tr>
<td>5.24</td>
<td>Regression expression relation modulus and cylinder compressive strength</td>
</tr>
<tr>
<td>5.25</td>
<td>Regression equations relating the experimental static and dynamic modulus of elasticity and relative density</td>
</tr>
<tr>
<td>5.26</td>
<td>Regression equations relating modulus to density and compressive strength of concrete</td>
</tr>
<tr>
<td>5.27</td>
<td>Poisson's ratio of PAC and reference NWC</td>
</tr>
<tr>
<td>5.28</td>
<td>Comparison of observed and predicted modulus of elasticity of PAC</td>
</tr>
<tr>
<td>5.29</td>
<td>Ratios of estimated modulus to observed modulus</td>
</tr>
<tr>
<td>6.1</td>
<td>Development of shrinkage of PAC with drying time</td>
</tr>
<tr>
<td>6.2</td>
<td>Comparison of observed shrinkage and calculated shrinkage from Eqn. 6.4</td>
</tr>
<tr>
<td>6.3</td>
<td>Regression equation relating shrinkage of PACs to shrinkage of reference concrete, for various mix composition and ages</td>
</tr>
<tr>
<td>6.4</td>
<td>Influence of water/cement ratio and aggregate/cement ratio on drying shrinkage</td>
</tr>
<tr>
<td>6.5</td>
<td>Effect of concrete properties on drying shrinkage of PAC</td>
</tr>
<tr>
<td>6.6</td>
<td>Influence of initial water curing duration on shrinkage of PAC</td>
</tr>
<tr>
<td>6.7</td>
<td>Effect of drying condition on shrinkage</td>
</tr>
<tr>
<td>6.8</td>
<td>Empirical constants for drying shrinkage prediction</td>
</tr>
<tr>
<td>6.9</td>
<td>Effect of polystyrene aggregate content and water/cement ratio on ultimate shrinkage</td>
</tr>
<tr>
<td>6.10</td>
<td>Effect of density on ultimate shrinkage</td>
</tr>
</tbody>
</table>
6.11 Variation of exponential coefficient, $k$ (Eqn. 6.8) with time
6.12 Reversible and irreversible part of shrinkage of PAC and NWC
6.13 Comparison of shrinkage of PAC with other lightweight and normal weight concretes
6.14 Instantaneous strain on loading
6.15 Summary of creep properties at 150 days under load
6.16 Effect of cement paste content on creep strain
6.17 Influence of strength of concrete on creep of PAC
6.18 Values of $\alpha$ and specific creep for various cement paste content and ages
6.19 Effect of curing and storage conditions
6.20 Constants for predicting the creep of PAC loaded at the age of 28 days
6.21 Predicted creep properties
6.22 Strength and modulus of elasticity of lightweight aggregates concrete
6.23 Creep recovery of concrete loaded at stress/strength of 0.3 and maintained for 150 days
6.24 Comparison of predicted ultimate creep coefficient
6.25 Comparison of predicted ultimate shrinkage strain

7.1 Bond strength of PAC compared with reference normal weight concrete
7.2 Comparison of Eqn. (7.2) and (7.2a) relating compressive strength and bond strength for horizontally embedded reinforcement
7.3 Effect of concrete density on bond strength of vertical bars
7.4 Effect of concrete density on bond strength of horizontal bars
7.5 Effect of orientation of bar on bond strength
7.6 Influence of bar position on bond strength
7.7 Development length for vertically embedded bars
7.8 Development length for horizontally embedded bars
7.9 Development length as a function of bar position

8.1 Properties of fresh concretes used in freezing and thawing investigation
8.2 Results of freezing and thawing tests (Series 1)

xxx
<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.3</td>
<td>Relative dynamic modulus of elasticity and pulse velocity (Series 1)</td>
<td>366</td>
</tr>
<tr>
<td>8.4</td>
<td>Summary of freezing and thawing test results for PAC without normal weight coarse aggregate (Series 2)</td>
<td>374</td>
</tr>
<tr>
<td>8.5</td>
<td>Relative dynamic modulus of elasticity (Series 2)</td>
<td>376</td>
</tr>
<tr>
<td>8.6</td>
<td>Impact strength of 28 days water cured PAC</td>
<td>384</td>
</tr>
<tr>
<td>8.7</td>
<td>Effect of the moisture conditions of concrete on impact strength</td>
<td>385</td>
</tr>
<tr>
<td>8.8</td>
<td>Effect of curing duration on impact strength</td>
<td>386</td>
</tr>
<tr>
<td>8.9</td>
<td>Effect of storage conditions on impact resistance</td>
<td>392</td>
</tr>
<tr>
<td>8.10</td>
<td>Effect of duration of curing on impact strength</td>
<td>396</td>
</tr>
<tr>
<td>8.11</td>
<td>Effect of method of polystyrene aggregate incorporation on impact response</td>
<td>398</td>
</tr>
<tr>
<td>8.12</td>
<td>Effect of fibre reinforcement on impact strength of PAC after 28 days of water curing</td>
<td>400</td>
</tr>
<tr>
<td>9.1</td>
<td>Properties of materials</td>
<td>430</td>
</tr>
</tbody>
</table>
## LIST OF PLATES

<table>
<thead>
<tr>
<th>Plate</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>Appearances of polystyrene aggregate concrete having various workability</td>
<td>72</td>
</tr>
<tr>
<td>7.1</td>
<td>Typical failure modes for reference concretes</td>
<td>310</td>
</tr>
<tr>
<td>7.2</td>
<td>Typical failure modes for PAC having nominal density of 2000 kg/m³</td>
<td>310</td>
</tr>
<tr>
<td>7.3</td>
<td>Typical failure modes for PAC having nominal density of 1800 kg/m³</td>
<td>311</td>
</tr>
<tr>
<td>7.4</td>
<td>Typical failure modes for PAC having nominal density of 1600 kg/m³</td>
<td>311</td>
</tr>
<tr>
<td>7.5</td>
<td>Typical deformation of concrete around reinforcing bar for reference concretes</td>
<td>312</td>
</tr>
<tr>
<td>7.6</td>
<td>Typical deformation of concrete around reinforcing bar for PAC having nominal density of 2000 kg/m³</td>
<td>312</td>
</tr>
<tr>
<td>7.7</td>
<td>Typical deformation of concrete around reinforcing bar for PAC having nominal density of 1800 kg/m³</td>
<td>313</td>
</tr>
<tr>
<td>7.8</td>
<td>Typical deformation of concrete around reinforcing bar for PAC having nominal density of 1600 kg/m³</td>
<td>313</td>
</tr>
<tr>
<td>8.1</td>
<td>Typical modes of failure of plain PAC with normal weight coarse aggregate (left side) and PAC without normal weight coarse aggregate (right side) under repeated impact.</td>
<td>382</td>
</tr>
</tbody>
</table>
NOTATION

\( c \) = Creep of concrete  
\( c_p \) = Creep of paste  
\( E_a \) = Modulus of elasticity of aggregate  
\( E_c \) = Static modulus of elasticity  
\( E_d \) = Dynamic modulus of elasticity  
\( E_m \) = Modulus of elasticity of matrix (or mortar)  
\( f_{c,28} \) = Compressive strength of concrete at 28 days  
\( f_{cyt} \) = Cylinder compressive strength  
\( f_{cf} \) = Flexural tensile strength of concrete  
\( f_{\alpha} \) = Indirect tensile strength  
\( f_{cu} \) = Cube compressive strength  
\( f_o \) = Compressive strength of reference concrete  
\( G_d \) = Dynamic modulus of rigidity  
\( g \) = Volumetric content of aggregate  
\( K \) = Bulk modulus of elasticity  
\( k \) = A coefficient, ratio or factor used with and without numerical subscripts  
\( p \) = Porosity  
\( t \) = Time  
\( \alpha \) = A coefficient  
\( \beta \) = A coefficient with or without numerical subscripts  
\( \Delta \) = Positive or negative increment  
\( \varepsilon \) = Strain  
\( \varepsilon_i \) = Instantaneous strain  
\( \varepsilon_c \) = Strain due to concrete creep  
\( \varepsilon_{sh} \) = Strain due to shrinkage  
\( \varepsilon_{sh,o} \) = Shrinkage strain of reference concrete  
\( \varepsilon_{sp} \) = Total load induced strain per MPa  
\( \phi(t) \) = Creep coefficient  
\( \mu \) = Poisson’s ratio  
\( \lambda \) = Wavelength of vibration  
\( \rho \) = Density of concrete  
\( \rho_o \) = Density of reference concrete
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACI</td>
<td>American Concrete Institute</td>
</tr>
<tr>
<td>ASTM</td>
<td>American Society for Testing and Materials</td>
</tr>
<tr>
<td>CEB</td>
<td>Euro-International Committee for Concrete</td>
</tr>
<tr>
<td>CUR</td>
<td>Commissie voor Uitvoering van Research</td>
</tr>
<tr>
<td>CUW</td>
<td>Calculated unit weight</td>
</tr>
<tr>
<td>DOE</td>
<td>Department of the Environment (Building Research Establishment, Watford, UK)</td>
</tr>
<tr>
<td>FIP</td>
<td>International Federation for Prestressing</td>
</tr>
<tr>
<td>LWC</td>
<td>Lightweight concrete</td>
</tr>
<tr>
<td>LWAC</td>
<td>Lightweight aggregate concrete</td>
</tr>
<tr>
<td>MUW</td>
<td>Measured unit weight</td>
</tr>
<tr>
<td>NWC</td>
<td>Normal weight concrete</td>
</tr>
<tr>
<td>PA</td>
<td>Polystyrene aggregate</td>
</tr>
<tr>
<td>PAC</td>
<td>Polystyrene aggregate concrete</td>
</tr>
<tr>
<td>RILEM</td>
<td>International Union of Testing and research laboratories for Materials and Construction</td>
</tr>
</tbody>
</table>