



University of Southern Queensland

**AN INVESTIGATION INTO THE EFFECT OF MATERIAL  
COMPOSITION ON THE FUNDAMENTAL PROPERTIES OF  
PERMEABLE CONCRETE**

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A Dissertation submitted by

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For the award of Master of

Engineering and Surveying 2012

## CERTIFICATION OF DISSERTATION

I certify that the work in this thesis has not been previously submitted for any degree and nor has it been submitted as part of a requirement for a degree except where fully acknowledged within the text.

I also certify that I have written this thesis and that any help that I have received in my research work and in the preparation of this thesis has been acknowledged. I also certify that I have fully referenced all sources of information and literature that I have used in this thesis.

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## ABSTRACT

The use of permeable concrete in the construction industry has been increasing around the world during the last few years. The fundamental properties of permeable concrete must thus be comprehensively evaluated and elucidated in order to obtain the full benefits of this material. This research investigated the effects of material composition on the mechanical properties (compressive strength, stress-strain behaviour and the modulus of elasticity) and on the hydraulic properties (porosity ratio and permeability) of the permeable concrete.

Eight different permeable concrete mix designs were prepared with two aggregate sizes in two different proportions, different sand ratios, two aggregate to cement ratios and a constant water to cement ratio. The target 28-day compressive strength was designed to be between 15MPa and 35MPa. The porosity ratio was designed to be between 25% and 15%, whilst the permeability was designed to be between 12mm/sec to 2mm/sec.

A review of the published literature revealed no standard experimental procedure for determining the stress-strain behaviour and the modulus of elasticity of permeable concrete using the strain gauge method. The only method in use was the platen-to-platen method. This research involved the development of a testing method for determining these properties using the strain gauge method. The results are compared with those that were obtained using the platen-to-platen method. A significant difference was found between the properties that were measured by these two methods.

A semi-empirical equation to represent the complete stress-strain behaviour for unconfined permeable concrete is proposed as part of this research. Various existing models for low-strength concrete and normal-strength concrete were used and

compared with the experimental data. Various parameters were studied and their relationships were experimentally determined. The only parameters needed to run the new model is the ultimate compressive strength and the density. The proposed semi-empirical stress-strain equations were compared with actual cylinder tests results under axial compression; the new model gives a good representation of the mean behaviour of the actual stress-strain response of the permeable concrete.

## LIST OF PUBLISHED PAPERS

Hussin, M, Zhuge,Y, Bullen ,F & lokuge, W 2011, 'Laboratory Evaluation of the Stress-Strain relationship of Permeable Concrete', *Advanced Materials Research*, vols. 243-249, pp. 3259-3262, viewed item: DOI: 10.4028/[www.scientific.net/AMR.243-249.3259](http://www.scientific.net/AMR.243-249.3259).

Hussin, M, Zhuge,Y, Bullen ,F & lokuge, W 2012, 'Investigation of Some Fundamental Properties of Permeable Concrete', *Advanced Materials Research*, vol. 487, pp. 869-73, viewed item: DOI: 10.4028/[www.scientific.net/AMR.487.869](http://www.scientific.net/AMR.487.869).

Hussin, M, Zhuge,Y, Bullen ,F & lokuge, W 2012, 'A mathematical model for complete stress-strain curve prediction of permeable concrete'. Submitted to 22<sup>nd</sup> AUSTRALASIAN CONFERENCE ON THE MECHANICS OF STRUCTURES AND MATERIALS (ACMSM). ACMSM will be held at the University of Technology Sydney, Australia on 11-14 December, 2012.

# TABLE OF CONTENT

<b>CERTIFICATION OF DISSERTATION</b>	<b>I</b>
<b>ACKNOWLEDGEMENT</b>	<b>II</b>
<b>ABSTRACT</b>	<b>III</b>
<b>LIST OF PUBLISHED PAPERS</b>	<b>V</b>
<b>TABLE OF CONTENT</b>	<b>VI</b>
<b>LIST OF FIGURES</b>	<b>X</b>
<b>LIST OF TABLES</b>	<b>XIII</b>
<b>LIST OF SYMBOLS</b>	<b>XV</b>
<b>CHAPTER 1:INTRODUCTION</b>	
<i>1.1 Background</i>	<i>1</i>
<i>1.1.1 Permeable concrete</i>	<i>1</i>
<i>1.1.2 Historical use of permeable concrete</i>	<i>4</i>
<i>1.2 Objectives of the investigation</i>	<i>6</i>
<i>1.3 Scope of the investigation</i>	<i>7</i>
<i>1.4 Thesis outline</i>	<i>8</i>
<b>CHAPTER 2: LITERATURE REVIEW</b>	
<i>2.1 Introduction</i>	<i>9</i>
<i>2.2 Fundamental properties of permeable concrete</i>	<i>10</i>
<i>2.2.1 Compressive strength</i>	<i>11</i>
<i>2.2.2 Modulus of elasticity (MOE)</i>	<i>13</i>
<i>2.2.3 Stress-strain behaviour</i>	<i>16</i>
<i>2.2.4 Measurements techniques for the axial deformation (non platen to platen)</i>	<i>20</i>
<i>2.2.4.1 Contact methods</i>	<i>21</i>
<i>2.2.4.1.1 The compressometer</i>	<i>21</i>
<i>2.2.4.1.2 Starin gauge</i>	<i>22</i>
<i>2.2.4.1.3 DMEC (demountable mechanical strain gauge measurements)</i>	<i>23</i>
<i>2.2.4.2 Contact free methods</i>	<i>24</i>
<i>2.2.4.2.1 The LVDT(linear variable differential transformer)</i>	<i>24</i>
<i>2.2.4.2.2 Laser sensors</i>	<i>25</i>

2.2.4.2.3 <i>The CCD (charge-coupled-device camera)</i>	26
2.2.4.2.4 <i>Photogrammetry</i>	27
2.2.5 <i>Porosity</i>	27
2.2.6 <i>Porosity measurements</i>	30
2.2.7 <i>Permeability</i>	32
2.2.8 <i>Permeability measurements</i>	33
2.2.9 <i>Relationship between compressive strength and porosity</i>	36
2.2.10 <i>Relationship between the permeability and the porosity</i>	39
2.3 <i>The cost of permeable concrete</i>	41
2.4 <i>Maintaining the permeable concrete pavement</i>	43
2.5 <i>Conclusion</i>	44
<b>CHAPTER 3: MATERIALS AND EXPERIMENTAL PROCEDURES</b>	
3.1 <i>Introduction</i>	46
3.2 <i>Materials</i>	46
3.2.1 <i>Aggregate</i>	46
3.2.2 <i>Cement</i>	47
3.3 <i>Mixing of the permeable concrete and the casting and curing of the test specimens</i>	49
3.4 <i>Dry density of the permeable concrete</i>	51
3.5 <i>Tests methods</i>	52
3.5.1 <i>Compressive strength</i>	52
3.5.2 <i>Strain and Modulus of Elasticity (MOE) measurements</i>	54
3.5.3 <i>Strain gauging</i>	55
3.5.4 <i>Photogrammetry</i>	57
3.5.5 <i>Porosity test</i>	59
3.5.6 <i>Determination of the porous area using image analysis</i>	60
3.5.7 <i>Water permeability test</i>	62
3.6 <i>Conclusion</i>	64
<b>CHAPTER 4: EXPERIMENTAL RESULTS AND ANALYSIS</b>	
4.1 <i>Introduction</i>	65
4.2 <i>Permeable concrete testing results and analysis</i>	65
4.2.1 <i>Density</i>	65
4.2.2 <i>Compressive strength</i>	67



4.2.3 Modulus of elasticity (MOE)	70
4.2.3.1 The platen-to-platen method results	70
4.2.3.2 The strain gauge method results	71
4.2.3.3 Compressometer method results	73
4.2.4 Evaluation of the MOE along the permeable concrete from top to bottom	74
4.2.5 The stress-strain behaviour	77
4.2.6 Failure behaviour of permeable concrete	85
4.2.7 Volumetric porosity	87
4.2.8 Determination of the pore area	90
4.2.9 Permeability	94
4.3 Relationships among the fundamentals properties of the permeable concrete	96
4.3.1 Density and compressive strength	96
4.3.2 Compressive strength and the MOE	98
4.3.3 Porosity and compressive strength	101
4.3.4 Porosity and permeability	102
4.4 Conclusion	104

## **CHAPTER 5: DEVELOPMENT OF A MATHEMATICAL MODEL FOR PREDICTION OF THE COMPLETE STRESS-STRAIN CURVE OF PERMEABLE CONCRETE**

5.1 Introduction	107
5.2 Review of previous models for conventional concrete	109
5.2.1 The empirical model of Sargin, Ghosh and Handa (1971)	110
5.2.2 The empirical model of Kent and Park (1971)	111
5.2.3 The empirical model by Popovics (1973)	113
5.3 A mathematical stress-strain model for permeable concrete	115
5.4 Proposed stress-strain relationship	117
5.4.1 The effect of the porosity on the stress-strain curve	119
5.4.2 Estimating strain at peak stress ( $\epsilon_o$ )	120
5.4.3 Estimating the initial modulus of elasticity ( $E_{it}$ )	122
5.4.4. Proposed stress-strain relationship	126

<i>5.4.5 Examination of the proposed model</i>	<i>128</i>
<i>5.5 Conclusion</i>	<i>131</i>

**CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS FOR FUTURE RESEARCH**

<i>6.1 Conclusions</i>	<i>133</i>
<i>6.1.1 Effect of the composition materials on the fundamental properties</i>	<i>133</i>
<i>6.1.2 Stress-strain behaviour and modulus of elasticity</i>	<i>135</i>
<i>6.1.3 Proposed stress-strain model</i>	<i>136</i>
<i>6.2 Limitations of this research</i>	<i>137</i>
<i>6.3 Recommendations for future research</i>	<i>138</i>

**APPENDICES**

Appendix A: Porosity test experimental data .....	140
Appendix B: Permeability test experimental data .....	146
Appendix C: Compressive strength, corresponding strain, modulus of elasticity and densities of the permeable concrete specimens .....	149
<b>REFERENCES .....</b>	<b>150</b>
<b>STANDARDS .....</b>	<b>157</b>

# LIST OF FIGURES

## CHAPTER 1:

FIGURE 1.1 PERMEABLE CONCRETE PAVING DEMONSTRATION .....	3
--	---

## CHAPTER 2:

FIGURE 2.1 STRESS-STRAIN RELATIONS FOR CEMENT PASTE, AGGREGATE AND CONCRETE .....	14
FIGURE 2.2 STRESS-STRAIN DIAGRAMS FOR BRITTLE AND DUCTILE MATERIALS .....	18
FIGURE 2.3 STRESS-STRAIN CURVES OF THE PERMEABLE CONCRETE .....	20
FIGURE 2.4 COMPRESSOMETER TYPES .....	22
FIGURE 2.5 STRAIN GAUGE .....	22
FIGURE 2.6 DEMEC TYPES.....	23
FIGURE 2.7 LVDT .....	24
FIGURE 2.8 LASER SENSORS.....	25
FIGURE 2.9 CCD TECHNOLOGY .....	26
FIGURE 2.10 PHOTOGRAMMETRIC TECHNOLOGY .....	27
FIGURE 2.11 TYPES OF PORES OF PERMEABLE CONCRETE .....	29
FIGURE 2.12 TWO-DIMENSION IMAGES OF THE PERMEABLE CONCRETE SAMPLE.....	30
FIGURE 2.13 FALLING HEAD PERMEABILITY TEST SET UP.....	34
FIGURE 2.14 CONSTANT HEAD METHOD SET-UP.....	36
FIGURE 2.15 RELATIONSHIP BETWEEN 7-DAY COMPRESSIVE STRENGTH AND THE POROSITY.....	37
FIGURE 2.16 THE EXPONENTIAL RELATIONSHIP BETWEEN THE COMPRESSIVE STRENGTH AND THE POROSITY .....	38
FIGURE 2.17 RELATIONSHIP BETWEEN COMPRESSIVE STRENGTH AND POROSITY .....	39
FIGURE 2.18 RELATIONSHIP BETWEEN THE PERMEABILITY AND THE POROSITY .....	40
FIGURE 2.19 AN EXPONENTIAL RELATIONSHIPS FOUND BETWEEN WATER PERMEABILITY AND THE POROSITY RATIO .....	40
FIGURE 2.20 COST PER SQUARE METRE FOR TRADITIONAL AND PERMEABLE CONCRETE.....	42

## CHAPTER 3:

FIGURE 3.1 BASALT AGGREGATE AND THE SAND USED FOR THE PREPARATION OF THE PERMEABLE CONCRETE MIXES .....	47
FIGURE 3.2 WORKABILITY ASSESSMENTS FOR THE PERMEABLE CONCRETE .....	51
FIGURE 3.3 PERMEABLE CONCRETE SAMPLES (A).DURING AND (B).AFTER CAPPING WITH SULPHUR .....	53
FIGURE 3.4 AN 500kN AVERY MACHINE USED FOR THE COMPRESSION STRENGTH TEST .....	54
FIGURE 3.5 THE SAMPLE'S CENTRAL LOCATION IN THE MACHINE DURING THE TEST .....	54
FIGURE 3.6 THE LOCAL AND THE GLOBAL STRAIN IN THE CONCRETE SAMPLES.....	55
FIGURE 3.7 STEPS IN PREPARING AND FIXING THE STRAIN GAUGE ONTO THE PERMEABLE CONCRETE SAMPLE .....	57
FIGURE 3.8 THE STRAIN MEASUREMENT SET-UP USING PHOTOGRAMMETRY TECHNOLOGY .....	58

FIGURE 3.9 POROSITY TEST EQUIPMENT .....	60
FIGURE 3.10 IMAGE-ANALYSIS PROCEDURES TO DETERMINE THE PORE VOIDS AREA .....	62
FIGURE 3.11 PERMEABILITY TEST SET-UP .....	63
FIGURE 3.12 PERMEABLE CONCRETE SPECIMEN WRAPPED WITH CLING WRAP .....	63

## CHAPTER 4

FIGURE 4.1 THE DEVELOPMENT OF COMPRESSIVE STRENGTH WITH AN INCREASE IN SAND RATIO IN PERMEABLE CONCRETE FOR GA AND GB MIXES .....	69
FIGURE 4.2 THE STRESS-STRAIN CURVES OF THE PERMEABLE CONCRETE .....	70
FIGURE 4.3 A PERMEABLE CONCRETE MIX SAMPLE SHOWING THE LOCATION OF THE THREE STRAIN GAUGES. ....	75
FIGURE 4.4 STRESS-STRAIN CURVES FOR SPECIMENS MEASURED WITH THREE STRAIN GAUGES.....	76
FIGURE 4.5 THE DIFFERENCE IN POROSITY THAT WAS MEASURED USING ERADS IMAGINE 2011 SOFTWARE .....	76
FIGURE 4.6 THE STRESS-STRAIN CURVES FOR GA.....	79
FIGURE 4.7 THE STRESS-STRAIN CURVES FOR GB.....	79
FIGURE 4.8 THE STRESS-STRAIN CURVES FOR GC.....	80
FIGURE 4.9 GENERAL STRESS-STRAIN CURVES FOR THE PERMEABLE CONCRETE .....	83
FIGURE 4.10 STRESS-STRAIN CURVES FOR PERMEABLE CONCRETE .....	84
FIGURE 4.11 THE SUDDEN CRACK IN THE PERMEABLE CONCRETE SPECIMEN WITH LOW POROSITY .....	86
FIGURE 4.12 THE GRADUALLY DEVELOPED CRACK IN THE PERMEABLE CONCRETE SPECIMEN WITH HIGH POROSITY .....	86
FIGURE 4.13 THE FAILURE PATTERN THROUGH THE CEMENT PASTE IN THE PERMEABLE CONCRETE SPECIMEN .....	87
FIGURE 4.14 THE DEVELOPMENT OF THE PORE AREAS THROUGH THE PERMEABLE CONCRETE SPECIMEN .....	93
FIGURE 4.15 TWO-DIMENSIONAL PERMEABLE CONCRETE'S SPECIMEN WITH CONNECTED AND UN-CONNECTED VOIDS .....	95
FIGURE 4.16 THE RELATIONSHIP BETWEEN THE DENSITY AND THE COMPRESSIVE STRENGTH.....	97
FIGURE 4.17 THE RELATIONSHIP BETWEEN THE COMPRESSIVE STRENGTH AND THE MOE.....	99
FIGURE 4.18 THE RELATIONSHIP BETWEEN THE MOE DERIVED FROM THE TWO TESTING METHODS .....	100
FIGURE 4.19 THE RELATIONSHIP BETWEEN THE POROSITY AND THE COMPRESSIVE STRENGTH.....	101
FIGURE 4.20 THE RELATIONSHIP BETWEEN THE POROSITY AND THE PERMEABILITY. ....	103

## CHAPTER 5

FIGURE 5.1 TYPICAL STRESS-STRAIN CURVES FOR CONFINED AND UNCONFINED CONCRETE.....	110
FIGURE 5.2 TYPICAL STRESS-STRAIN CURVES FOR CONFINED AND UNCONFINED CONCRETE.....	112
FIGURE 5.3 TYPICAL STRESS-STRAIN CURVE FOR CONFINED AND UNCONFINED CONCRETE .....	113
FIGURE 5.4 EXPERIMENTAL DATA AND MODEL FITS FOR THE STRESS-STRAIN RESPONSE OF	

PERMEABLE CONCRETE MADE USING (A) SINGLE-SIZED AGGREGATES, AND (B) BLENDED AGGREGATES .....	116
FIGURE 5.5 STRESS-STRAIN CURVES FOR PERMEABLE CONCRETE .....	120
FIGURE 5.6 THE EXPERIMENTAL AND CALCULATED $\epsilon_o$ VERSUS THE COMPRESSIVE STRENGTH .....	122
FIGURE 5.7 THE RELATIONSHIP OF EXPERIMENTAL AND CALCULATED $E_{IT}$ VERSUS $P^{1.5} \times F'_C{}^{0.5}$ .....	125
FIGURE 5.8 THE RELATIONSHIP BETWEEN THE POROSITY RATIO AND N VALUE .....	128
FIGURE 5.9 (A-E) MODEL PREDICTIONS .....	131

# LIST OF TABLES

## CHAPTER 3

TABLE 3.1 CHEMICAL COMPOSITION OF THE ORDINARY PORTLAND CEMENT .....	48
TABLE 3.2 MIX PROPORTIONS FOR THE PERMEABLE CONCRETE MIXES BY WEIGHT.....	49

## CHAPTER 4

TABLE 4.1 DENSITIES OF THE PERMEABLE CONCRETE MIXES .....	67
TABLE 4.2 RESULTS OF THE 28-DAY COMPRESSIVE STRENGTH TESTS FOR THE PERMEABLE CONCRETE MIXES .....	68
TABLE 4.3 MOE RESULTS (PLATEN-TO-PLATEN METHOD) FOR PERMEABLE CONCRETE MIXES .....	71
TABLE 4.4 MOE RESULTS (STRAIN GAUGE METHOD) FOR PERMEABLE CONCRETE MIXES .....	72
TABLE 4.5 MOE RESULTS (COMPRESSOMETER METHOD) FOR PERMEABLE CONCRETE MIXES. GOEDE (2009).....	73
TABLE 4.6 THE POROSITY RATIOS AT ROOM TEMPERATURE .....	88
TABLE 4.7 THE POROSITY RATIOS AFTER STORING SPECIMENS IN THE OVEN.....	89
TABLE 4.8 SOLID AND PORE AREAS FOR DIFFERENT SECTIONS THROUGH THE PERMEABLE CONCRETE SPECIMENS.....	91
TABLE 4.9 THE RESULTS OF THE PERMEABILITY TESTS .....	95
TABLE 4.10 THE PROPERTIES OF THE PERMEABLE CONCRETE SPECIMENS.....	104

## CHAPTER 5

TABLE 5.1 STRESS-STRAIN BEHAVIOURS BASED ON THE MODEL BY SARGIN (1971) .....	111
TABLE 5.2 STRESS-STRAIN BEHAVIOUR BASED ON MODEL BY KENT (1971) .....	112
TABLE 5.3 STRESS-STRAIN BEHAVIOUR BASED ON THE MODEL BY POPOVICS (1973).....	114

## APPENDICES

### APPENDIX A

TABLE A.1 POROSITY FOR GA PERMEABLE CONCRETE SPECIMENS AT THE ROOM TEMPERATURE	140
TABLE A.2 POROSITY FOR GB PERMEABLE CONCRETE SPECIMENS AT THE ROOM TEMPERATURE.	141
TABLE A.3 POROSITY FOR GC PERMEABLE CONCRETE SPECIMENS AT THE ROOM TEMPERATURE.	142
TABLE A.4 POROSITY FOR GA PERMEABLE CONCRETE SPECIMENS AFTER STORING THEM IN THE OVEN .....	143
TABLE A.5 POROSITY FOR GB PERMEABLE CONCRETE SPECIMENS AFTER STORING THEM IN THE OVEN .....	144
TABLE A.6 POROSITY FOR GC PERMEABLE CONCRETE SPECIMENS AFTER STORING THEM IN THE OVEN .....	145

## **APPENDIX B**

TABLE B.1 PERMEABILITY OF GA PERMEABLE CONCRETE SPECIMENS .....	146
TABLE B.2 PERMEABILITY OF GB PERMEABLE CONCRETE SPECIMENS .....	147
TABLE B.3 PERMEABILITY OF GC PERMEABLE CONCRETE SPECIMENS .....	148

## **APPENDIX C**

TABLE C.1 COMPRESSIVE STRENGTH, CORRESPONDING STRAIN, MODULUS OF ELASTICITY AND DENSITIES VALUES OF THE PERMEABLE CONCRETE SPECIMENS .....	149
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## LIST OF SYMBOLS

$P$	<i>Porosity ratio</i>
$M_{dry}$	<i>Oven dry weigh</i>
$M_{sub}$	<i>Submerged weigh</i>
$V_T$	<i>Total volume</i>
$\rho_w$	<i>Density of water</i>
$P_c$	<i>Correct porosity in the site</i>
$P_i$	<i>Porosity in the site</i>
$D_a$	<i>Maximum aggregate size</i>
$D_c$	<i>Core diameter</i>
$P_{min}$	<i>Minimum porosity</i>
$P_{max}$	<i>Maximum porosity</i>
$K$	<i>Permeability coefficient</i>
$a$	<i>Cross-section area of the cylinder pipe</i>
$A$	<i>Cross-section area of the specimen</i>
$L$	<i>Length of the specimens</i>
$t$	<i>Time for water to pass from level <math>h_1</math> to <math>h_2</math></i>
$h_1$	<i>Initial water level (290mm)</i>
$h_2$	<i>Final water level (70mm)</i>
$E_{itsg}$	<i>MOE for the strain gauge</i>
$E_{itp}$	<i>MOE for the platen-to-platen</i>
$E_{it}$	<i>Initial tangent modulus of elasticity</i>
$E_o$	<i>Secant modulus of elasticity at peak stress</i>
$\beta$	<i>Material parameter</i>
$f_c$	<i>Concrete stress</i>
$f'_c$	<i>Maximum stress</i>
$\varepsilon_{max}$	<i>Concrete strain when concrete stress is equal to <math>0.5 f'_c</math> on the descending part of the stress-strain curve</i>
$\varepsilon$	<i>Concrete strain</i>
$\varepsilon_d$	<i>Strain corresponds to a stress value of <math>0.3 f'_c</math> in the descending part of the stress-strain curve</i>
$\varepsilon_o$	<i>Corresponding strain at maximum stress</i>
$\lambda$	<i>Power transformation</i>
$d_n$	<i>Number averaged pore size</i>
$\phi_A$	<i>Area fraction of pores</i>
$d_{MFS}$	<i>Mean free spacing of pores</i>
$S_p$	<i>Specific surface area of pores</i>



$\Gamma_{3D}$	<i>Three-dimensional of pore distribution density</i>
$\alpha_0, \alpha_1, \alpha_2$	<i>Parameters</i>
$\rho$	<i>Dry unit weight</i>
$n$	<i>Parameters</i>
$P_{area}\%$	<i>Percentage of the pore area</i>
$A_p$	<i>Total cross-section pores in the specific part of the specimen</i>
$A_t$	<i>Total cross-sectional area of the specific part of the specimen</i>