

THE IN-PLANE FAILURE OF  
BRICKWORK

BY

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## PREFACE

This thesis is the result of a three-year research work for the degree of doctor of philosophy in the Department of Civil Engineering and Building Science, University of Edinburgh since October 1977.

During this period three papers have been accepted for publication. The titles are as follows:

1. "The In-plane Failure of Masonry - An Overview"  
Co-authors A.W. Page and A.W. Hendry, A paper to be presented for the "Seventh International Symposium on Load Bearing Brickwork", November 1980.
2.  "Strength of Brickwork Under Biaxial Stresses" Co-author A.W. Hendry, A paper to be presented for the "Seventh International Symposium on Load Bearing Brickwork", November 1980.
3. "On the Failure of Masonry Shear Walls" Co-authors A.W. Page and A.W. Hendry, International Journal of Masonry Construction, June 1980, Vol. 1, No. 2.

It is declared that the thesis has been composed by the author himself, and all the work and results in the thesis have been carried out and achieved solely by him under the supervision of Professor A.W. Hendry, unless otherwise stated.

Edinburgh, September 1980

*UOM Verified Signature*

W. Samarasinghe

This thesis presents the results of an experimental investigation into the strength of brickwork under biaxial tension-compression. Since there is insufficient experimental evidence available on the strength of brickwork under biaxial stress to explain the behaviour of brick masonry walls under in-plane loads, experiments were carried out on one-sixth scale model brickwork panels under uniform stress conditions. An idealized failure surface is suggested based on experimental results, and the effect of shear bond strength and tensile bond strength on the results is discussed.

An iterative plane stress finite element computer programme incorporating the above information is used to simulate the in-plane behaviour of brickwork. Brickwork is treated as an elastic, isotropic material with limited capacity when stressed in a state of biaxial tension-compression. The model reproduces the non-linear behaviour of masonry produced by progressive cracking. Shear wall tests have been used to test the validity of the analytical model. Sensitivity analysis of the elastic constants used in the model are performed to illustrate their influence on the calculated stresses.

The influence of the stress distribution on shear wall behaviour, and the derivation of a failure criterion for local failure in masonry shear walls, are described. This criterion, in terms of the vertical stress and shear stress at a point, has been derived for particular values of horizontal stress from the three dimensional surface mentioned above. The effect of the shape of the specimen, testing technique, and boundary conditions on the shear strength of masonry panels is discussed.

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CONTENTS

	<u>Page</u>
LIST OF FIGURES	(iv)
LIST OF TABLES	(vi)
NOTATION	(vii)
1. INTRODUCTION	1
2. REVIEW OF IN-PLANE BEHAVIOUR OF BRICKWORK	8
2.1 INTRODUCTION	8
2.2 ANISOTROPIC NATURE OF BRICKWORK	9
2.3 FAILURE OF MASONRY IN TERMS OF PRINCIPAL STRESSES	10
2.4 SPECIFIC CASES COVERED BY A BIAXIAL STRENGTH ENVELOPE	16
2.4.1 Failure of Masonry under Uniaxial Load Normal to the Bed Joint	16
2.4.2 Tensile Strength of Brickwork	19
2.4.3 Failure of Masonry Shear Walls	20
2.5 CONCLUSIONS	24
3. EXPERIMENTAL STUDY: MATERIAL PROPERTIES	25
3.1 INTRODUCTION	25
3.2 PROPERTIES OF BRICKS	25
3.2.1 Compressive Strength of Bricks	25
3.2.2 Tensile Strength of Bricks	26
3.2.3 Water Absorption of Bricks	29
3.3 MORTAR PROPERTIES	29
3.3.1 Compressive Strength of Mortar	31
3.4 PROPERTIES OF BRICKWORK	31
3.4.1 Scale Effect of Model Brickwork	31
3.4.2 Elastic Properties of Brickwork	32
3.5 CONCLUSIONS	38
4. EXPERIMENTAL STUDY: BRICKWORK UNDER BIAXIAL STRESSES	39
4.1 INTRODUCTION	39
4.2 TESTS ON BRICKWORK UNDER UNIFORM BIAXIAL STRESS FIELD	45
4.2.1 Construction of Walls for the Preparation of Test Specimens	45
4.2.2 Curing	46
4.2.3 Control Specimens	46
4.2.3.1 Mortar Cubes	46
4.2.3.2 Brick-Mortar Cubes	47
4.2.4 Preparation of Test Specimens	47
4.2.5 Friction Reduction Packing	49
4.2.5.1 Platen Restraint	50
4.2.5.2 Techniques Adopted in Concrete to Eliminate Platen Effect	50
4.2.5.3 Adopted Technique to Minimize the Platen Effect	51

	<u>Page</u>
4.2.6 Test Rig and Instrumentation	52
4.2.6.1 Mechanism for Tensile Load Application and Setting up of the Specimen	52
4.2.6.2 Test Set up for the Application and Measurement of Compressive Load	54
4.2.7 Uniaxial and Biaxial Tests	56
4.2.7.1 Uniaxial Tension Test	56
4.2.7.2 Biaxial Tension-Compression Test	58
4.2.7.3 Uniaxial Compression Test	60
4.2.7.4 Strain Measurement	61
4.2.8 Mode of Failure	61
4.2.8.1 Mode of Failure of Uniaxial Tension Tests	62
4.2.8.2 Mode of Failure in Uniaxial Compression Tests	63
4.2.8.3 Mode of Failure in Biaxial Tension-Compression Tests	64
4.2.9 Tests on Control Specimens	70
4.2.10 Analysis of Experimental Results	72
4.2.11 The Influence of Shear Bond Strength to Tensile Bond Strength Ratio on the Shape of the Failure Envelope	75
4.2.12 Generalizing the Failure Envelopes	80
4.2.13 A General Failure Surface for Brickwork under Uniform Biaxial Stresses	81
4.3 TESTS ON BRICKWORK UNDER NON-UNIFORM BIAxIAL STRESS	83
4.3.1 Introduction	83
4.3.2 Preparation of Specimens	86
4.3.3 Method of Load Application and Measurement	87
4.3.4 Test Procedure	87
4.3.5 Analysis of Results and Mode of Failure	89
4.4 CONCLUSIONS	92
5. A THEORETICAL MODEL FOR THE IN-PLANE BEHAVIOUR OF BRICKWORK	94
5.1 INTRODUCTION	94
5.2 REVIEW OF PREVIOUS METHODS OF ANALYSIS	95
5.3 FINITE ELEMENT METHOD	101
5.4 NON-LINEAR BEHAVIOUR OF BRICKWORK	102
5.5 THE ADOPTED FINITE ELEMENT MODEL	103
5.5.1 Displacement Function	103
5.5.2 Derivation of Element Stiffness Matrix	105
5.5.3 Structure of the Computer Programme and Operation	107
5.5.3.1 Explanation of Subroutines	108
5.6 TESTING THE VALIDITY OF FAILURE CRITERION USING THE ANALYTICAL MODEL	112
5.6.1 Idealization of Brickwalls	112
5.6.2 Analytical Results	114
5.6.3 Comparison of Analytical Results with Experimental Results	117
5.7 SENSITIVITY ANALYSIS OF THE ELASTIC CONSTANTS	112
5.8 CONCLUSIONS	125

	<u>Page</u>
6. BEHAVIOUR OF BRICK MASONRY SHEAR WALLS	127
6.1 INTRODUCTION	127
6.2 LOCAL STRESS DISTRIBUTION IN A SHEAR WALL	129
6.2.1 Local Stress Distribution for Different Geometrical Shapes of Shear Walls	130
6.2.2 The Influence of Method of Load Application and Boundary Conditions	130
6.3 REVIEW OF SHEAR WALL TESTS	136
6.3.1 Test Techniques	137
6.3.2 Shear Wall Test Results	140
6.4 INFLUENCE OF $\sigma_x$ ON $\tau$ - $\sigma_y$ CURVE AT FAILURE	143
6.4.1 $\tau$ - $\sigma_y$ Curve at Failure for Zero Value of $\sigma_x$	149
6.4.2 $\tau$ - $\sigma_y$ Curves for Different Values of $\sigma_x$	149
6.5 INFLUENCE OF SOME PARAMETERS WHICH AFFECT THE SHEAR STRENGTH	153
6.5.1 The Influence of Panel Geometry on the Shear Strength	155
6.5.2 The Influence of Method of Load Application and Boundary Conditions on the Shear Strength	158
6.6 THE VARIATION OF PRINCIPAL TENSILE STRESS AT FAILURE WITH NORMAL STRESS ( $\sigma_y$ ) IN SHEAR WALLS	162
6.7 CONCLUSIONS	167
7. SUMMARY AND CONCLUSIONS	169
7.1 SUMMARY	169
7.2 CONCLUSIONS	171
REFERENCES	175
APPENDIX A	A1
APPENDIX B	B1
APPENDIX C	C1



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LIST OF FIGURES

	<u>Page</u>	
Figure 2.1	Diagonal Tension Test	13
Figure 2.2	Biaxial Tension-Tension Failure Criterion	15
Figure 2.3	Variation of Flexural Strength with Bed Joint Angle	18
Figure 3.1	Testing of Bricks in Tension	28
Figure 3.2	Water Absorption of Bricks	30
Figure 3.3	Uniaxial Compression Test on Brickwork Panels	33
Figure 3.4	Stress-Strain Curves in Compression for Panels with Varying Bed Joint Angles	35
Figure 3.5	Horizontal-Vertical Strain Curves in Compression for Panels with Varying Bed Joint Angles	36
Figure 4.1(a)	Typical Failure Envelope for the Biaxial Strength of Concrete	41
Figure 4.1(b)	Khoo-Hendry Biaxial Strength Envelope for Brick	42
Figure 4.1(c)	Biaxial Strength Envelope for Grouted Concrete Masonry	42
Figure 4.2	Typical Shape of Brick-Mortar Cube	48
Figure 4.3	A Wall Panel Before Saw Cut and a Saw Cut Specimen	48
Figure 4.4	Pin-Joint Mechanism for Tensile Load Application	53
Figure 4.5	Glueing the Tensile Blocks to Test Specimen	53
Figure 4.6	Uniaxial Tension Test on Brickwork	55
Figure 4.7	Test Rig for Application of Compression on Specimens Under Biaxial Stresses	55
Figure 4.8	Tests on Brickwork with Varying Bed Joint Orientation	57
Figure 4.9	Biaxial Tension-Compression Test	59
Figure 4.10	Stresses on an Element on Bed and Perpend Joints	66
Figure 4.11	Variation of Normal Stress at Bed and Perpend Joints with Varying ( $f_c/f_t$ ) Ratio	68
Figure 4.12	Tension Test on Brick-Mortar Cubes	71
Figure 4.13	Biaxial Strength Curves for Brick Panels for Different Bed Joint Orientations	73
Figure 4.14	Biaxial Strength Curves	76
Figure 4.15	Failure Criterion for Joint Failure	76
Figure 4.16	Influence of $\tau_0/t_0$ Ratio on the Biaxial Strength at Low Compression ( $\theta = 45^\circ$ )	79
Figure 4.17	Influence of $\tau_0/t_0$ Ratio on the Biaxial Strength at Low Compression ( $\theta = 67.5^\circ$ )	79
Figure 4.18	Idealized Biaxial Strength Curves for Brickwork	82
Figure 4.19	Failure Surface for Brickwork Under Biaxial Stresses	84
Figure 4.20	Shear Wall Test	88
Figure 4.21	Average Shear Stress vs. Normal Stress at Failure for Shear Walls.	91

	<u>Page</u>	
Figure 5.1	Typical Finite Element Subdivision	104
Figure 5.2	Flow Diagram of the Computer Model	109
Figure 5.3	An Idealized Shear wall for Analysis	113
Figure 5.4	Crack Propagation in Shear Walls	115
Figure 5.5	A Probable Failure Surface for Brickwork Under Biaxial Compression	118
Figure 5.6	Shear Stress- Normal Stress Envelopes for Shear Walls	119
Figure 5.7	Predicted and Experimental Crack Patterns for Shear Walls	121
Figure 5.8	A Brickwall Under Racking Shear and Compression. (A diagram refers to table 5.1 and 5.2)	123
Figure 6.1	Influence of Panel Geometry on the Stress Distribution in Shear Walls	131
Figure 6.2	Shear Test Specimens Under Different Load Conditions	133
Figure 6.3	Influence of the Test Technique on the Stress Distribution on Shear Walls	135
Figure 6.4	Test Techniques for the Determination of "Masonry" Shear Strength	138
Figure 6.5	Shear Wall Test Results Presented by Different Investigators	141
Figure 6.6	The Stresses on a Small Element in a Shear Wall	144
Figure 6.7	Failure Criterion for Brick Masonry in Terms of $\tau$ and $\sigma_y$ ( $\sigma_x = 0.0$ )	147
Figure 6.8	Failure Criterion for Brick Masonry in Terms of $\tau$ and $\sigma_y$ ( $\sigma_x = 0.0$ ) - Enlarged scale	148
Figure 6.9	$\tau$ - $\sigma_y$ Interaction for Different Values of $\theta$	151
Figure 6.10	$\tau$ - $\sigma_y$ Failure Criterion for Varying Values of $\sigma_x$	152
Figure 6.11	Predicted Failure Modes for Shear Walls Having Different Wall Lengths	156
Figure 6.12	Variation of Shear Strength with Panel Geometry ( $\sigma_n = 1.0 \text{ N/mm}^2$ )	157
Figure 6.13	Predicted Failure Modes for Shear Wall Specimens Subjected to Different Loading Techniques	160
Figure 6.14	Determination of Diagonal Tensile Strength of Brickwork	163
Figure 6.15	Interaction Between Principal Diagonal Tension and Vertical Stress	165
Figure 6.16	Interaction Between Principal Diagonal Tension and Vertical Stress (Enlarged scale)	166

LIST OF TABLES

		<u>Page</u>
TABLE 3.1	Dimensions of Bricks	26
TABLE 3.2	Physical Properties of Bricks	27
TABLE 3.3	Elastic Modulus and Poisson's Ratio for Brickwork	37
TABLE 3.4	Elastic Modulus and Poisson's Ratio for Brickwork. (Chinwah's Results)	37
TABLE 4.1	The Values of $f_c/f_t$ Ratios at which the Normal Stress at Bed and Perpend Joints Equal to Zero	67
TABLE 5.1	Calculated Stresses Along XX* in a Shear Wall for Different Values of Elastic Modulus	123
TABLE 5.2	Calculated Stresses Along XX* in a Shear Wall for Different Values of Poisson's Ratio	124
TABLE 6.1	Critical Stresses for Different Test Techniques	161
TABLE 6.2	Average Stresses at Initiation of Failure Under Different Loading Techniques	161



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## NOTATIONS

Each symbol used in the text is explained where it first appears. However, a summary of frequently used symbols is also presented below for convenience.

Note: (1) The following general terminology has been adopted:

{ } denotes a column vector

[ ] denotes a row vector, or rectangular or square matrix

[ ]<sup>T</sup> denotes the transpose of a matrix or a column vector.



(2) The notation adopted in the computer programme is listed in Appendix D.  
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$\sigma_1$	Major principal stress
$\sigma_2$	Minor principal stress
$\sigma_t$	Principal tensile stress at failure
$\sigma_n$	Average compressive stress at the brick-mortar interface
$\sigma_N$	Stress normal to the brick-mortar interface
$\sigma_{NB}$	Normal stress at the bed joints
$\sigma_{NP}$	Normal stress at the perpend joints
$\sigma_x, \sigma_y$	Local stresses parallel to x and y directions (parallel to bed joints and perpendicular to bed joints respectively)
$\tau_0$	Initial shear bond strength at the brick-mortar interface
$\tau$	Local shear stress
$\tau_{av}$	Average shear stress at the brick-mortar interface
$t_0$	Tensile bond strength at the brick-mortar interface
$\theta$	Direction of $\sigma_1$ relative to the bed joint direction
$f_c$	Principal compressive stress
$f_t$	Principal tensile stress
$f_m$	Compressive strength of masonry
$f_{td}$	Diagonal tensile strength of brickwork
$f_{bt}$	Flexural tensile strength of brick unit

$\mu$	Coefficient of friction
$\bar{X}$	mean
S.D.	Standard deviation
C. of V.	Coefficient of variation
$u, v,$	Displacements in x and y directions
$2a, 2b$	Rectangular element length and height respectively
{c}	Displacement function coefficients
{t}	Element displacements
[Z]	Transformation relating displacement function coefficients to element displacements
$[Z]_n$	Transformation relating nodal displacement function coefficients
{n}	Nodal displacements for an element
[P]	Transformation relating nodal and element displacements
{ $\epsilon$ }	Element strains
$\epsilon_x, \epsilon_y, \epsilon_{xy}$	Strain in x and y directions and shear strain
[s]	Transformation relating element strains to element displacements
[B]	Transformation relating strains and nodal displacements
[D]	Constitute strain-stress matrix
E	Elastic Modulus
$\nu$	Poisson's Ratio
{ $\sigma$ }	Element stress
{f}	Nodal forces
[K]	Element stiffness matrix
[k]	Structure stiffness matrix
W	Load applied normal to the bed joints for shear walls
P	Shearing load applied for shear walls
$\alpha$	$\tan^{-1}(W/P)$