THE IN-PLANE DEFORMATION AND FAILURE OF BRICKWORK

by

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CERTIFICATE

I hereby certify that the work embodied in this thesis is the result of original research and has not been submitted for a higher degree to any other

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ABSTRACT

This thesis presents a method for the simulation of the in-plane behaviour of brickwork using the finite element technique. The proposed finite element model reproduces the non-linear characteristics of brickwork caused by material non-linearity and progressive joint failure. Brickwork is considered as an assemblage of elastic brick continuum elementsacting in conjunction with linkage elements simulating the mortar joints. The joint elements are assumed to have high compressive strength, (with non-linear deformation characteristics), low tensile strength, and limited shear capacity depending upon the bond strength and degree of of compression present.

The material properties for this model are determined from uniaxial tests on bricks,and panels and couplets of brickwork. Tests on a restrained brickwork deep beam and a simply supported,composite wall-beam panel are used as a basis for comparison between predicted theory and experimental evidence. To reduce the required capacity of testing equipment, all brickwork tests are performed at half scale. An investigation of possible scale effects is also carried out.

Sensitivity analyses of the critical parameters influencing brickwork behaviour are performed to illustrate the potential of the model for use as both a research tool and an aid to design.

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NOTATION

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

{ } denotes a column vector

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

$[\ ]^T$ denotes the transpose of a matrix or column vector.

(2) The notation adopted in the computer program is listed in Appendix G.

{a}	Displacement function coefficients
A	Cross-sectional area of axial linkage element
[B]	Transformation relating strains and nodal displacements
2a, 2b	Rectangular element length and height respectively
C	Joint cohesion (shear bond strength)
[C]	Constitutive stress-strain matrix
[D]	Constitutive strain-stress matrix
{d}	Nodal displacements for an element
E	Modulus of elasticity
E_{bp}	Modulus of elasticity of brick loaded parallel to bed joint
E_{bn}	Modulus of elasticity of brick loaded normal to bed joint
E_b	Average modulus of elasticity of brick
E'	Tangent modulus of elasticity
{f}	Nodal forces for an element
{F}	Nodal forces for the structure
G_b	Averaged shear modulus of brick
G'	Tangent shear modulus of mortar
[k]	Element stiffness matrix
[K]	Structure stiffness matrix
L	Element length

L_b	Total brick thickness in a measured gauge length
L_m	Total mortar thickness in a measured gauge length
L_t	Total gauge length
$\{m\}$	Element displacements
$[N]$	Transformation relating nodal and element displacements
NB	Half bandwidth of structure stiffness matrix
$\{P\}$	Body forces for initial stress correction
s, n	Shear and normal displacement of a joint element
$[S]$	Transformation relating element strains to element displacements
T	Wall thickness
t_b	Brick thickness (i.e. vertical distance between bed joints)
t_m	Joint thickness
u,v,w	Displacements in x, y and z directions
$[Z]$	Transformation relating displacement function coefficients to element displacements
$[Z_N]$	Transformation relating nodal and displacement function coefficients
α_1 to α_8	Displacement function coefficients
β_1 to β_4	Displacement function coefficients
$\gamma_{xy}, \gamma_{yx}, \gamma_{zx}$	Components of shear strain
γ_b	Shear strain in brick
γ_m	Shear strain in mortar
γ_t	Total shear strain in brick and mortar
Δ_b	Brick deformation
Δ_m	Mortar deformation
Δ_t	Total deformation
$\{\delta\}$	Nodal displacements for the structure
$\{\varepsilon\}$	Element strains
$\{\varepsilon_o\}$	Initial strains for an element

$\varepsilon_x, \varepsilon_y, \varepsilon_z$	Components of normal strain
ε_b	Brick strain
ε_m	Mortar strain
ε_t	Total strain
θ	Angle of bed joint inclination to the applied load
ν	Poisson's ratio
π	Total potential energy
σ_1, σ_2	Maximum and minimum principal stresses
$\sigma_x, \sigma_y, \sigma_z$	Components of noraml stress
σ_n	Normal stress on mortar joint
σ_{nu}	Ultimate normal stress on mortar joint
$\{\sigma\}$	Element stresses
$\{\sigma_o\}$	Initial stresses for the element
τ	Shear stress on mortar joint
τ_u	Ultimate shear stress on mortar joint
$\tau_{xy}, \tau_{yz}, \tau_{zx}$	Components of shear stress
ϕ	Angle between bed joint and measured gauge length
$\{\phi\}$	Surface tractions for an element