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LABORATORY EVALUATION AND MODELLING OF SHEAR STRENGTH OF INFILLED JOINTS UNDER CONSTANT NORMAL STIFFNESS (CNS) CONDITIONS

A thesis submitted
in fulfillment of the requirements for the award of the degree

UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

DOCTOR OF PHILOSOPHY

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THESIS CERTIFICATION

I, H.Senaka Welideniya, declare that this thesis, submitted in fulfilment of the requirements for the award of Doctor of Philosophy, in the Department of Civil, Mining and Environmental Engineering, Faculty of Engineering, University of Wollongong, is wholly my own work unless otherwise referenced or acknowledged. The document has not been submitted for qualification at any other academic institution.

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RELATED PUBLICATIONS

Indraratna, B., Welideniya, H.S. and Brown, E.T. (2004).A Shear Strength Model for Idealised Infilled Joints under Constant Normal Stiffness (CNS), *Geotechnique* (accepted for publication in 2005 issue of *Geotechnique*).

Welideniya H.S. & Buddhima Indraratna (2004). The impact of joint orientation and the confining stress on the shear behaviour of graphite infilled joints. *The 9th Australia New Zealand Conference on Geomechanics, Auckland, New Zealand*, pp. 253-259.

Indraratna, B. and Welideniya, H.S. (2003). Shear behaviour of graphite infilled joints based on Constant Normal Stiffness (CNS) test conditions. *Proc. 10th Congr., Int. Soc. Rock Mech. – Technology roadmap for rock mechanics, Johannesburg*, Vol. 1, pp. 569-574.

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ABSTRACT

Infill materials found in natural rock joints may cause a reduction in joint shear strength, influencing rock mass stability. The shear strength of rock mass, already reduced by these discontinuities, will further diminish if they are filled with sediments, thereby posing significant concerns for any construction or excavation carried out in rock. These concerns invite accurate quantification of the shear strength of infilled joints and proper understanding of the basic mechanics of discontinua and the principles involved in their shear deformation. The practical application of any models developed through such studies will be of immense help to mining, tunnelling, and all other underground construction works. The geotechnical research work carried out by the University of Wollongong in the late 90's included infilled joint modelling using hyperbolic techniques. A new shear strength model was developed in these studies for predicting unfilled and infilled joint strength based on the Fourier transform method, energy balance principle and the hyperbolic stress-strain simulation.

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Taking into account the field conditions frequently encountered, the diversity observed in joint shear response and the occasional inadequacy of data (for the estimation of Fourier coefficients and the hyperbolic constants), this study was undertaken to develop a semi-empirical methodology for predicting the shear strength of infilled joints. In this research study joint shear behaviour was studied under CNS and CNL conditions and also the effect of joint orientation and confinement. The study aimed to develop a methodology which includes joint surface characteristics, joint properties, and infill materials. A new model for predicting the shear strength of infilled joints based on a series of tests carried out on two types of model joint surfaces (with asperity angles of 9.5^0 and 18.5^0) is presented. Graphite, bentonite and clayey sand were used as infill materials. All tests were carried out in a large-scale shear apparatus under constant normal stiffness (CNS) conditions. The results indicate that at low infill thickness to asperity height ratio (t/a), the combined effect of the basic friction angle (φ_b) and the joint asperity angle (i) is pronounced, but diminishes with increasing t/a ratio so that the shear strength converges towards the infill alone. This decrease in shear strength with increasing t/a ratio is represented in a normalised manner by dividing the peak shear stress by the corresponding normal stress. Summation of two algebraic functions (*A* and *B*) that represent the joint and infill characteristics, correctly model the decay of normalised shear strength with increasing t/a ratio. The new model successfully describes the shear strength of the graphite, clay (bentonite) and clayey sand filled model joints.

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NOTATION

a	asperity height
a, b	integration intervals
a_o, a_n, b_n	Fourier coefficients
A_j	joint surface area
h	shear displacement
i	initial asperity angle
$i(h)$	angle of the tangent drawn at any distance on the dilation curve
k_n	constant normal stiffness
n	harmonic numbers
NSD	normalised strength drop
t	infill thickness
T	period of Fourier series for $\Delta\sigma_n$
$(t/a)_{crit}$	critical infill thickness to asperity height
p, q	hyperbolic constants
σ_{no}	initial normal stress
δ_p	horizontal displacement corresponding to peak shear stress
δ_{vh}	dilation at any shear displacement, h
σ_{nh}	normal stress at any shear displacement, h
$\Delta\tau_p$	change in peak shear stress
$\Delta\sigma_n$	change in normal stress
$(\tau_p)_{infilled}$	peak shear stress of infilled joint
$(\tau_p)_{clean}$	peak shear stress of clean joint
τ_h	shear stress at any shear displacement, h
ϕ_b	basic friction angle of joint
φ_{fill}	peak friction angle of infill
A and B	components of the new proposed shear strength model
κ	$(t/a)/(t/a)_{cr}$ ratio
α, β	empirical coefficients defining the shape of functions A and B, respectively.

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