A COMPUTATIONAL STUDY ON MULTIPLE PERFORATED HOLLOW CIRCULAR SECTION

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UNIVERSITI SAINS MALAYSIA

2017

A COMPUTATIONAL STUDY ON MULTIPLE PERFORATED HOLLOW CIRCULAR SECTION

by

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Thesis submitted in fulfillment of the requirements for the degree of Doctor of Philosophy

June 2017

ACKNOWLEDGEMENTS

First of all, I would like to express my gratitude to my supervisor, Associate Professor Dr. Choong Kok Keong, for his guidance and motivation throughout this study. His guidance and incisive advice have inspired me to generate fruitful approaches in achieving the objectives in this research. Without his effort, I would not able to proceed and bring this research to a completion.

My heartfelt gratitude is extended to my beloved family that supports me unlimitedly all along without any hesitation. I truly treasure their encouragement and moral support throughout these years. May they always be blessed with the merits of triple gems.

Last but not the least, my sincere thanks and regards to all the technicians and administrative staffs in School of Civil Engineering, my colleagues and friends for their unlimited support and hard work. Their helpful and insightful assistance in any form has brought my life journey to a higher level of wisdom and consciousness.

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AR	Array pattern
C	Circular perforation shape
CNC	Computerized numerical control
EG	Elongated perforation shape
EL	Elliptical perforation shape
ELT	Equilateral triangle arrangement pattern
FN	Fix number approach
FS	Fix size approach
HL	Helical pattern
LFO	Load flow orientation
LVDT	Linear Variable Differential Transducer
PST	Principal stress trajectory
RB	Strain rosette installed at physical model's bottom surface
RB1	Strain rosette installed at physical model's bottom surface – component 1
RB2	Strain rosette installed at physical model's bottom surface – component 2
RB3	Strain rosette installed at physical model's bottom surface – component 3
RIT	Right isosceles triangle arrangement pattern
RT	Strain rosette installed at physical model's top surface
RT1	Strain rosette installed at physical model's top surface – component 1
RT2	Strain rosette installed at physical model's top surface – component 2
RT3	Strain rosette installed at physical model's top surface – component 3
SGD	Strain gauge installed at diagonal (45° to physical model's longitudinal axis) direction
SGV	Strain gauge installed parallel to physical model's longitudinal direction

LIST OF SYMBOLS

A	Effective cross sectional area
a	Half of the larger dimension for 'elongated' shape
α_t	Local load flow orientation in the resolved t direction
α_z	Local load flow orientation in the resolved z direction
b	Half of the smaller dimension for 'elongated' shape
b^*	Helix pitch coefficient for right hand helix
b^{-*}	Helix pitch coefficient for left hand helix
β	Angle measured between two perforations along circumference
β_p	Angle of major principal plane to local t-axis
γ	Right hand helix slope
γ^*	Left hand helix slope
γ_{tz}	Shear strain
D	Diameter of model
D_t	Displacement in tangential axis
D_z	Displacement in longitudinal axis
d	Total numbers of helix duplication along circumference direction
δ	Axial displacement
E	Modulus of elasticity
ε_I	Strain value for strain component I in strain rosette
ε_{II}	Strain value for strain component II in strain rosette
ε_{III}	Strain value for strain component III in strain rosette
ε_{p1}	Major principal strain
ε_{p2}	Minor principal strain
ε_t	Normal strain in t direction
ε_z	Normal strain in z direction
F	Force recorded under compression load
F_{ref}	Force at yield stress for control model under compression load
H	Total height of model
H_{cl}	Horizontal clearance between perforations for array models
I	Moment of inertia

J	Polar moment of inertia
K	Distance between center of perforations along left hand helix
K_{cl}	Clear distance between perforations along left hand helix
κ	Angle of right hand helix to tangential axis
Λ	Distance between center of perforations along right hand helix
Λ_{cl}	Clear distance between perforations along right hand helix
λ	Angle of left hand helix to tangential axis
M	Distance between center of perforations along circumference
M_{cl}	Clear distance between perforations along circumference
μ	Angle between left and right hand helices
m	Numbers of layers of perforations along longitudinal axis
NE	Equivalent (von Mises) stress resultant
N_{maj}	Major principal stress resultant
N_{min}	Minor principal stress resultant
N_t	Stress resultant component in tangential axis
N_{tz}	Shear stress resultant in t-z plane
N_z	Stress resultant component in longitudinal axis
n	Numbers of perforations along circumference direction
p	Total number of perforations along a single helix line
R	Radius of model
σ_y	Material yield strength
t	Thickness of model
θ	Rotational angle of right hand helix
θ_I	Angle of strain component I to horizontal axis
θ_{II}	Angle of strain component II to horizontal axis
θ_{III}	Angle of strain component III to horizontal axis
V_{cl}	Vertical clearance between perforations for array models
ν	Poisson's ratio

KAJIAN PENGIRAAN KE ATAS KERATAN BULATAN BERONGGA YANG BERLIANG BERBILANG

ABSTRAK

Berasal dari kekurangan dalam kajian mengenai kesan liang berbilang, serta kekurangan kepelbagaian dalam parameter liang berbilang dalam kajian lepas, kajian ini bertujuan untuk mengkaji kemungkinan idea keratan bulatan berongga berliang berbilang yang meniru geometri dan corak tebukan yang dijumpai di permukaan rangka kaktus Cholla (sejenis kaktus yang dijumpai di padang pasir panas Barat Daya Amerika). Kesan parameter liang ke atas tingkah laku struktur, dan mekanisma pemindahan beban dalam keratan berongga berliang berbilang telah disiasat secara meluas melalui analisis unsur terhingga. Analisa telah dijalankan di bawah kes beban mampatan, lenturan dan kilasan. Parameter liang yang disiasat adalah: bentuk dan orientasi, peratusan tebukan, nisbah aspek, corak susunan global, sudut kecondongan heliks yang terbentuk di antara liang, dan kelegaan di antara liang berjiranan. Model dengan corak jajaran menunjukkan prestasi yang lebih baik daripada model dengan corak heliks di bawah kes beban mampatan dan lenturan, dan ia adalah sebaliknya untuk kes beban kilasan. Antara variasi corak heliks, corak segi tiga sama sisi menunjukkan prestasi terbaik di bawah kes beban mampatan dan lenturan. Sebaliknya, corak segi tiga sama kaki kanan menghasilkan prestasi terbaik di bawah kes beban kilasan. Bentuk elips dengan paksi utamanya selari dengan paksi membujur model memaparkan prestasi terbaik di bawah kes beban mampatan dan lenturan; manakala bentuk bulat menghasilkan prestasi terbaik untuk kes beban kilasan. Nisbah aspek yang disyorkan untuk bentuk elips bergantung kepada susunan liang dan jenis beban. Had atas untuk peratusan tebukan adalah disyorkan sebagai 30%

untuk membolehkan tindak balas struktur kekal dalam keadaan lelurus. Merujuk kepada analisa ke atas garis trajektori tegasan prinsipal (PST), didapati sudut kecenderungan relatif lebih kecil pada kawasan selepas liang menunjukkan berlakunya halangan aliran beban yang kurang teruk. Model yang berprestasi lebih baik adalah berkait dengan model yang mempunyai keluasan kawasan di mana garis PST tidak dapat condong kembali ke jajaran asal, yang lebih kecil. Model dengan pusaran (didapati dalam gambarajah PST) dan edaran semula aliran beban (didapati dalam gambarajah orientasi aliran beban) dengan bentuk yang lebih lancar, dan saiz yang lebih kecil sepadan dengan model yang mengalami halangan aliran beban kurang teruk. Penemuan daripada kajian ini menunjukkan bahawa idea keratan bulatan berongga berliang berbilang yang novel dan ringan boleh digunapakai dari segi struktur dan boleh diterokai lagi untuk kegunaan praktikal.

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ABSTRACT

Originated from the insufficiency in the studies on effect of multiple perforations, and lack of variability in multiple perforation parameters in the available past studies, this study studied the feasibility of the idea of multiple perforated circular hollow section mimicking the geometry and pattern of perforations found on the surface of Cholla cactus (a cacti genus found in hot deserts of American Southwest) skeleton. Effect of perforation parameters on the structural behaviour of the section, the mechanism of load transfer affected by the perforations, and the load carrying capacity of multiple perforated hollow section were extensively investigated by means of finite element analysis. Analysis was carried out under compression, flexural and torsional load cases. The perforation parameters investigated are: shapes and orientations, percentage of perforations, aspect ratios, global arrangement patterns, inclination angles of helices formed where perforations are located, and clearances between neighbouring perforations. Models with perforations arranged in array pattern are found to perform better under compression and flexural load cases. Models with helical pattern perform better under torsional load case. Among models with perforations arranged in helical patterns, equilateral triangle pattern produces the best performance under compression and flexural load cases. On the contrary, right isosceles triangle pattern produces the best performance under torsional load case. Elliptical shape perforation with its larger axis parallel to the longitudinal axis of model produces best performance under compression and flexural load cases, while circular shape produces best performance under torsional load case. The recommended aspect ratios for elliptical shape depend on the perforation arrangement and load case. The upper limit of percentage of perforations for multiple perforated models is recommended as 30%, beyond which the relationship between structural responses and percentage of perforations ceases to be linear. Based on the analysis of principal stress trajectory (PST) lines, it is found that smaller relative inclination of PST lines at regions after perforations shows less severe load flow obstruction. Models showing better performance are associated with those having smaller size of the regions where PST lines are unable to tilt back to original alignment. It is found that models which produce eddies (in PST diagrams) and load flow recirculations (in load flow orientation diagrams) with smoother shape and smaller size are associated to models experiencing less severe load flow obstruction. Findings from this study indicates that the idea of novel and lightweight multiple perforated hollow circular section is structurally feasible and could be explored further for practical usage.