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**THE OPTIMUM REINFORCEMENT ARRANGEMENTS FOR
CONCRETE PILE CAPS**

Mr. Luck Siridanupath

**A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering
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Concrete Pile Caps**
By **Mr. Luck Siridanupath**
Department **Civil Engineering**
Thesis Advisor **Assistant Professor Karoon Chandrangsu, Ph.D.**

Accepted by the Graduate School, Chulalongkorn University
in partial fulfillment of the requirements for the Master's degree

S. Bunnag
.....Dean of Graduate School
(Associate Professor Supradit Bunnag, Ph.D.)

Thesis Committee

V. Chovichien
.....Chairman
(Associate Professor Vinit Chovichien, Ph.D.)

Karoon Chandrangsu
.....Member
(Assistant Professor Karoon Chandrangsu, Ph.D.)

Suthum Suriyamongkol
.....Member
(Assistant Professor Suthum Suriyamongkol, Ph.D.)

Thaksin Thepchatri
.....Member
(Assistant Professor Thaksin Thepchatri, Ph.D.)

หัวข้อวิทยานิพนธ์	การจัดแบบเหล็กเสริมที่ดีที่สุด สำหรับฐานรากบนเสาเข็ม
ชื่อนิสิต	นายลักษณะ ศิริदानุภัทร
อาจารย์ที่ปรึกษา	ผู้ช่วยศาสตราจารย์ ดร.การณ จันทรางศุ
ภาควิชา	วิศวกรรมโยธา
ปีการศึกษา	๒๕๒๒



บทคัดย่อ

ในงานวิจัยนี้เพื่อศึกษาถึงผลของการจัดแบบเหล็กเสริมที่มีต่อประสิทธิภาพในการรับน้ำหนักของโครงสร้าง โดยเฉพาะฐานรากบนเสาเข็มซึ่งต้องการความแข็งแรง และความปลอดภัย ดังนั้นจึงต้องมีการวิเคราะห์ และทดสอบหาพฤติกรรมที่เกิดขึ้นจริงในการรับน้ำหนักของฐานราก ในการวิเคราะห์การกระจายของหน่วยแรงภายในฐานรากบนเสาเข็ม ที่เกิดขึ้นเนื่องจากแรงร่วม-ศูนย์จากเสา และแรงปฏิกิริยาจากเสาเข็ม ได้อาศัยการคำนวณโดยโปรแกรมคอมพิวเตอร์ ด้วยวิธีการไฟไนท์เอลเมนต์ พบว่ารูปแบบของการกระจายหน่วยแรงภายในฐานราก เป็นรูปแบบของโครงข้อหมุน ๓ มิติ โดยแรงกดจากเสาจะถ่ายโดยตรงสู่เสาเข็ม ในการทดลอง ใช้แบบจำลอง ๑ ใน ๓ ของขนาดจริง โดยวิธีการวิเคราะห์แบบจำลองจะสามารถคำนวณการจัดเหล็กเสริมแบบต่างๆโดยคำนึงถึงการกระจายแรงภายในฐานรากดังกล่าวได้ ผลจากการทดลองใช้ในการเปรียบเทียบหาแบบเหล็กเสริมที่ดีที่สุด โดยพิจารณาจากพฤติกรรมทางโครงสร้าง เช่น ความสัมพันธ์ระหว่างแรงกระทำกับการโก่งตัวของฐานราก ลักษณะการแตกร้าว ลักษณะการบิด และความสัมพันธ์ระหว่างแรงกระทำกับอัตราส่วนการยืดหดของเหล็กเสริมและคอนกรีต การวิเคราะห์ให้ข้อสรุปว่า การจัดแบบเหล็กเสริมต่างๆกันมีผลต่อพฤติกรรมทางโครงสร้างดังกล่าว และการจัดแบบเหล็กเสริมลักษณะโครงข้อหมุนดีที่สุด

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Name Mr. Luck Siridanupath
Thesis Advisor Assistant Professor Karoon Chandrangsou, Ph.D.
Department Civil Engineering
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ABSTRACT

The distribution of stress within a pile cap which subjected to column load and pile reactions was obtained by a standard three dimensional stress analysis computer program based on the Finite Element Method. The results showed that the distribution of principal stress trajectories is in the form analogous to a system of truss structure. In the experimental program, one-third scale models of pile caps with different reinforcement arrangements conforming to truss analogy and conventional beam analogy were constructed and tested to failure. Comparison of structural performance, cracking pattern, mode of failure, and strength between these models were carefully observed. It can be concluded that the reinforcement arrangements have a considerable influence on structural efficiency and the most efficient reinforcement arrangement in pile cap should be in a form of truss analogy.

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LIST OF SYMBOLS

A_s	=	total area of tensile reinforcement
a	=	depth of stress block in concrete for ultimate strength design of beam
b	=	width of pile cap
c	=	width of a square column
d	=	effective depth of the pile cap measured from the extreme compression fiber to the centroid of the tensile reinforcement
E_c	=	modulus of elasticity of concrete
E_s	=	modulus of elasticity of steel
f_c	=	allowable compressive strength of concrete
f'_c	=	ultimate compressive strength of concrete
f_r	=	modulus of rupture of concrete
f_s	=	allowable tensile stress of steel
f_y	=	yield strength of steel
f_u	=	ultimate strength of steel
g	=	shear span, distance between inner face of support to face of column
h	=	thickness of pile cap
h_p	=	width of support
I_g	=	moment of inertia of gross concrete section about the centroidal axis, neglecting the reinforcement
j	=	ratio of distance between the centroid of compression and centroid of tension to the effective depth

k	=	spacing factor of piles
L	=	center to center distance between piles
M	=	maximum bending moment at the section being considered
M_{cr}	=	cracking moment at the section being considered
M_u	=	ultimate moment at the section being considered
n	=	modular ratio of the elasticity of steel to that of concrete
P	=	total column load
P_{cr}	=	cracking load of pile cap
P_u	=	ultimate load of pile cap
p	=	uniformly distributed load of column
q_p	=	uniformly distributed reaction of pile
r, s, t	=	local coordinates at centroid of a finite element
T	=	total tie-tension in pile cap
u	=	allowable bond stress in concrete
V	=	shear force at the section being considered
v	=	allowable shearing stress in concrete for peripheral shear
v_c	=	allowable shearing stress in concrete without web reinforcement
X, Y, Z	=	global coordinates in finite element structure
Σ_o	=	total perimeter requirement of tensile reinforcement
e_c, e_{ct}	=	strain in concrete subjected to compression and tension respectively
e_y	=	strain at yielding in steel
σ_y, σ_{yz}	=	horizontal stress and vertical shearing stress in concrete at section being considered