ผลของการเร่งอายุทางกายภาพต่อสมบัติเชิงกลของผลิตภัณฑ์ประกอบแต่งอีพอกซีเสริมแรงด้วยเส้นใยสำหรับการซ่อมแซมและเสริมความแข็งแรงของโครงสร้างคอนกรีต

นาย บูรณินทุ์ กัมพลพันธ์

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมเคมี ภาควิชาวิศวกรรมเคมี
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2545

ISBN 974-17-1032-1

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

I21166543

EFFECTS OF PHYSICAL AGING ON MECHANICAL PROPERTIES OF FIBER-REINFORCED EPOXY COMPOSITES FOR STRUCTURAL REPAIR AND STRENGTHENING OF CONCRETE STRUCTURE

Mr. Booranin Kamponpan

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering in Chemical Engineering
Department of Chemical Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2002

ISBN 974-17-1032-1

Thesis Title	Effects of Physical Aging on Mechanical Properties of Fiber-Reinforced Epoxy Composites for Structural Repair and Strengthening of Concrete Structure
By	Mr. Booranin Kamponpan
Field of study	Chemical Engineering
Thesis Advisor	Dr.Sirijutaratana Covavisaruch, Ph D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master 's Degree

……………………………………………… Dean of Faculty of Engineering

(Professor Somsak Panyakeow, D. Eng.)

THESIS COMMITTEE

Sutham Vanich……………………………………………… Chairman

(Associate Professor Sutham Vanichseni, Ph.D.)

S. Covavisaruch……………………………………………… Thesis Advisor

(Sirijutaratana Covavisaruch, Ph.D.)

Sasithorn Boon-Long……………………………………………… Member

(Assistant Professor Sasithorn Boon-Long, Dr. 3ieme Cycle)

……………………………………………… Member

(Sarawut Rimdusit, Ph.D.)

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

บูรณินทุ์ กัมพลพันธ์ : ผลของการเร่งอายุทางกายภาพต่อสมบัติเชิงกลของผลิตภัณฑ์ประกอบแต่งอีพอกซีเสริมแรงด้วยเส้นใยสำหรับการซ่อมแซมและเสริมความแข็งแรงของโครงสร้างคอนกรีต. (EFFECTS OF PHYSICAL AGING ON MECHANICAL PROPERTIES OF FIBER-REINFORCED EPOXY COMPOSIETS FOR STRUCTURAL REPAIR AND STRENGTHENING OF CONCRETE STRUCTURE) อ. ที่ปรึกษา : ดร.สิริจุฑารัตน์ โควาวิสารัช, 156 หน้า. ISBN 974-17-1032-1.

งานวิจัยนี้ศึกษาผลของการเร่งอายุทางกายภาพต่อสมบัติเชิงกลของผลิตภัณฑ์ประกอบแต่งอีพอกซีเสริมแรงด้วยเส้นใยสำหรับการซ่อมแซมและเสริมความแข็งแรงของโครงสร้างคอนกรีต อีพอกซีเรซินที่ใช้คือ diglycydyl ether of bisphenol A (DGEBA) ที่บ่มด้วย polyoxypropylenediamine ส่วนเสริมแรงที่ใช้มี 2 ประเภทได้แก่ เส้นใยคาร์บอนและเส้นใยอะรามิด ปัจจัยในการเร่งอายุที่ทำการศึกษาได้แก่ อุณหภูมิในการเร่งอายุ ความชื้นและแสง UV งานวิจัยนี้มีการประยุกต์ใช้หลักการออกแบบการทดลองแบบ 2^k แฟกทอเรียล และการวิเคราะห์ความถดถอยทำให้ได้สมการความถดถอยพหุคูณเชิงเส้นที่แสดงสมบัติเชิงกลของผลิตภัณฑ์ประกอบแต่งอีพอกซีเสริมแรงด้วยเส้นใย นอกจากนี้ยังสามารถแสดงและเรียงลำดับปัจจัยที่มีนัยสำคัญต่อสมบัติเชิงกลดังกล่าว สำหรับผลิตภัณฑ์ประกอบแต่งที่เสริมแรงด้วยเส้นใยคาร์บอนพบว่า ปัจจัยหลักที่มีผลต่อความทนทานต่อแรงดัดคือ ความชื้น, อุณหภูมิและผลร่วมของอุณหภูมิกับแสง UV ตามลำดับ ความทนทานต่อแรงกดมีผลกระทบจากปัจจัยสี่ปัจจัยได้แก่ ความชื้น, แสง UV, ผลร่วมของความชื้นกับแสง UV และผลร่วมของความชื้นกับอุณหภูมิ ปัจจัยสำคัญที่มีผลต่อค่าความเหนียวเมื่อแตกและพลังงานในการแตกคือ ผลร่วมของอุณหภูมิและแสง UV, แสง UV และอุณหภูมิตามลำดับ สำหรับผลิตภัณฑ์ประกอบแต่งที่เสริมแรงด้วยเส้นใยอะรามิดพบว่า ความชื้นและผลร่วมของความชื้นกับอุณหภูมิส่งผลกระทบต่อความทนทานต่อแรงดัดตามลำดับ ปัจจัยสำคัญที่มีผลต่อความทนทานต่อแรงกดได้แก่ ความชื้น, ผลร่วมของความชื้นกับแสง UV และแสง UV ตามลำดับ สำหรับค่าความเหนียวเมื่อแตกและพลังงานในการแตกพบว่า ได้รับอิทธิพลจากอุณหภูมิ การศึกษานี้ยังแสดงว่าอุณหภูมิแปรสภาพแก้วจะมีค่าเพิ่มขึ้นเล็กน้อยตามอุณหภูมิในการเร่งอายุ จากการประยุกต์หลักการซ้อนทับของเวลากับอุณหภูมิ และสมการของ Williams, Landels และ Ferry (WLF equation) งานวิจัยนี้สามารถดัดแปลงค่าแฟกเตอร์ในการเลื่อน (Shift factor) ซึ่งขึ้นกับอุณหภูมิเพื่อใช้ในการทำนายอายุการใช้งานของผลิตภัณฑ์ประกอบแต่งอีพอกซีที่เสริมด้วยเส้นใยคาร์บอนและเส้นใยอะรามิด พารามิเตอร์ในสมการที่ได้ดัดแปลงในสมการ WLF นี้ จะสามารถใช้ได้กับระบบผลิตภัณฑ์ประกอบแต่งอีพอกซีเสริมแรงด้วยเส้นใยซึ่งมีค่าอุณหภูมิแปรสภาพแก้วต่างๆกัน

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

ภาควิชา วิศวกรรมเคมี ลายมือชื่อนิสิต บูรณินทุ์ กัมพลพันธ์
สาขาวิชา วิศวกรรมเคมี ลายมือชื่ออาจารย์ที่ปรึกษา
ปีการศึกษา 2545

4270400121 : MAJOR CHEMICAL ENGINEERING

KEY WORD : EPOXY RESIN / PHYSICAL AGING / CARBON FIBER / ARAMID FIBER / TIME-TEMPERATURE SUPERPOSITION

BOORANIN KAMPONPAN : EFFECTS OF PHYSICAL AGING ON MECHANICAL PROPERTIES OF FIBER-REINFORCED EPOXY COMPOSITES FOR STRUCTURAL REPAIR AND STRENGTHENING OF CONCRETE STRUCTURE. THESIS ADVISOR : SIRIJUTARATANA COVAVISARUCH, 156 pp. ISBN 974-17-1032-1.

This research aims to investigate the effects of physical aging on mechanical properties of fiber-reinforced epoxy composites for concrete structure application. The epoxy resin was diglycydyl ether of bisphenol A (DGEBA) cured with polyoxypropylenediamine. The two reinforcing fibers in this study consisted of carbon fiber and aramid fiber. A 2^k factorial experimental design had been applied so that the multiple linear regression models of mechanical properties of fiber-reinforced epoxy composites were obtained. They are useful tools for identifying factors affecting significantly the mechanical properties of the epoxy composites studied in sequential order. For carbon fiber reinforced composites, results showed that the main factors affecting the flexural strength were moisture, thermal and interaction of thermal-UV irradiation respectively. Four factors namely the humidity, UV irradiation, humidity-UV irradiation and thermal-humidity effectively influenced the compressive strength. Significant effects arised from the interaction of thermal-UV irradiation, UV irradiation and thermal effects were observed respectively on fracture toughness and fracture energy. For aramid fiber reinforced composites, moisture and interaction of thermal-moisture effects influenced respectively the flexural strength. The main factors affecting the compressive strength were humidity, humidity-UV irradiation and UV irradiation respectively. Fracture toughness and fracture energy were largely affected by thermal effect. Glass transition temperature was found to increase slightly with the aging temperature. By application of the concept of time-temperature superposition and the WLF equation, the temperature dependence of the shift factor was modified. The two parameters in the WLF equation for prediction of the service life of epoxy composites reinforced with carbon fiber and aramid fiber were determined based upon the corresponding glass transition temperature of the composites.

ศูนย์วิทยทรัพยากร
จุฬาลงกรณ์มหาวิทยาลัย

Department Chemical Engineering Student's signature Booranin Kamponpan
Field of study Chemical Engineering Advisor's signature S. Covavisaruch
Academic year 2002

ACKNOWLEDGEMENT

This research is an endeavor with the assistance of many people. First of all, I sincerely appreciate and would like to thank many important advises from my thesis advisor, Dr. Sirijutaratana Covavisaruch. I may not be able to accomplish this thesis if I do not have any support from her. In addition, I would like to thank members of my thesis committee, namely Associate Professor Dr. Sutham Vanichseni, Assistant Professor Dr. Sasithorn Boon-Long and Dr. Sarawut Rimdusit, who have commented and given many helpful recommendations for completing my thesis.

Furthermore, thanks are extended to all organizations that had generously supported raw materials and testing facilities. They are Nontri Company Limited for the provision of epoxy resin, curing agent and fiber tow sheets as well as many technical recommendations from Mr. Thammachart Kulprapa, Managing Director of the company, Department of Metallurgical Engineering for the use of compression testing machine. Special thanks go to The Siam Fibre-Cement Company Limited and Nawa Plastic Industry Company Limited for the kind support in the use of QUV accelerated weathering tester. The assistance from these organizations had truly helped clearifying the obstacles of this work.

Additionally, thanks go to everyone in the polymer engineering laboratory who spent their valuable time encouraging me until I finish my work. I remember every discussion in which they had contributed and all their support.

Finally, I would like to dedicate this paragraph to my lovely family, my parents and my sister who have given me their warmth, love and support even in my difficult time. All of them are my inspiration. I have never felt lonely. That’s why I can go through every situation.

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LIST OF NOMENCLATURES

SYMBOL

a_c	critical length
a_T , S_T , S_S	shift factor
k	independent variables
t	thickness of the test specimen
t_n	plate thickness in the plane of the crack
t_g	relaxation time at glass transition temperature
t_S	relaxation time at reference temperature
t_T	relaxation time at temperature T
t_{T_0}	relaxation time at temperature T_0
x_1	coded variable of the aging temperature
x_2	coded variable of humidity
x_3	coded variable of UV exposure
y	mechanical properties
A	aging temperature
B	humidity
C	UV exposure
C_1, C_2	parameters for WLF equation
$C_1^{'}$,$C_2^{'}$,$C_1^{''}$,$C_2^{''}$	modified parameters for WLF equation
E	Young's modulus
E'	storage modulus
E''	loss modulus
G_{Ic}	fracture energy
K_{Ic}	critical stress intensity factor
M_c	average molecular weight between crosslinks
P	load at the break point
T_g , $T_g^{'}$	glass transition temperature

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T_r , T_S	reference temperature
W	width of the test specimen
W_m	moment arm
Y	geometry constant
α	slope
β	y-intercept
β_j	regression coefficients
σ_c	stress at failure
tan δ	loss factor
ε	random error
ρ	density
ν	Poisson's ratio

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