

經濟部幕僚單位及行政機關人員從事兩岸交流活動報告書

出席

**The Eleventh International Conference on
High-Performance Ceramics (CICC-11)**

國際研討會

研討會議報告

研提人單位：國立臺北科技大學

職稱：計畫主持人、協同主持人

姓名：鄭大偉 教授、李韋皞 博士

參訪期間：2019 年 05 月 25 日至 2019 年 05 月 30 日

報告日期：2019 年 06 月 12 日

(本報告請檢送 1 式 3 份)

政府機關（構）人員從事兩岸交流活動（參加會議）報告

壹、交流活動基本資料

- 一、活動名稱：The Eleventh International Conference on High - Performance Ceramics (CICC-11)
- 二、活動日期：2019年5月25日至5月29日，共計5日。
- 三、主辦單位：中國硅酸鹽學會
- 四、報告撰寫人服務單位：國立臺北科技大學。

貳、活動（會議）重點

一、活動性質

本研討會係由中國硅酸鹽學會所主辦，為2年一次之世界級著名國際研討會，本次參與之專家學者來自全球各地，包含：美國、德國、義大利、日本、澳洲、韓國、台灣、中國大陸...等，總計超過600名教授學者進行成果發表，大會發表主題類別超過25項，全場發表文章超過1400篇次，可謂相當盛大。研討會內容包含：先進陶瓷材料、磁性陶瓷材料、3D列印陶瓷材料、生醫陶瓷材料....等，其中包含[Ecofriendly Geopolymer and Geopolymer-Developed Ceramics]此項主題，與本研究案實屬同類型研究方向，因此於此會議議程中進行報告時，不僅能向國際專家學者展現台灣現今之研究成果，更能與其進行意見交流，進而達到技術成長。

二、活動內容

會議係由2019年5月25日起始，25日當日為會議報到日，26日~29日為正式會議報告日期，並於29日晚間進行閉幕儀式，相關議程各議程之主題如下：

List of Symposia

May 25	09:30 ~ 21:00	On-site Registration (Lobby of Conference Hall)	(A) Powder Processing and Forming Technology for Advanced Ceramics
May 26	08:10 ~ 08:30	Opening Ceremony (International Conference Center)	(B) Flash and Other Field Assisted Sintering Techniques: Beyond Materials Consolidation
	09:30 ~ 12:00	Plenary Lectures (International Conference Center)	(C) 3D-Print of Ceramics
	14:00 ~ 18:00	Oral Presentations (The 2nd and 3rd Floor, Conference Hall)	(D) Mechanical Behavior and Structural Applications of Ceramics and CMCs
	14:00 ~ 18:00	Exhibition (The 2nd Floor, Conference Hall)	(E) Advanced Structural Ceramics for Extreme Environments
May 27	08:00 ~ 18:00	Oral Presentations (The 1st, 2nd and 3rd Floor, Conference Hall)	(F) Polymer Derived Ceramics
	08:00 ~ 18:00	Exhibition (The 2nd Floor, Conference Hall)	(G) Borides and Boron Related Materials
May 28	08:00 ~ 18:00	Oral Presentations (The 2nd and 3rd Floor, Conference Hall)	(H) Advanced Materials for Next Generation Nuclear Energy
	08:00 ~ 18:00	Poster Presentations (The 1st Floor, Conference Hall)	(I) Advanced Refractories
	08:00 ~ 18:00	Exhibition (The 2nd Floor, Conference Hall)	(J) Ecofriendly Geopolymer and Geopolymer-Developed Ceramics
May 29	08:00 ~ 10:00	Plenary Lectures (The 3rd Floor, Conference Hall)	(K) Advanced Ceramic Coatings for Structural and Functional Applications
	10:20 ~ 18:00	Oral Presentations (The 2nd and 3rd Floor, Conference Hall)	(L) Tribology of Ceramics
	08:00 ~ 18:00	Poster Presentations (The 1st Floor, Conference Hall)	(M) Transparent Ceramics and Luminescent Materials
	08:00 ~ 18:00	Exhibition (The 2nd Floor, Conference Hall)	(N) Dielectric, Pyroelectric, Piezoelectrics, and Ferroelectrics
	08:00 ~ 18:00	Exhibition (The 2nd Floor, Conference Hall)	(O) Perovskite
	18:30 ~ 21:00	Closing Banquet (International Conference Center)	(P) Lead-Free Piezoelectric Ceramics
			(Q) Magnetic and Multiferroic Ceramics
			(R) Sensitive Materials and Devices
			(S) Emerging Materials for Energy Harvesting and Storage
			(T) Thermoelectric Materials and Devices for Energy Conversion
			(U) Porous and Cellular Ceramics
			(V) Advances in Bioceramics
			(W) Functional Ceramics for Environmental Applications
			(X) Virtual Materials Design and Ceramic Genome
			(Y) The Belt & Road Ceramics Forum

三、 遭遇之問題

本研究團隊針對無機聚合技術之發展及相關成果均相較於各國發展之卓越，但世界知名度及成果展現度卻不及其他初始起步之研究團隊或國家。

四、 我方因應方法及效果

透過研討會簡報過程中，將本研究團隊之相關科研成果及實際量化成果完整且系統性展性，並與相關科研單位組建交流群組，不僅能展現本研究團隊之技術能力，未來更能與國際間相關之無機聚合技術研究團隊，有良好且零距離之溝通平台。

五、 心得及建議

無機聚合材料發展迄今已超過 30 年，由於其製程及設備簡單，整體材料本身具多項良好之工程特性，且反應均可於常溫環境下完成，較傳統卜特蘭水泥更具節能減碳之優勢。因此，近年無機聚合材料受到國際各研究單位之重視，亦有許多國家陸續開發相關技術之產品。

國際已有許多國家針對無機聚合材料已有實際商轉化產品，包含澳洲、印度、英國、美國、法國、德國、捷克...等，此外，中國大陸也正逐步重視此材料之研究發展中，對比於台灣國內，仍趨於保守心態，因此仍未能有效且大規模之研究，因此相比於各國之研究成果，雖然多元化應用之開發勝於其他國家，但是就研究團隊之規模及研究精進度而言，仍屬弱勢。

因此，藉由此次研討會之參與，並且和世界各國之無機聚合技術領域專家進行意見交流後，著實能提升自我研究之視野及多項突破性之思考，也能透過多方交流之成果，搭建起未來跨國研究之可行性，期望未來能確實達到跨國且跨領域之共同交流合作，藉以將無機聚合技術不僅於台灣國內成功推向商轉化，更能於世界上站穩一席之地。

參、謹檢附參加本次活動（會議）之相關資料如附件，報請備查。

職



2019 年 06 月 07 日

附件一

1. 參與人員發表之文章摘要及簡報資料

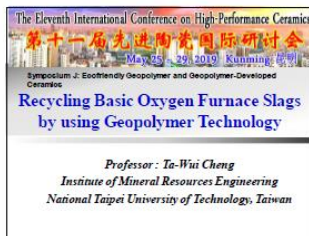
● 鄭大偉教授(計畫主持人)

發表題目：Recycling Basic Oxygen Furnace Slags by using Geopolymer Technology

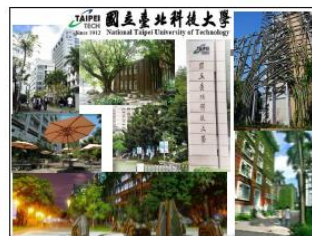
文章摘要：

Basic Oxygen Furnace (BOF) Slag is a by-product of iron making. There are 1.6 million tons produced in Taiwan every year. It has great engineering properties. However, the main problem for BOF slag is expansion. In this study, geopolymer technology was developed for stabilization/reutilization BOF slag. Geopolymer processes contain large amount of free silicon. These free silicon can react with free-lime in BOF slag, and thus to form a stable calcium silicate compound, therefore inhibit the expansion of the BOF slag. This will not only completely solve the BOF slag production problem but also can turn them into valuable products. It is of great significance to reach the goals of waste recycling, social, economic, academic development and in accordance with the principles of Circular Economy.

簡報資料：



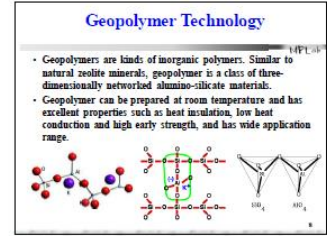
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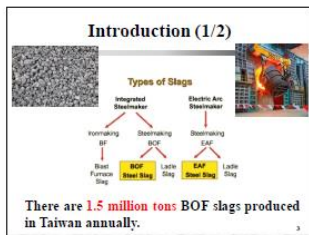
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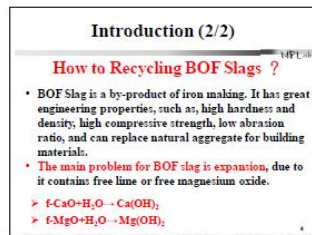
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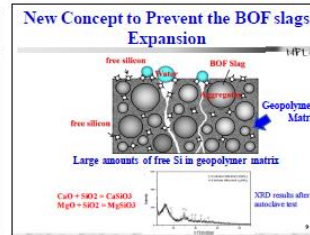
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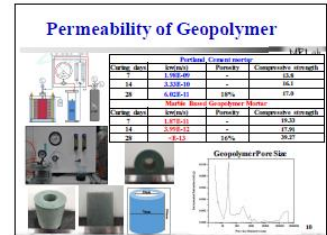
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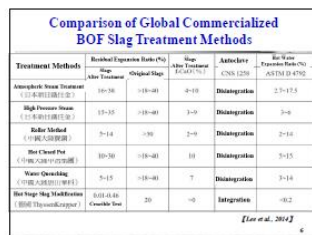
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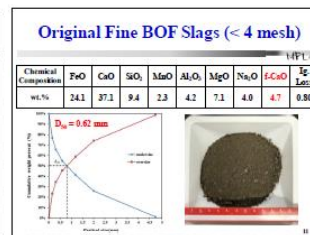
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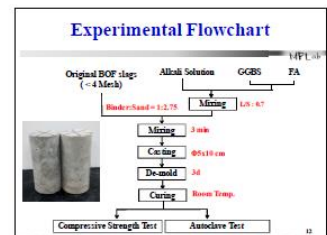
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Autoclave Expansion Tests

CNS1258 (Method of Test for Autoclave Expansion of Portland Cement)

Test Samples
Autoclave
Expansion Measurement

Expansion Rate (%) = $\frac{\text{Size after test} - \text{Original Size}}{\text{Original Size}} \times 100\%$

20R = 0.7 kg/cm²
21R = 1.4 kg/cm²
22R = 2.1 kg/cm²
23R = 2.8 kg/cm²
24R = 3.5 kg/cm²
25R = 4.2 kg/cm²
26R = 4.9 kg/cm²
27R = 5.6 kg/cm²
28R = 6.3 kg/cm²
29R = 7.0 kg/cm²
30R = 7.7 kg/cm²
31R = 8.4 kg/cm²
32R = 9.1 kg/cm²
33R = 9.8 kg/cm²
34R = 10.5 kg/cm²
35R = 11.2 kg/cm²
36R = 11.9 kg/cm²
37R = 12.6 kg/cm²
38R = 13.3 kg/cm²
39R = 14.0 kg/cm²
40R = 14.7 kg/cm²

Calculation Method of Volume Change Rate of Cylindrical Specimen

Vernier caliper

Age (d)	1	2	3	0.1	0.2
Initial Test	105.77	105.78	105.78	105.78	105.78
After Test	105.72	105.72	105.72	105.72	105.72
Length Change Rate (%)	-0.05	-0.05	-0.05	-0.05	-0.05
Initial Volume (cm ³)	432	432	432	432	432
Volume Change Rate (%)	-0.05	-0.05	-0.05	-0.05	-0.05
Volume After Test	409.92	409.92	409.92	409.92	409.92
Volume Change Rate (%)	-5.35	-5.35	-5.35	-5.35	-5.35

Effect of additional sodium silicate on stabilized BOF slag Changes After Autoclave Test (28days)

	Length Change Ratio (%)	Diameter Change Ratio (%)	Volume Change Ratio (%)
5%	0.16	0.25	0.67
10%	0.17	0.18	0.53
20%	0.13	0.17	0.47

The amount added is 5%, 10%, 20% of the BOF slag content.

Effect of additional sodium silicate on stabilized BOF slag Compressive Strength

Before Autoclave Test

After Autoclave Test

GGBS/FA Based Geopolymer System

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Aggregate	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.06% Diameter Changed : 0.10% Volume Changed : 0.20%

Effect of SiO₂/Na₂O Molar Ratio on Compressive Strength

Before Autoclave Test

After Autoclave Test

Effect of additional sodium silicate on stabilized BOF slag Changes After Autoclave Test

	Length Change Ratio	Diameter Change Ratio	Volume Change Ratio
5%	0.16	0.25	0.67
10%	0.17	0.18	0.53
20%	0.13	0.17	0.47

Additional Sodium Silicate (5%) on Stabilized BOF slag

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.16% Diameter Changed : 0.25% Volume Changed : 0.67%

Effect of GGBS:FA Ratio on Compressive Strength (SiO₂/Na₂O=1.5)

Before Autoclave Test

After Autoclave Test

Effect of additional sodium silicate on stabilized BOF slag

Powders	Blinder	NaOH Concentration	SiO ₂ /Al ₂ O ₃	SiO ₂ /Na ₂ O	Additional Sodium Silicate
GGBS : FA	Sand	6M	50	1.5	5%
					10%
					20%

The amount added is 5%, 10%, 20% of the BOF slag content.

Additional Sodium Silicate on Stabilized BOF slag (10%)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.17% Diameter Changed : 0.19% Volume Changed : 0.57%

Additional Sodium Silicate on Stabilized BOF slag (20%)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.12% Diameter Changed : 0.17% Volume Changed : 0.47%

Effect of Sodium Silicate Concentration on Stabilized BOF Slag Changes After Autoclave Test

Blinder	Blinder	NaOH	SiO ₂ /Al ₂ O ₃	SiO ₂ /Na ₂ O	Total Amount added 10%
GGBS : FA	Sand	6M	50	1.5	Na ₂ SiO ₃ / Water
g	kg	mol	mol	mol	mol
5	5	1.5	1.5	1.5	3.7
					5.5
					7.3

Effect of Sodium Silicate Concentration on Stabilized BOF Slag Changes After Autoclave Test (7days)

Na ₂ SiO ₃ / Water	Length (%)	Diameter (%)	Volume (%)
3 : 7	0.05	0.13	0.31
5 : 5	0.04	0.08	0.22
7 : 3	0.02	0.05	0.13

(35days)

Na ₂ SiO ₃ / Water	Length (%)	Diameter (%)	Volume (%)
3 : 7	0.03	0.01	0.06
5 : 5	0.01	-0.02	-0.02
7 : 3	0.00	-0.03	-0.06

The amount added is 10% of the BOF slag content.

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 5 : 5 (7days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.04% Diameter Changed : 0.09% Volume Changed : 0.22%

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 5 : 5 (28days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.01% Diameter Changed : -0.02% Volume Changed : -0.02%

Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Compressive Strength)

Effect of Sodium Silicate Concentration on Stabilized BOF Slag Changes After Autoclave Test

Length Change Ratio

Diameter Change Ratio

Volume Change Ratio

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 7 : 3 (7days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.02% Diameter Changed : 0.05% Volume Changed : 0.13%

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 7 : 3 (28days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.00% Diameter Changed : -0.01% Volume Changed : -0.00%

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 3 : 7 (7days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.05% Diameter Changed : 0.13% Volume Changed : 0.31%

Sodium Silicate Concentration on Stabilized BOF Slag Sodium Silicate : Water = 3 : 7 (28days)

CNS 1258 - Autoclave Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

Before Autoclave Test

After Autoclave Test

Length Changed : 0.03% Diameter Changed : 0.01% Volume Changed : 0.06%

Effect of Sodium Silicate Concentration on Stabilized BOF Slag (70°C Hydration Reactions Test for 7days)

After Room Temperature Curing:

Na ₂ SiO ₃ / Water	7day	28day	56day
3 : 7	0.13	-0.01	0.03
5 : 5	0.10	0.00	0.03
7 : 3	-0.06	-0.14	-0.24

After 180°C Steam Test:

Na ₂ SiO ₃ / Water	7day	28day	56day
3 : 7	0.02	-0.05	0.07
5 : 5	0.03	0.06	0.06
7 : 3	-0.02	-0.01	-0.02

The amount added is 10% of the BOF slag content.

Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Na₂SiO₃ : Water = 3 : 7) (70°C Hydration Reactions Test for 7days)

CNS 15311 - 70°C Hydration Reactions Test		Alkal Solution	
Blinder	Sand	Blinder	Sand
GGBS	FA	NaOH	Na ₂ O
g	kg	mol	mol
5	5	1.5	1.5

After Room Temperature Curing 28Days

After 180°C Steam Test

Volume changed : 0.13%

Volume changed : 0.02%

Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Na₂SiO₃ : Water = 3 : 7) (70°C Hydration Reaction: Test for 28days)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 28days After 180°C Steam Test

Volume changed : -0.01% Volume changed : -0.05%

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Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Na₂SiO₃ : Water = 5 : 5) (70°C Hydration Reaction: Test for 7days)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag <td>Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td></td>	Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td>	L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td>	NaOH / Na ₂ O <td>SiO₂ / Al₂O₃</td>	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 7days After 180°C Steam Test

Volume changed : -0.09% Volume changed : -0.03%

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2018/07/23 First Ready-Mixed Plant Test Stabilization BOF slags using Geopolymer Technology

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2018/07/23 First Ready-Mixed Plant Test Trial batch No.1 (FA : GGBS=5 : 5)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag <td>Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td></td>	Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td>	L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td>	NaOH / Na ₂ O <td>SiO₂ / Al₂O₃</td>	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 28days After 180°C Steam Test

Volume changed : -0.01% Volume changed : -0.05%

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Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Na₂SiO₃ : Water = 5 : 5) (70°C Hydration Reaction: Test for 28days)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag <td>Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td></td>	Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td>	L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td>	NaOH / Na ₂ O <td>SiO₂ / Al₂O₃</td>	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 28days After 180°C Steam Test

Volume changed : -0.09% Volume changed : -0.06%

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Effect of Sodium Silicate Concentration on Stabilized BOF Slag (Na₂SiO₃ : Water = 7 : 3) (70°C Hydration Reaction: Test for 7days)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag <td>Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td></td>	Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td>	L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td>	NaOH / Na ₂ O <td>SiO₂ / Al₂O₃</td>	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 7days After 180°C Steam Test

Volume changed : -0.06% Volume changed : -0.02%

40

Fresh Properties

Trial batch No.1 (FA : GGBS=5 : 5)

45

2018/07/23 First Ready-Mixed Plant Test Trial batch No.2 (FA : GGBS=6 : 4)

CNS 15311-70°C Hydration Reaction Test		CNS 15311-70°C Hydration Reaction Test		Alkal Solution		
Blender	FA	Sand / BOF slag	Blender / Sand	L/S	NaOH / Na ₂ O	SiO ₂ / Al ₂ O ₃
GGBS	FA	Sand / BOF slag <td>Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td></td>	Blender / Sand <td>L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td></td>	L/S <td>NaOH / Na₂O <td>SiO₂ / Al₂O₃</td> </td>	NaOH / Na ₂ O <td>SiO₂ / Al₂O₃</td>	SiO ₂ / Al ₂ O ₃
S	S	S	S	S	S	S

After Room Temperature Curing 28days After 180°C Steam Test

Volume changed : -0.14% Volume changed : -0.01%

41

Ready-Mixed Plant Test

42

Fresh Properties

Trial batch No.1 (FA : GGBS=5 : 5)

47

First Test Compressive Strength & Autoclave Tests

Date	Type	Blender	Compressive Strength (MPa)						
			1d	3d	7d	28d	Autoclave	28d	
10/07/23	OP	3	28.3	32.7	37.1	32.8	41.1	41.1	41.1
10/07/23	OP	4	28.3	32.7	37.1	32.8	41.1	41.1	41.1
10/07/23	OP	5	28.3	32.7	37.1	32.8	41.1	41.1	41.1

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Casting 1 M³ Test Body

Shap : 270 mm
Shap Flow : 510*490 mm
Compressive Strength
1day : 20.0 MPa
3day : 32.1 MPa
7day : 36.1 MPa
28day : 40.8 MPa

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2018/09/27 Second Ready-Mixed Plant Test

Trial batch No. 1 - Amount of alkali solution decreased

Item	GGBS	FA	BOF Slag	Alkal Solution	Water	BOF Slag	Water	Total
1.0m ³	1.0	1.0	1.0	1.0	1.0	1.0	1.0	7.0

Trial batch No. 2 - Amount of alkali solution & GGBS decreased

Item	GGBS	FA	BOF Slag	Alkal Solution	Water	BOF Slag	Water	Total
1.0m ³	0.8	1.0	1.0	1.0	1.0	1.0	1.0	6.8

Trial batch No. 3 - Added marble powder

Item	GGBS	FA	BOF Slag	Alkal Solution	Water	BOF Slag	Water	Total
1.0m ³	0.8	1.0	1.0	1.0	1.0	1.0	1.0	6.8

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GPI Fresh Properties (Amount of alkali solution decreased)

56

Making New Jersey's Guardrail

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CO₂ Emission Evaluation -1 BOF Slag Based Geopolymer Mortar

Trial batch No.1 (FA : GGBS=5 : 5)

Formula	GGBS*	FA	BOF Slag (<4 mesh)	Alkal Solution**
Weight (kg)	250	250	1600	250
Factor	4.3*10 ⁻⁴	0	0	4.81*10 ⁻⁴
Sum	0.001075	0	0	0.00235

Total : 0.1100 Tons CO₂/m³ BOF slag based geopolymer mortar

*Average of finding the mortar plant using incorporated and output. Consider converting 4.07kg/gal and 4.31kg/gal. **Lime A Pack, 2013

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GP2 Fresh Properties (Amount of alkali solution & GGBS decreased)

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GP3 Fresh Properties (Add Marble Powder)

58

CO₂ Emission Evaluation -2 BOF Slag Based Geopolymer Mortar

Item	Portland Cement Mortar* (2017 National CO ₂ Emissions Inventory Report)	Purified Cement Mortar* (Product Carbon Footprint Comparing Service Providers)	BOF slag Based Geopolymer Mortar
CO ₂ Emission Factor (Ton CO ₂ /m ³ Mortar)	0.3123	0.5040	0.1100
CO ₂ Emission Reduction Ratio	64.8 %	78.2 %	-

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2018/09/27 Second Ready-Mixed Plant Test Stabilization BOF slags using Geopolymer Technology

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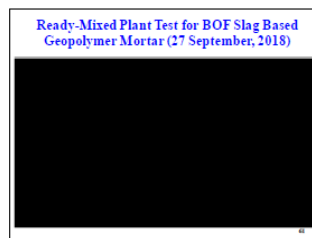
Second Test Compressive Strength & Autoclave Tests

Date	Type	Blender	Compressive Strength (MPa)			
			1d	3d	7d	28d
10/07/23	OP	3	23.5	26.9	19.4	31.2
10/07/23	OP	4	18.5	—	37.2	19.5
10/07/23	OP	5	21	31.9	29.3	41.9

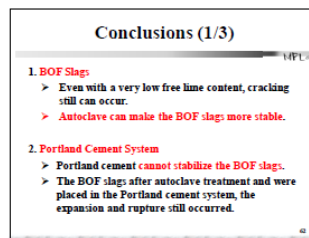
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Making 1 M³ Test Body & New Jersey's Guardrail

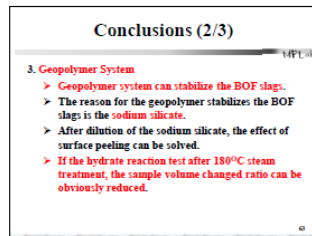
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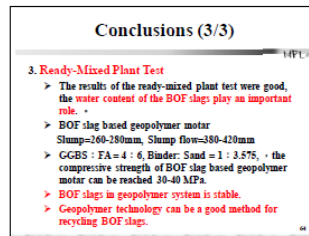
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● 李韋線博士(協同主持人)

發表題目：The effect of microstructure development on mechanical properties of slag-based geopolymer

文章摘要：

Geopolymer materials have been developed over 30 years. Until recently, geopolymer is heeded by global research institutes and many countries, due to geopolymers containing great properties, simple production equipment and fabrication process at room temperature. It has good development potential for engineering application.

There are many parameters can affect the geopolymer characteristics, such as sources of raw materials, concentration or different $\text{SiO}_2/\text{Na}_2\text{O}$ molar ratios of alkali solutions. However, little researchers focus on the relationship between those parameters and geopolymer microstructures. A systematic discussion was lacked.

In this study, metakaolin, ground-granulated blast-furnace slag, coal fly ash were used as raw materials. After raw materials mixing with different formulations of alkaline solution, geopolymer materials were formed. NMR, XRD and FT-IR were used to analyze the interior Si, Al structures after curing various days. In order to understand the relationship between each other, all of the Si, Al structures analyzed results were compared with its mechanical properties.

According to the results, the ground-granulated blast-furnace slag involved in geopolymer reaction, it becomes the major influence factor on slurry setting time, compressive strength and the amount of Si-O-Al bonding structures. According to the ^{29}Si NMR and XRD analysis results, with GGBF slag involving in the reaction, the geopolymer Si Q_4 structure increased and the pozzolanic reaction also occurred. Both of above reaction can improve the compressive strength of the geopolymer. On the other hand, when GGBF slag was added, the pozzolanic reaction caused Q2 and Q3 structures increased, consequently reduced the degree of polymerization of Si. However, both Q2 and Q3 structures can provide the material strength

development.

In this study, the microstructural development of three kinds of commonly used raw materials in geopolymer was investigated. Based on the experimental results, it is expected to be able to through this study as the basis for later research.

簡報資料：

The effect of microstructure development on mechanical properties of slag-based geopolymer

Wei-Hao Lee
Institute of Mineral Resources Engineering
National Taipei University of Technology

TAIPEI TECH 2019 / 05 / 28

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Introduction(2/4)

Raw materials for Geopolymer materials:

- Mesokasin
- GGBF-Slag powder
- Coal Fly Ash
- Industrial by-product waste (Rich in Si or Al)

The proportion of various raw materials in SiO₂ paper on Geopolymer materials (Data source: Scopus, from 1978-2017)

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The definition of microstructure analysis in this study

The definition of functional group in FTIR

Chemical Bond	Wavelength(cm ⁻¹)
O-H	3340-3450
C-O	2366
OH	1649
C-O	1400-1450
C-O (Q series)	950-1100
Si-O-Al (non-bridging)	700-800

The definition of Al coordination and Chemical shift

Al coordination	Chemical shift (ppm)
4	-2.5 ~ 15
5	15 ~ 40
6	50 ~ 75

The definition of Si-Q' and Chemical shift

Chemical shift (ppm)	Q1	Q2	Q3	Q4	Q5	Q6	Q7
	-72	-77	-81	-85	-90	-95	-101

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Materials – GGBF-Slag

Chemical Composition (wt%)

SiO ₂	49.2
Al ₂ O ₃	14.3
Fe ₂ O ₃	8.2
MgO	7.1
LOI	—
Others	3.7

FTIR, XRD, SEM images

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Outline

- 1 Introduction
- 2 Experiment & Materials
- 3 Results and Discussion
- 4 Conclusion

2

Introduction(3/4)

Geopolymeric technology

Alkali solution + Aluminosilicate → Geopolymer

SiO₂, Al₂O₃

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The calculation of Si-bonding type

The proportion of Si-O-Al / Si-O-Si

$$\sum_{i=1}^n (n_i - 1) \times 100\% = \frac{\sum_{i=1}^n (n_i - 1) \times 100\%}{\sum_{i=1}^n (n_i - 1) \times 100\% + \sum_{i=1}^n n_i \times 100\%} \times 100\%$$

The polymerization degree of Si

$$Q^* = \frac{Q1 + 2(Q2+Q3) + 4(Q4)}{Q1 + Q2 + (Q2+Q3) + Q4} \times 100\%$$

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Experiment procedures

Coal Fly Ash + Alkali solution → Mixing → Geopolymer paste → Moulding → Demoulding → Weathering test

Temperature: 14, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 days

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Introduction(1/4)

Geopolymer materials have been developed over 30 years. Until recently, geopolymer is headed by global research institutes and many countries, due to its excellent engineering characteristics and the great development potential for engineering application.

Journal paper of Geopolymer from 2010-2017 (Data source: Scopus, Scopus.com)

3

Introduction(4/4)

There are many parameters can affect the geopolymer characteristics, such as raw materials, concentration or different SiO₂/Na₂O molar ratios of alkali solution. However, only few researchers focus on the relationship between those parameters and geopolymer microstructures. A systematic discussion was lacked.

XRD, NMR, FT-IR

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Materials – Coal Fly Ash

Chemical Composition (wt%)

SiO ₂	60.2
Al ₂ O ₃	19.1
Fe ₂ O ₃	8.7
K ₂ O	3.4
CaO	2.7
TiO ₂	1.7
SO ₂	0.9
Others	6.4
LOI	2.9

FTIR, XRD, SEM images

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Weathering test [FCMA-WFC-610]

Temperature: -10 °C, 20 °C, 30 °C, 50 °C, 60 °C

Humidity (RH): 60%~80%, 90%~95%

Environmental control tester

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Coal Fly Ash based Geopolymer - Workability

Experiment No.	Alkali solution (SiO ₂ /Na ₂ O / SiO ₂ /Al ₂ O ₃)	LS	Viscosity (mPa·s)	Setting time (hr:min)
C-096-X	0.76	0	12400	10 hr 40 min / 23 hr 10 min
C-128-X	1.28	0	7000	17 hr 30 min / 23 hr 40 min
C-191-X	1.91	0	10700	15 hr 40 min / 23 hr 15 min
C-096-S0	0.76	50	12400	17 hr 30 min / 23 hr 40 min
C-128-S0	1.28	50	6700	19 hr 10 min / 24 hr 10 min
C-191-S0	1.91	50	9000	15 hr 30 min / 23 hr 45 min

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Coal Fly Ash based Geopolymer - ²⁷Al NMR analysis (curing for 3 days)

Alkali solution: SiO₂/Na₂O=1.28

Chemical shift (ppm)

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Coal Fly Ash based Geopolymer - Weathering Test

Compressive Strength (MPa)

80% Na₂O=0.76, 80% Na₂O=1.28, 80% Na₂O=1.91

Curing for 30 days, After Weathering Test

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Slag & Coal Fly Ash based Geopolymer - ²⁹Si NMR analysis (curing for 3 days)

Chemical shift (ppm)

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Coal Fly Ash based Geopolymer - ²⁹Si NMR analysis (curing for 28 days)

Chemical shift (ppm)

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Coal Fly Ash based Geopolymer - XRD analysis (curing for 28 days)

Intensity (Counts)

2θ (Degree)

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Coal Fly Ash based Geopolymer - Bonding type v.s. Compressive Strength

No.	Compressive Strength (MPa)	Si-O-Al (%)	Si-O-Si (%)
C-096-X	33.5	-6.0%	29.1
C-128-X	16	-2.5%	22.1
C-191-X	7.7	0.0%	16
C-096-S0	35.7	0.0%	29.7
C-128-S0	19.4	-0.3%	22.8
C-191-S0	9.5	-13.7%	18.1

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Slag & Coal Fly Ash based Geopolymer - ²⁹Si NMR analysis (curing for 28 days)

Chemical shift (ppm)

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Coal Fly Ash based Geopolymer - ²⁹Si NMR analysis (curing for 30 days)

Chemical shift (ppm)

15

Coal Fly Ash based Geopolymer - Compressive Strength

Compressive Strength (MPa)

80% Na₂O=0.76, 80% Na₂O=1.28, 80% Na₂O=1.91

Curing for 30 days, After Weathering Test

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Slag & Coal Fly Ash based Geopolymer - Workability

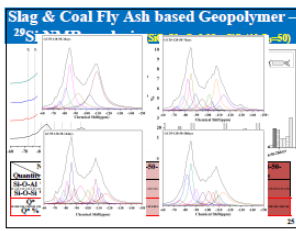
Experiment No.	Alkali solution (SiO ₂ /Na ₂ O / SiO ₂ /Al ₂ O ₃)	LS	Viscosity (mPa·s)	Setting time (hr:min)
GSS-096-X	0.76	0	8400	50 min / 1 hr 55 min
GSS-128-X	1.28	0	2400	35 min / 1 hr 20 min
GSS-191-X	1.91	0	1300	20 min / 1 hr 00 min
GSS-096-S0	0.76	50	7500	50 min / 2 hr 00 min
GSS-128-S0	1.28	50	4300	35 min / 1 hr 40 min
GSS-191-S0	1.91	50	4000	25 min / 1 hr 10 min
GSS-128-S0	1.28	70	6300	35 min / 1 hr 35 min
GSS-191-S0	1.91	70	3700	20 min / 1 hr 10 min

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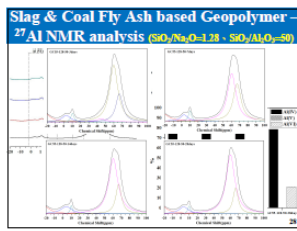
Slag & Coal Fly Ash based Geopolymer - ²⁹Si NMR analysis (curing for 30 days)

Chemical shift (ppm)

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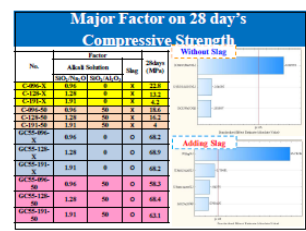


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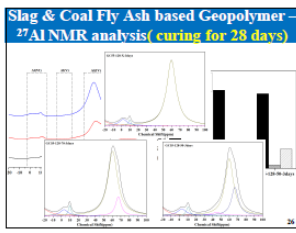
Slag & Coal Fly Ash based Geopolymer - Bonding type v.s. Compressive Strength

No.	Compressive Strength		Si-O-Al	Si-O-Si	Q ⁿ
	365 days	After Weathering test			
GC55-096-X	86.5	-12.9%	63.2	36.6	85.3
GC55-128-X	84.6	-4.5%	45.4	54.6	90.8
GC55-191-X	76.6	-9.4%	51.8	48.2	87.6
GC55-096-50	76	-10.1%	63.8	36.2	87
GC55-128-50	85	-3.4%	43.5	56.5	87.6
GC55-191-50	78	-4.9%	52.9	47.1	88.5
GC55-128-70	50.8	-0.4%	33.6	66.4	83.8

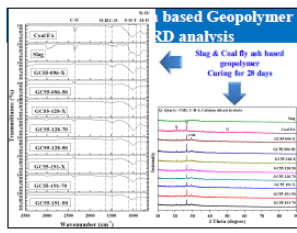
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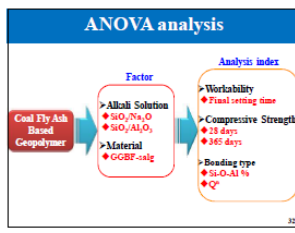
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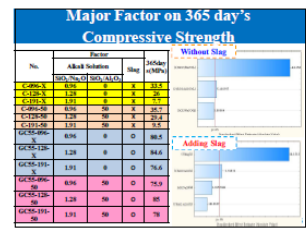
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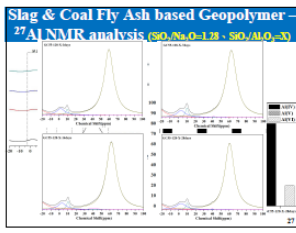
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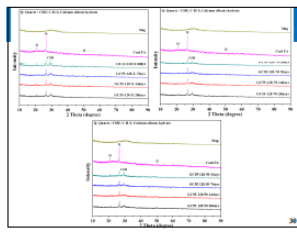
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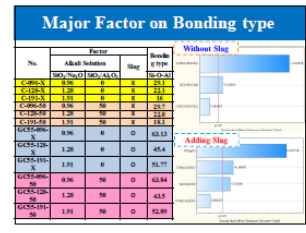


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Major Factor on Final Setting time

No.	Factor		Setting time (h)
	Alkali solution	Slag	
GC55-096-X	1.28	0	105
GC55-128-X	1.28	0	86
GC55-191-X	1.28	0	104
GC55-096-50	1.28	0	104
GC55-128-50	1.28	0	104
GC55-191-50	1.28	0	76

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Qⁿ & Si-O-Al amount effect on Compressive Strength-1

No.	Factor	Compressive Strength(MPa)	
		28days	365days
GC55-096-X	3.41	63.13	86.5
GC55-128-X	3.63	45.4	84.6
GC55-191-X	3.51	51.77	76.6
GC55-096-50	3.48	63.84	58.3
GC55-128-50	3.5	43.5	85
GC55-191-50	3.54	52.89	63.1
GC55-128-70	3.35	33.6	36.6
GC55-191-70	3.55	63.1	26.4
MS-128-X	3.26	67.6	45.9
MS-128-50	3.4	67.4	29
MS-128-60	3.35	68.3	25.3
MS-191-60	3.25	58.4	6.6

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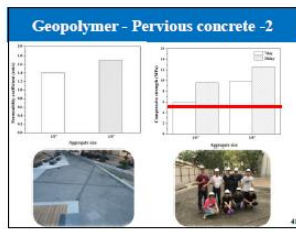


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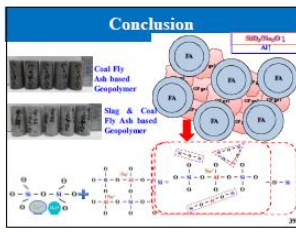
Qⁿ & Si-O-Al amount effect on Compressive Strength-2

Factor	k ²	Std. Err.	t	Std. Err.	p-value
Q ⁿ	0.655420	0.248376	2.63729	0.008272	
Si-O-Al(%)	-0.119966	0.248395	-0.221	0.82654	

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2. Ecofriendly Geopolymer and Geopolymer-Developed Ceramics 議程之相關發表文章

Programme Schedule • Afternoon, May 28

Symposium J: Ecofriendly Geopolymer and Geopolymer-Developed Ceramics
(Conference Hall, The Third Floor, Room 2)

14:00 ~ 16:00

Chair: D.C. Jia (*Harbin Institute of Technology, China*)

14:00		Welcome address D.C. Jia (<i>Harbin Institute of Technology, China</i>)
14:10	J001 Keynote	Recent development of geopolymer and geopolymer based composites P.G. He (<i>Harbin Institute of Technology, China</i>)
14:40	J004 Keynote	Ultra-high performance geopolymer concrete (UHPGC) Z.H. Zhang (<i>Hunan University, China</i>)
15:10	J020 Invited	Basic research on immobilization and disposal of nuclear waste with geopolymer X. Ma (<i>Southwest University of Science and Technology, China</i>)
15:35	J017 Invited	One-pot preparation of NaA zeolite microspheres for highly selective and continuous removal of Sr(II) from aqueous solution K.T. Wang (<i>Guangxi University, China</i>)

16:10 ~ 18:00

Chair: Z.H. Zhang (*Hunan University, China*)

16:10	J002 Keynote	Recycling basic oxygen furnace slags by using geopolymer technology T.W. Cheng (<i>National Taipei University of Technology, Taiwan</i>)
16:40	J003 Keynote	Progress in phosphate and geopolymer cements with primary battery and steel slag wastes H.A. Colorado (<i>Universidad de Antioquia, Colombia</i>)
17:10	J016 Invited	The effect of microstructure development on mechanical properties of slag-based geopolymer W.H. Lee (<i>National Taipei University of Technology, Taiwan</i>)
17:35	J011 Invited	Performance evaluation of geopolymer modified by different solid wastes H. Wang (<i>Rutgers University, USA</i>)

Programme Schedule • Morning, May 29

Symposium J: Ecofriendly Geopolymer and Geopolymer-Developed Ceramics
(Conference Hall, The Third Floor, Room 2)

10:00 ~ 11:40

Chair: Z.Y. Lai (*Southwest University of Science and Technology, China*)

10:00	J108	One-step synthesis of all-inorganic CsPbX₃ (X= Cl, Br, and I) aluminosilicate inorganic polymer composite to improve quantum dot stability J.Y. Cui (<i>Harbin Institute of Technology, China</i>)
10:20	J103	Early mechanical properties and microstructural evolution of slag/metakaolin-based geopolymers exposed to karst water J.C. Xiang (<i>Guangxi University, China</i>)
10:40	J109	Hydrothermal synthesis of zeolite and its adsorption and immobilization of cesium M.L. Wang (<i>Harbin Institute of Technology, China</i>)
11:00	J107	The effect of carboxyl starch sodium (CMS-Na) on the rheology behavior and geopolymerization kinetics of alkali-activated slag based geopolymer Z.X. Lin (<i>Guangxi University, China</i>)
11:20	J111	Using ion-exchanged geopolymer as versatile precursor for the design and preparation of celsian ceramics S. Fu (<i>Harbin Institute of Technology, China</i>)

Programme Schedule • Afternoon, May 29

Symposium J: Ecofriendly Geopolymer and Geopolymer-Developed Ceramics
(Conference Hall, The Third Floor, Room 2)

14:00 ~ 15:40

Chair: T.W. Cheng (*National Taipei University of Technology, Taiwan*)

14:00	J012 Invited	Design and preparation of engineered geopolymeric composites (EGC) X.L. Guo (<i>Tongji University, China</i>)
14:25	J013 Invited	Enhanced separation efficiency and durability of a geopolymer composite membrane coupled with laccase for dye removal in water Y.Y. Ge (<i>Guangxi University, China</i>)
14:50	J014 Invited	Development of building insulation materials from geopolymer M.R. Wang (<i>Harbin Institute of Technology, Weihai, China</i>)
15:15	J019 Invited	Geopolymers containing cesium and the structure transformation under hydrothermal or thermal treatment Z.Y. Lai (<i>Southwest University of Science and Technology, China</i>)

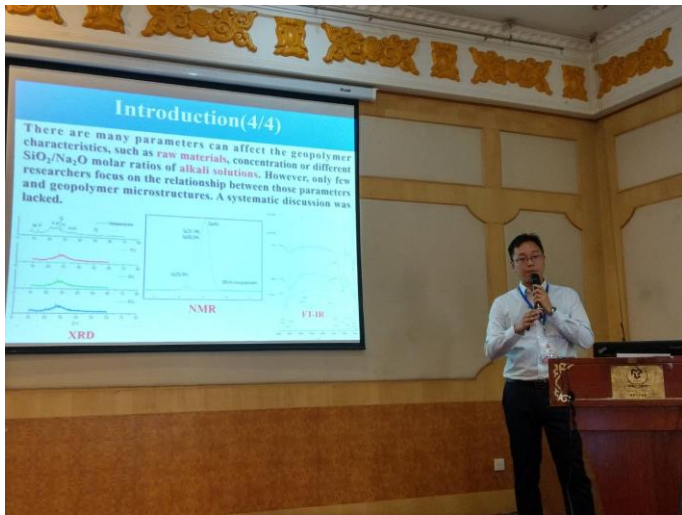
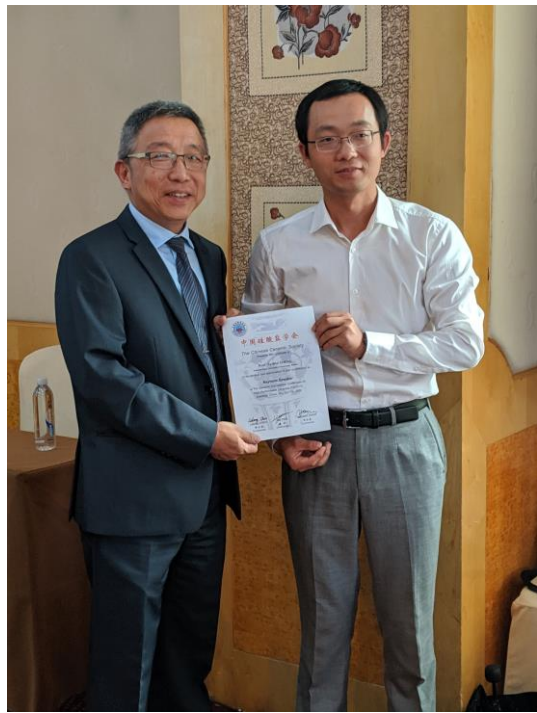
15:50 ~ 17:50

Chair: H.A. Colorado (*Universidad de Antioquia, Colombia*)

15:50	J015 Invited	Processing, microstructure, properties, and applications of highly porous geopolymers C.Y. Bai (<i>Harbin Engineering University, China</i>)
16:15	J018 Invited	Metakaolin-based geopolymer: formation process and the structures J. Li (<i>Southwest University of Science and Technology, China</i>)
16:40	J021 Invited	Geopolymerization and in-situ preparation of graphene/leucite through reduced graphene oxide/geopolymer composites S. Yan (<i>Northeastern University, China</i>)
17:05	J022 Invited	Effects of Li ⁺ substitution on the microstructure and properties of composites derived from C ₆ /C ₅₍₁₋₃₎ Li _x GPs J.K. Yuan (<i>Harbin Institute of Technology, China</i>)
17:30	J110	Bio-electrochemical studies for harvesting carbon dioxide to organic compounds R. Farooq (<i>COMSATS University Islamabad, Pakistan</i>)

3. 相關照片





4. 與會證書

