Self Compacting Geopolymer Concrete: Issues and Options

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History, Vision and Mission of UTP

Universiti Teknologi PETRONAS is a wholly-owned subsidiary of PETRONAS, Malaysia's national oil and gas corporation. Established in 1997, the university has the following vision and mission:

Vision

A Leader in Technology Education and Centre for Creativity and Innovation

Mission

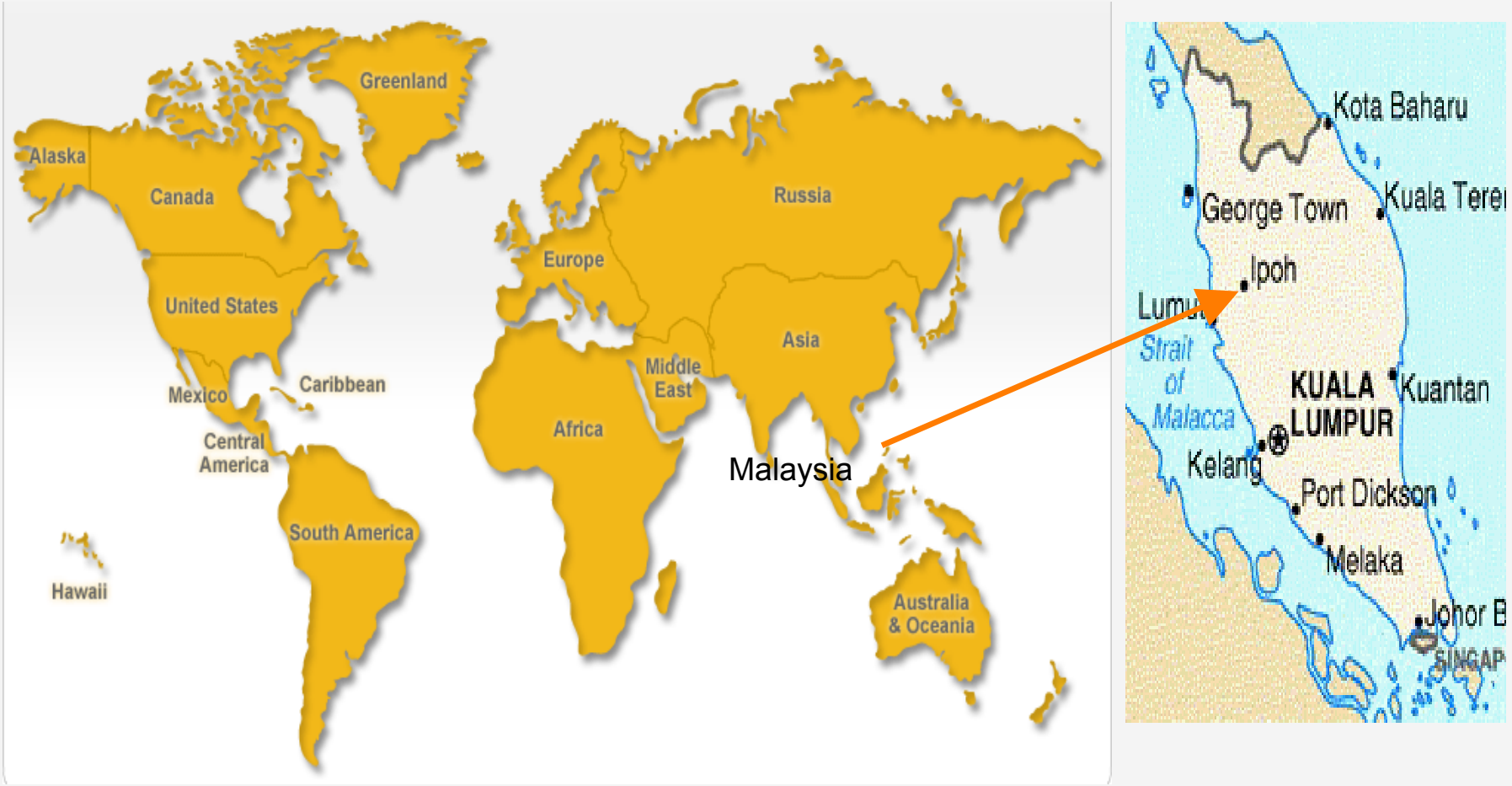
UTP is an institute of higher learning. We provide opportunities for the pursuit of knowledge and expertise for the advancement of engineering, science and technology to enhance the nation's competitiveness.

Our objective is to produce well-rounded graduates who are creative and innovative with the potential to become leaders of industry and the nation.

Our aim is to nurture creativity and innovativeness and expand the frontiers of technology and education for the betterment of society.

Location of the University

The campus is located in Malaysia, at a town called Bandar Seri Iskandar between Ipoh and Lumut, 200 km north of Kuala Lumpur.



The Motivation – why geopolymer concrete

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- **Depletion of Natural resources (Lime stone and Clay)**
  - To manufacture 1 ton of PC, 1.6 tons of raw materials are needed
- **Emission of CO_2 & other greenhouse gases into the atmosphere**
  - To produce 1 ton of PC, about 1 ton of CO_2 is released to the atmosphere
  - By the year 2020, the CO_2 emissions will rise by about 50% from the current levels
- **High energy Consumption**
  - To manufacture 1 ton of PC, about 6.5 million BTUs of energy is needed
  - Annual global production of concrete is about 9 billion cubic meters
- **Global usage of Concrete is 2nd to Water**

Cement production consumes a lot of limestone and emits CO_2

The Motivation – why self compacting

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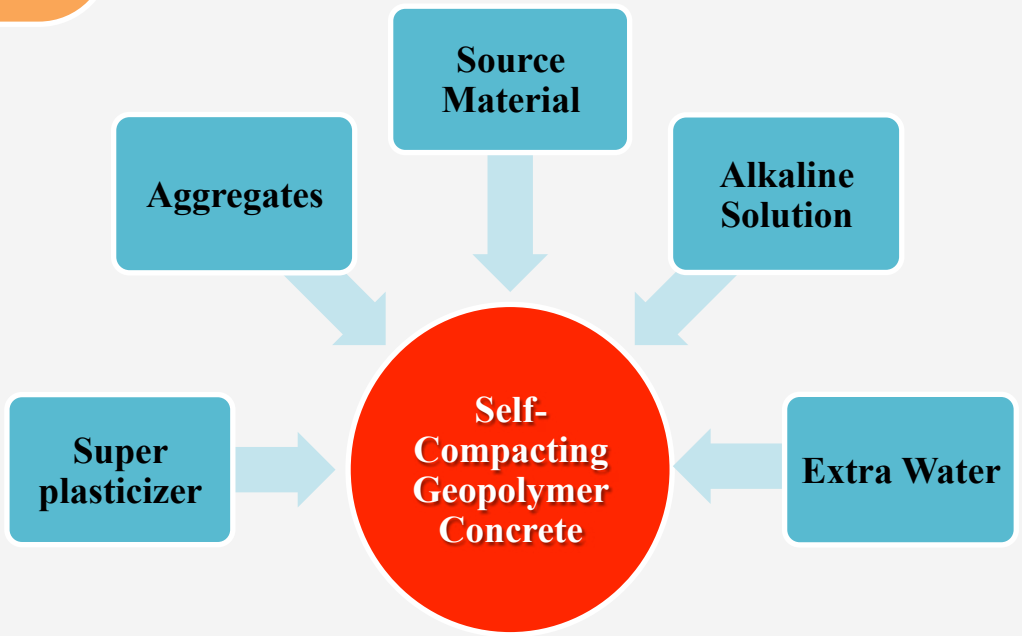
- Compaction is vital in concrete sometimes difficult
- Inadequate compaction significantly lowers ultimate performance of concrete.
- Placement of fresh concrete requires skilled operatives to ensure adequate compaction to attain full strength and durability

INTRODUCTION

Self-compacting Geopolymer Concrete

- **Relatively a new concept for geopolymer concrete**
- **Challenges : quick hardening, stiff matrix**



Self-compacting Concrete

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- Compacted into every corner of the formwork purely by means of its own weight.
- Highly flowable concrete that flows through congested reinforcement under its own weight.

Self-compacting Concrete

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- SCC offers many benefits and advantages over conventional concrete. These include:

  - improved quality of concrete
  - reduced construction time
  - easier placement in congested reinforcements
  - uniform and complete consolidation
  - increased bond strength
  - reduced noise levels due to absence of vibration
  - lower overall costs, and safe working environment.

Self-compacting Concrete

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- **A concrete mix can only be classified as SCC if the requirements for all the following three workability properties are fulfilled [EFNARC, (2005)].**

✓ **Filling ability {Test Methods: Slump flow, V-funnel}**

✓ **Passing ability {Test Methods: U-box, L-box, and J-ring}**

✓ **Stability or Segregation resistance {The ability to resist segregation and must meet both the filling ability and passing ability requirements}**

RESEARCH METHODOLOGY

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EXPERIMENTAL DETAILS

Materials

Fly ash

Aggregates

Alkaline Solution

Superplasticizer

Extra water

RESEARCH METHODOLOGY

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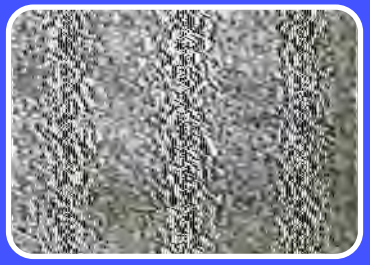
Fly Ash

- Low-calcium (ASTM Class F)
- obtained locally



Coarse Aggregate

- Well graded coarse aggregate of maximum size 14 mm
- used in SSD form

Fine Aggregate

- Natural Malaysian sand with the fineness modulus of 2.76
- sieved for the size less than 5mm

RESEARCH METHODOLOGY

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Sodium Silicate

- Solution form, Grade A53 with SiO_2 = 29.43%, Na_2O = 14.26% & water = 56.31%

Sodium hydroxide

- Pellet form with 99% purity
- To make solution, sodium hydroxide pellets were dissolved in the water

Superplasticizer

- Commercially available named as Sika Viscocrete-3430

RESEARCH METHODOLOGY

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Mix Proportion

- **Manufacture of SCGC was carried out by using the traditional trial and error methods**
- **To develop a suitable mix proportion, a total of 17 mixtures were prepared by varying the amount of extra water, curing time, curing temperature, dosage of superplasticizer and concentration of NaOH**

RESEARCH METHODOLOGY

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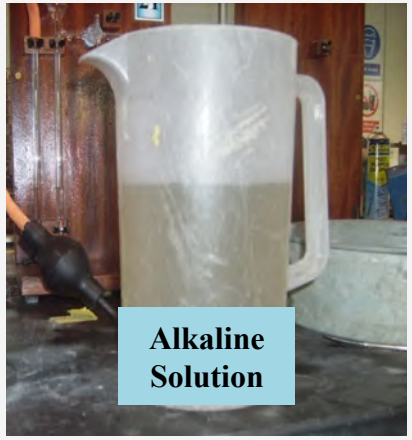
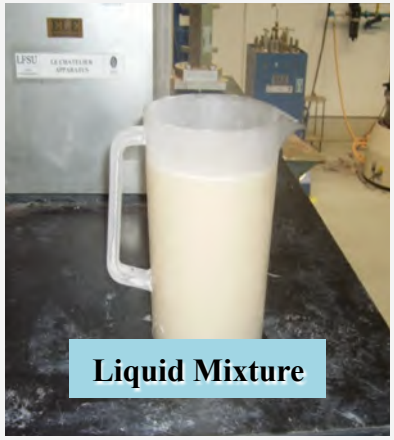
MIX PROPORTIONS

Mix Code	Fly Ash	F.Agg	C.Agg	Sodium Hydroxide		Sodium Silicate	Alkaline/ Fly ash	Super plasticizer		Extra water		Curing	
												Time	Temp
	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Mol	Kg/m^3	Ratio	Kg/m^3	%	Kg/m^3	%	hrs	°C
M_1	400	850	950	57	12	143	0.5	28	7	40	10	24	70
M_2	400	850	950	57	12	143	0.5	28	7	48	12	24	70
M_3	400	850	950	57	12	143	0.5	28	7	60	15	24	70
M_4	400	850	950	57	12	143	0.5	28	7	80	20	24	70
M_5	400	850	950	57	12	143	0.5	28	7	48	12	48	70
M_6	400	850	950	57	12	143	0.5	28	7	48	12	72	70
M_7	400	850	950	57	12	143	0.5	28	7	48	12	96	70
M_8	400	850	950	57	12	143	0.5	28	7	48	12	48	60
M_9	400	850	950	57	12	143	0.5	28	7	48	12	48	80
M_{10}	400	850	950	57	12	143	0.5	28	7	48	12	48	90
M_{11}	400	850	950	57	12	143	0.5	12	3	48	12	48	70
M_{12}	400	850	950	57	12	143	0.5	16	4	48	12	48	70
M_{13}	400	850	950	57	12	143	0.5	20	5	48	12	48	70
M_{14}	400	850	950	57	12	143	0.5	24	6	48	12	48	70
M_{15}	400	850	950	57	8	143	0.5	24	6	48	12	48	70
M_{16}	400	850	950	57	10	143	0.5	24	6	48	12	48	70
M_{17}	400	850	950	57	14	143	0.5	24	6	48	12	48	70

RESEARCH METHODOLOGY





Materials Used → Mixing → Testing for Fresh Properties → Casting & Curing → Testing for Hardened Properties

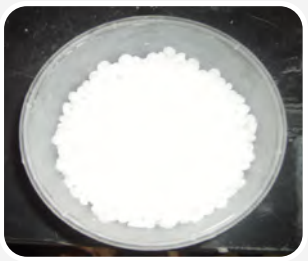















RESULTS AND DISCUSSIONS

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Fresh Properties of SCGC

- **Workability of freshly prepared SCGC was dependent on the dosage of SP and the amount of extra water.**
- **Addition of extra water improved the workability characteristics of freshly prepared concrete mixes.**
- **Concrete mixes containing more than 10% of extra water showed good flowability and produced desired results.**
- **However, mixture with amount of extra water as 20%, showed bleeding as well as segregation.**

RESULTS AND DISCUSSIONS

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Fresh Properties of SCGC

- **Addition of SP had positive influence on the fresh properties of the concrete.**
- **Workability characteristics were effectively improved with the increase in SP dosage.**
- **SP dosage of up to 5% was found insufficient to produce desired flowability.**
- **Mixes with SP dosage of 6% and 7% produced desired results and were within the EFNARC range of SCC.**

RESULTS AND DISCUSSIONS

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Fresh Properties of SCGC

- **Variation in concentration of NaOH was found to have a little effect on the workability properties of SCGC.**
- **Workability of fresh concrete was slightly reduced as the concentration of NaOH was increased from 8M to 14M.**

TEST RESULTS AND DISCUSSIONS

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WORKABILITY TEST RESTULTS

Mix Code	Workability Test Results				
	Slump flow	T_{50} Slump flow	V-Funnel Flow time	L-Box (H_2/H_1)	J-Ring
	(mm)	(sec.)	(sec.)	Ratio	(mm)
M_1	630	6.5	12.5	0.82	12
M_2	710	4.0	7	0.96	5
M_3	770	3.0	6	1.0	3
M_4	820	2.5	5.5	1.0	0
M_5	710	4.0	7	0.96	5
M_6	710	4.0	7	0.96	5
M_7	710	4.0	7	0.96	5
M_8	710	4.0	7	0.96	5
M_9	710	4.0	7	0.96	5
M_{10}	710	4.0	7	0.96	5
M_{11}	625	6.5	15.5	0.84	13
M_{12}	640	6.0	14	0.88	10
M_{13}	665	5.0	12.5	0.90	8
M_{14}	690	4.5	10	0.94	7
M_{15}	700	4.0	9.5	0.96	5
M_{16}	690	4.0	10	0.95	6
M_{17}	675	5.0	12	0.90	9
Acceptance Criteria for SCC as per EFNARC					
Min.	650 mm	2 sec.	6 sec.	0.8	0 mm
Max.	800 mm	5 sec.	12 sec.	1.0	10 mm

TEST RESULTS AND DISCUSSIONS

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COMPRESSIVE STRENGTH TEST RESTULTS

Mix Code	Compressive Strength Test Results			
	1-Day	3-Day	7-Day	28-Day
	(MPa)			
M_1	53.46	54.33	55.08	56.29
M_2	45.01	45.85	46.94	48.53
M_3	37.31	37.90	38.56	39.78
M_4	22.58	22.98	23.44	24.18
M_5	51.03	51.98	52.26	53.80
M_6	51.41	52.20	52.69	53.92
M_7	51.68	52.33	52.72	53.99
M_8	44.81	45.64	45.98	47.54
M_9	48.56	49.22	49.80	50.77
M_{10}	47.99	48.83	49.67	50.42
M_{11}	40.85	41.77	42.84	44.69
M_{12}	42.02	42.68	44.17	46.86
M_{13}	44.74	45.28	46.19	48.90
M_{14}	47.83	48.52	49.44	51.52
M_{15}	41.45	42.14	43.62	44.87
M_{16}	45.19	46.02	47.32	49.28
M_{17}	46.96	47.64	48.98	50.46

CONCLUSION

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From the experimental results, the following conclusions are drawn:

1. **The addition of extra water improved the workability characteristics of freshly prepared concrete; however, the inclusion of water beyond 15% resulted in bleeding and segregation of fresh concrete and decreased the comp. strength of the hardened concrete. The comp. strength of SCGC was significantly decreased as the amount of extra water exceeded 12% by mass of FA.**

2. **Longer curing time improved the geopolymerisation process resulting in higher comp. strength. The comp. strength was highest when the specimens were cured for a period of 96 hours; however, the increase in strength after 48 hours was not significant.**

CONCLUSION

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3. **Concrete specimens cured at 70°C produced the highest comp. strength as compared to specimens cured at 60°C, 80°C and 90°C.**

4. **The inclusion of SP not only improved the workability characteristics of fresh concrete but also increased the comp. strength of hardened concrete. SP dosage of up to 5% was found insufficient to produce desired flowability. Concrete specimens containing 7% of SP exhibited the highest comp. strength at all ages.**

5. **The concentration variation of NaOH of 8M to 14M was found to have a small effect on the workability of concrete. Concrete samples with NaOH concentration of 12M produced maximum compressive strength.**

THANK YOU

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