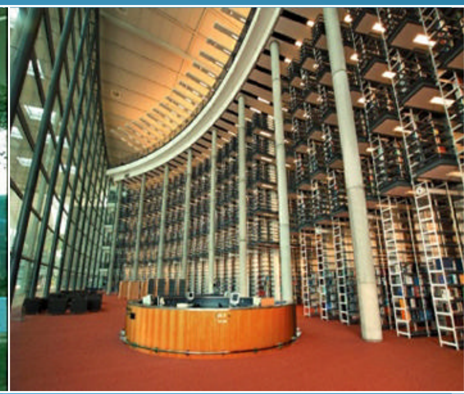
GEOPOLYMER CONCRETE

Muhd Fadhil Nuruddin

Civil Engineering Department

Universiti Teknologi PETRONAS - Malaysia






OBJECTIVE

GEOPOLYMER CONCRETE FOR SUSTAINABLE FUTURES

Objectives

- **To develop a geopolymer concrete with MIRHA that meets 28 day cube strength of 40-50 Mpa**
- **To establish the most appropriate curing regime for in-situ construction**
- **To identify the mechanical properties of geopolymer concrete i.e. compression and tension**
- **To identify the cementing potential of geopolymer concrete through scanning electron microscopy (SEM)**

INTRODUCTION

About 3% of the Earth's land surface is occupied by urban areas (Global Rural urban mapping project data)

By 2025 about 66% of the world's population will live in urban areas on 7% of the land (C.M.Dordi)

Annual global production of concrete is about 5 billion cubic yards (The Cement Association of Canada)

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In 2005, Cement production made a new record of 2.31 billion metric ton by the increase of 5.5%/yr

Production of cement will increase from about 1.5 billion tons in 1995 to 2.2 billion tons in 2010 (Malhotra , 1999).

Causes of Global warming

- Emission of greenhouse gases, such as CO_2
- CO_2 contributes about 65% of global warming (McCaffery,2002)
- Expected to rise by 50% by 2020 (Malhotra, 2004)
- One ton of Portland cement emits approximately one ton of CO_2 into the atmosphere (Davidovits, 1994: McCaffery, 2002)

Depletion of raw material

- To produce one ton of Portland cement 1.6 tons of raw materials (especially limestone) are needed (T.R Naik).
- Extraction of raw materials from the earth is 20% faster than the earth replenish it (T.R Naik).
- Whole geographical regions running out of limestone resource (T.R Naik).

METHODOLOGY

Materials Selection

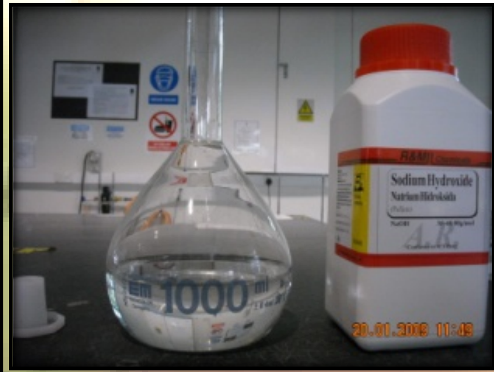
Oxide Content of Fly Ash

Oxide	Percentages (%)
SiO_2	51.19 %
Al_2O_3	24.00 %
Fe_2O_3	6.60 %
CaO	5.57 %
MgO	2.40 %
SO_3	0.88 %
K_2O	1.14 %
Na_2O	2.12 %

Oxide Content of MIRHA

Oxide	Percentage (%)
SiO_2	88.90 %
MgO	0.72 %
SO_3	0.32 %
CaO	0.63 %
K_2O	3.65 %
Al_2O_3	0.16 %
Fe_2O_3	0.45 %

8 Molar of NaOH solutions was produced from 99% purity NaOH pellets



$NaSiO_2$ contains Na_2O: 14.73%, SiO_2: 29.75%, and water: 55.52%.

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Material Selection

- **<u>Sodium Silicate</u>**
  - **Commercial Grade**
  - **Used in a form of solution containing 56.31% of water, 29.43% of SiO_2 and 14.26% of Na_2O.**

- **<u>Sodium Hydroxide</u>**
  - **Commercial grade**
  - **Used in form of pellets (40g/mol)**
  - **Concentration of solution is 8M**

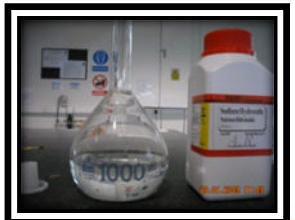
- **<u>Sugar</u>**
  - **Commonly used white plain sugar**

Mixture Proportion

Mix Code	Fly Ash	Coarse	Fine	NaOH	Na_2SiO_3	Water	Sugar
	(kg/m3)						
A1	350	1200	645	41	103	35	3.5
A2	350	1200	645	41	103	35	7
A3	350	1200	645	41	103	35	10.5
A01	350	1200	645	41	103	35	0
A02	350	1200	645	41	103	52.5	0
HG	350	1200	645	41	103	35	10.5
EE	350	1200	645	41	103	35	10.5
O1	350	1200	645	41	103	35	3.5
O2	350	1200	645	41	103	35	7
O01	350	1200	645	41	103	35	0
O02	350	1200	645	41	103	52.5	0

Research Methodology

Material Preparation → Mixing → Curing → Testing






MIRHA Geopolymer Concrete Mixture

Failure of testing cube

Failure of Cylinder in Tension

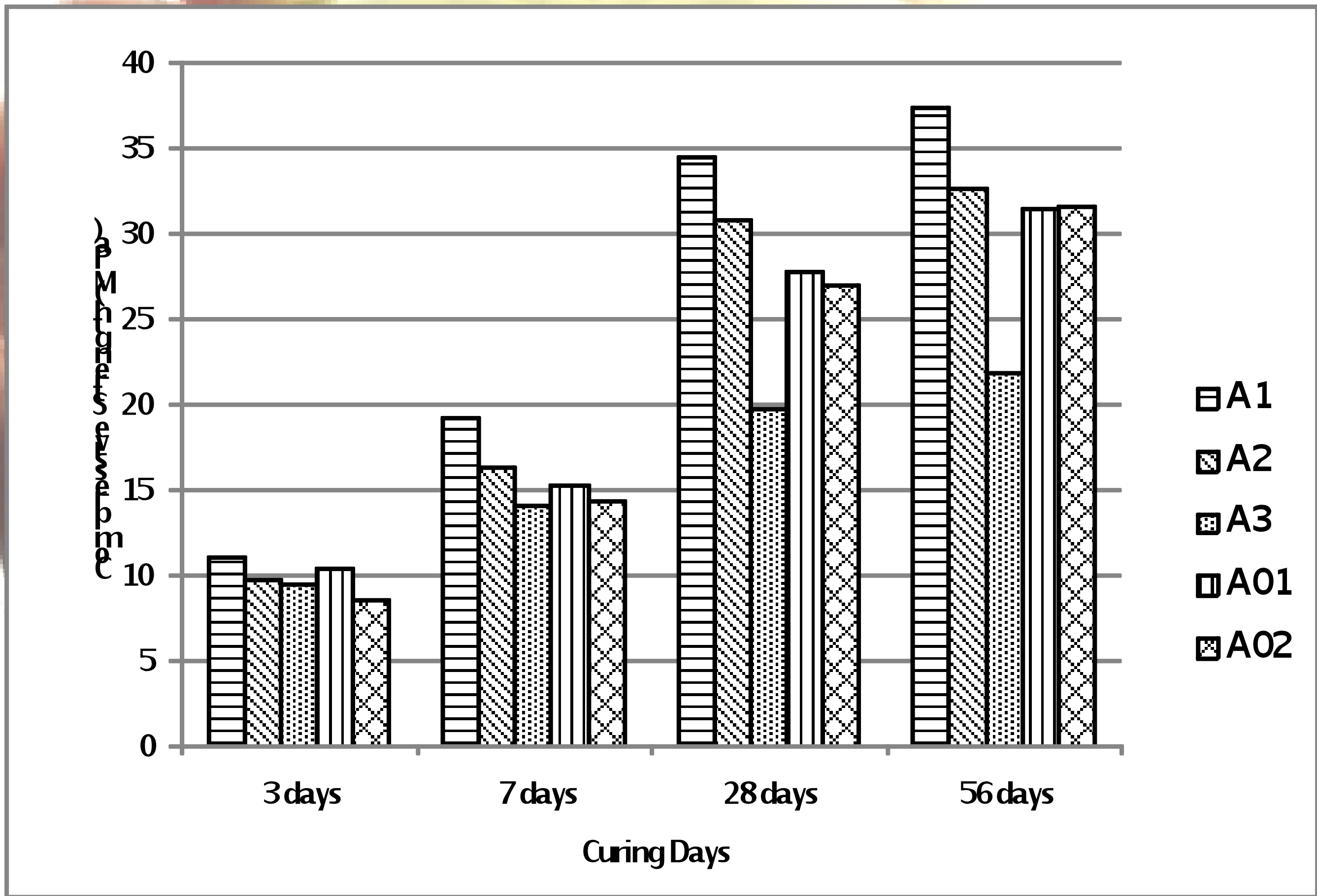
RESULTS & DISCUSSION

Result and Discussion

Mix Code	1	3	7	28	56
	days				
A1	n/a	11.10	19.20	34.52	37.42
A2	n/a	9.82	16.40	30.85	32.65
A3	n/a	9.50	14.11	19.73	21.92
A01	n/a	10.47	15.32	27.80	31.50
A02	n/a	8.58	14.44	27.03	31.57
HG	n/a	5.00	9.00	15.00	16.96
EE	n/a	34.50	42.30	48.70	50.60
O1	31.86	33.56	32.57	37.03	n/a
O2	36.20	36.10	36.58	39.80	n/a
O01	23.04	23.42	24.13	24.33	n/a
O02	33.31	34.39	34.14	35.30	n/a

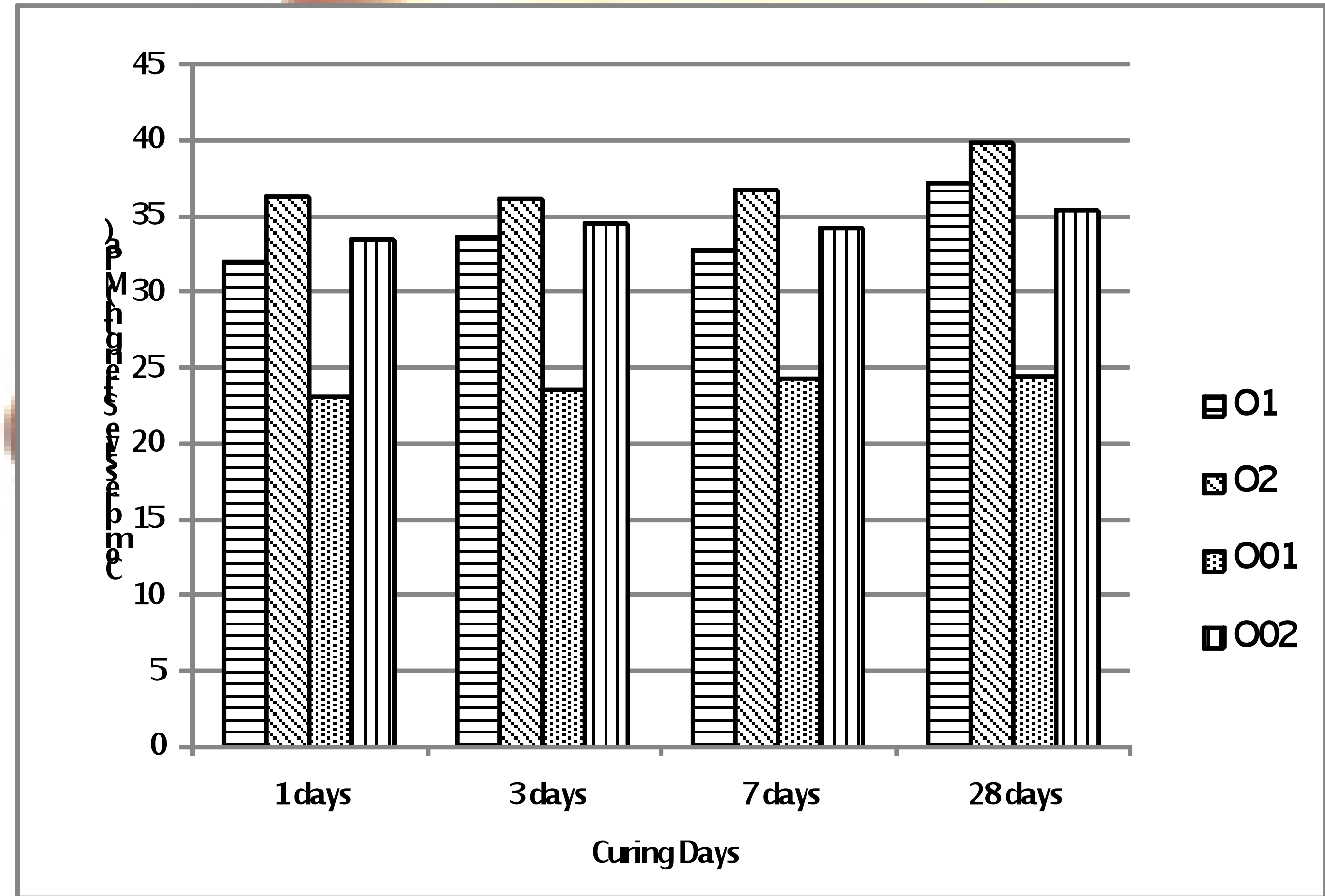
Result and Discussion

Compressive strength results of ambient curing geopolymer concrete



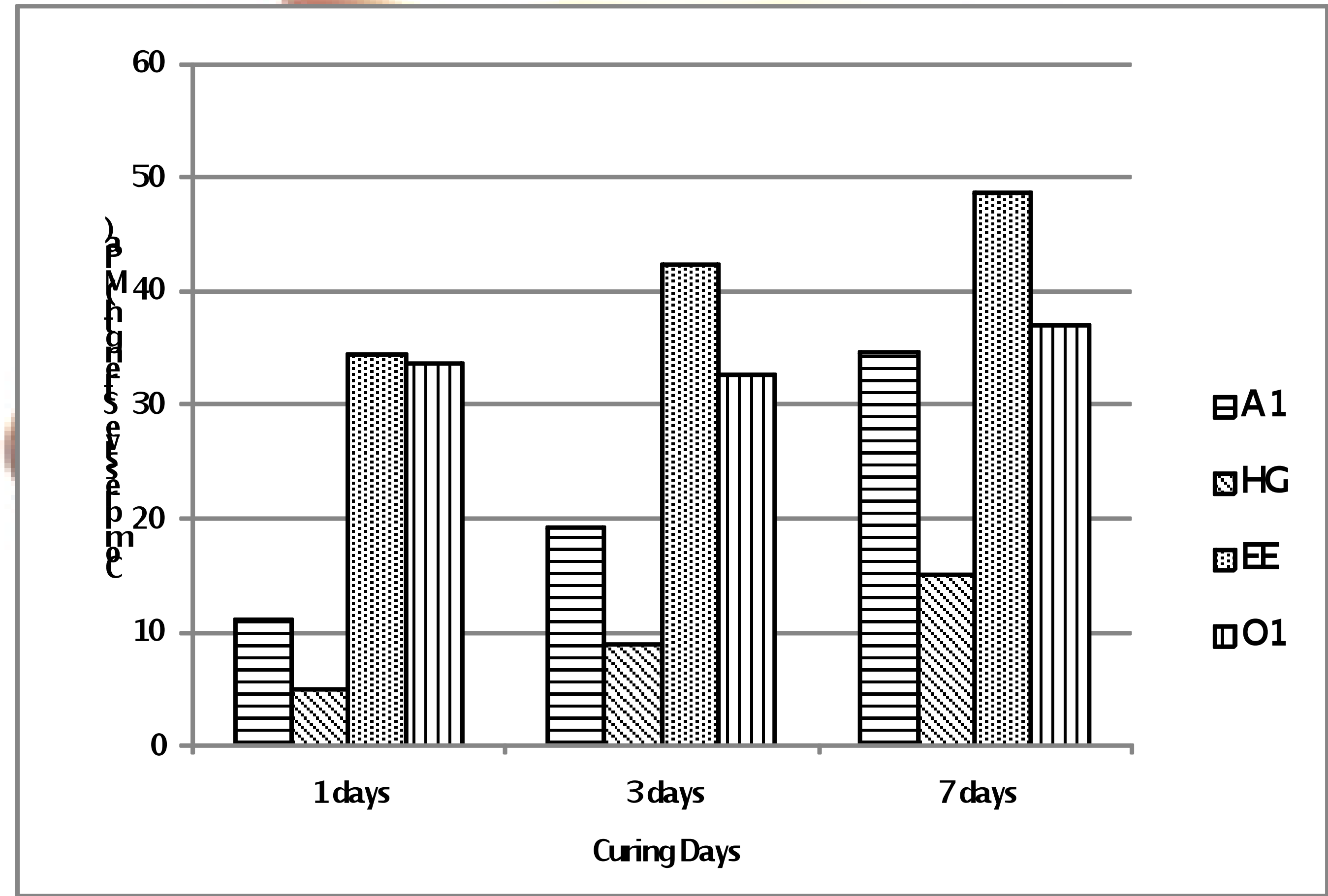
Result and Discussion

Compressive strength results of oven curing geopolymer concrete

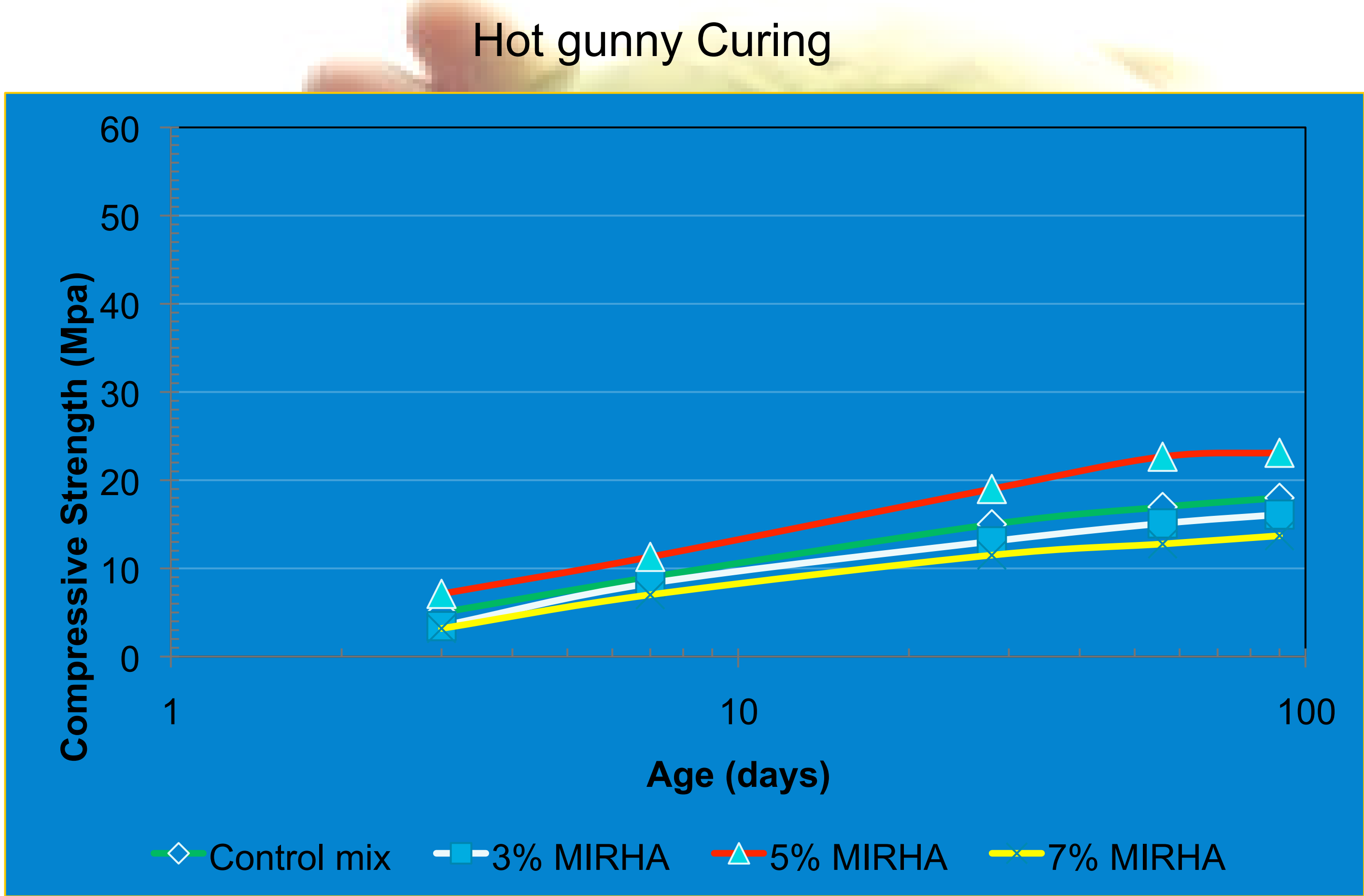


Result and Discussion

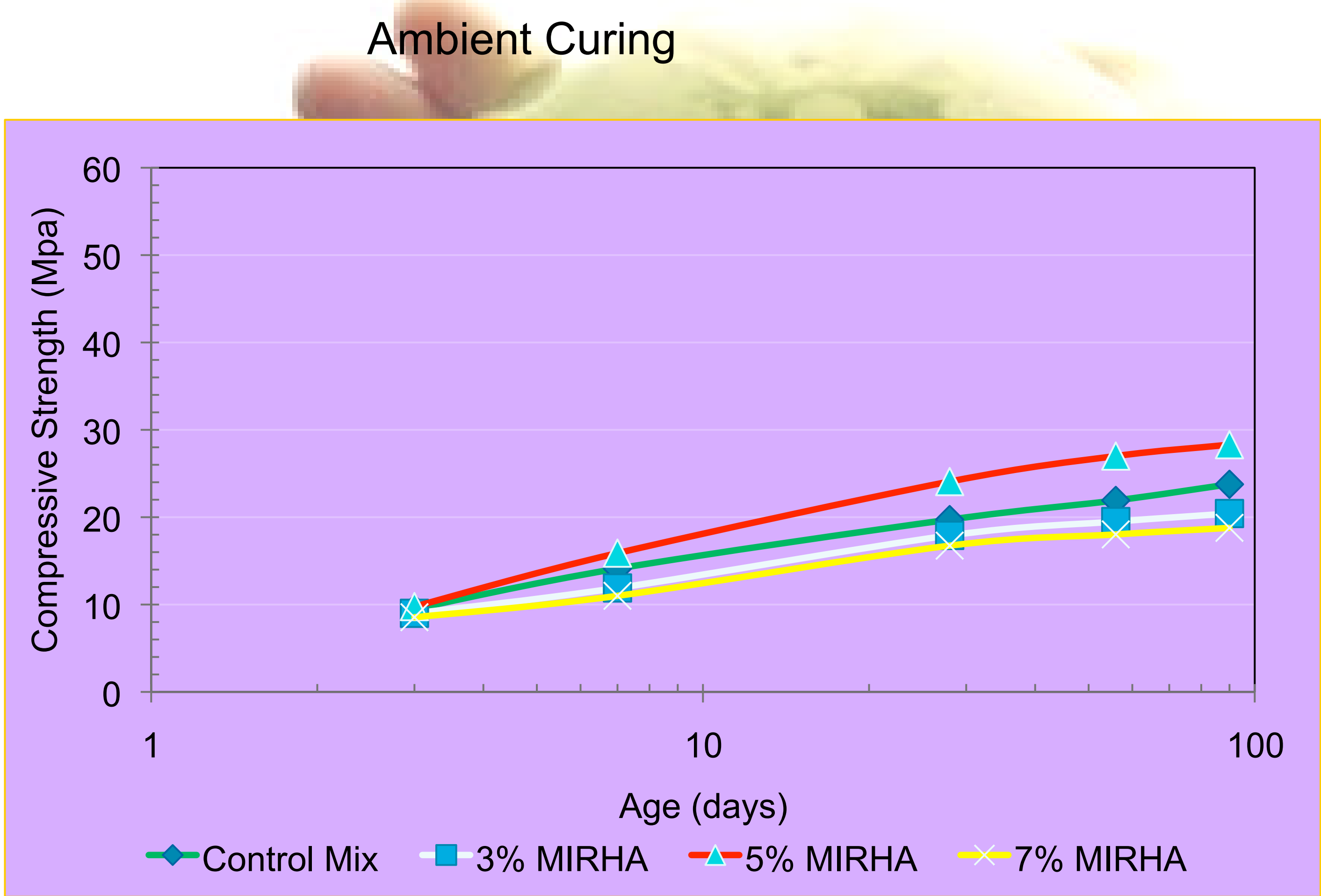
Comparison between each curing method



Result and Discussion



Result and Discussion



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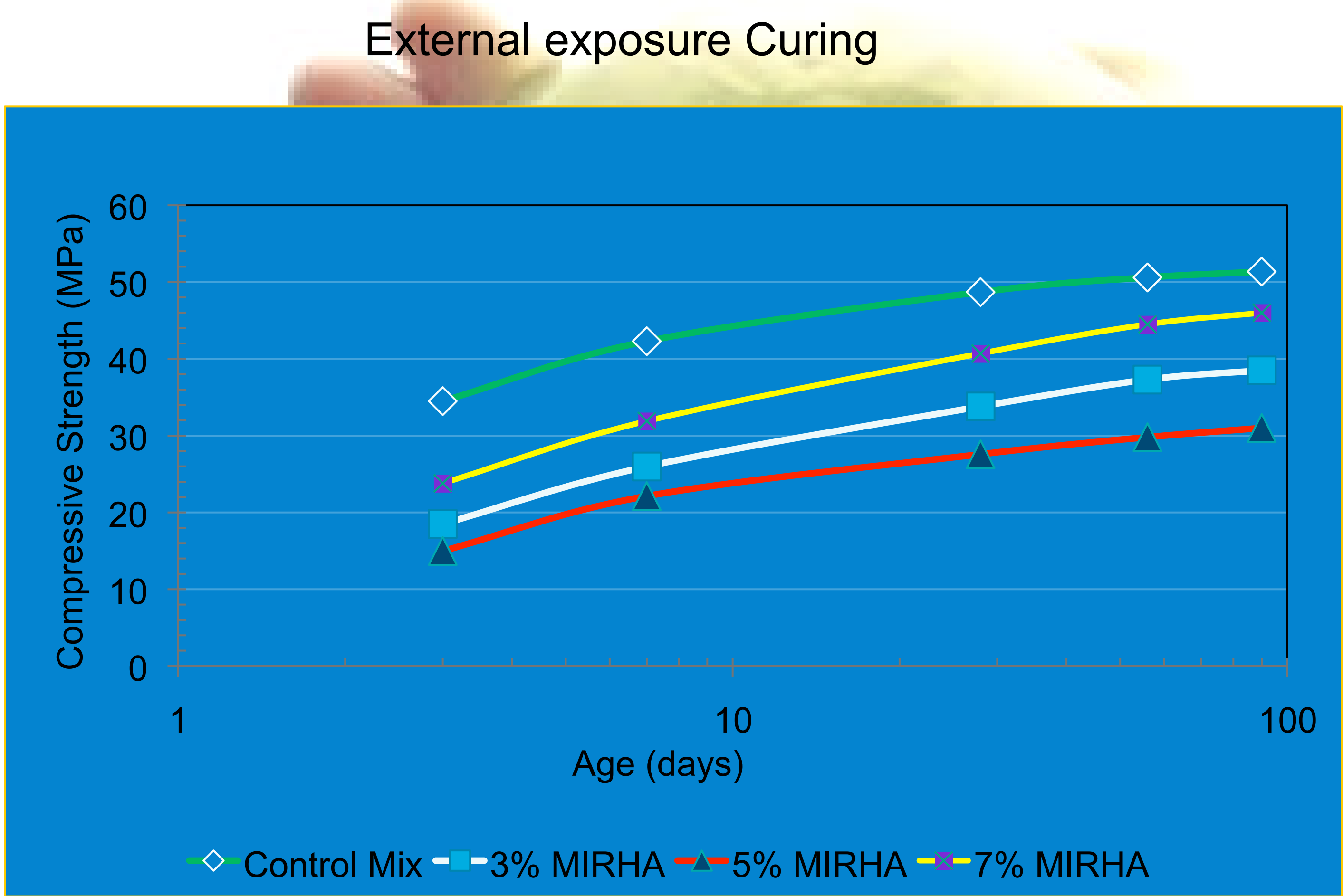
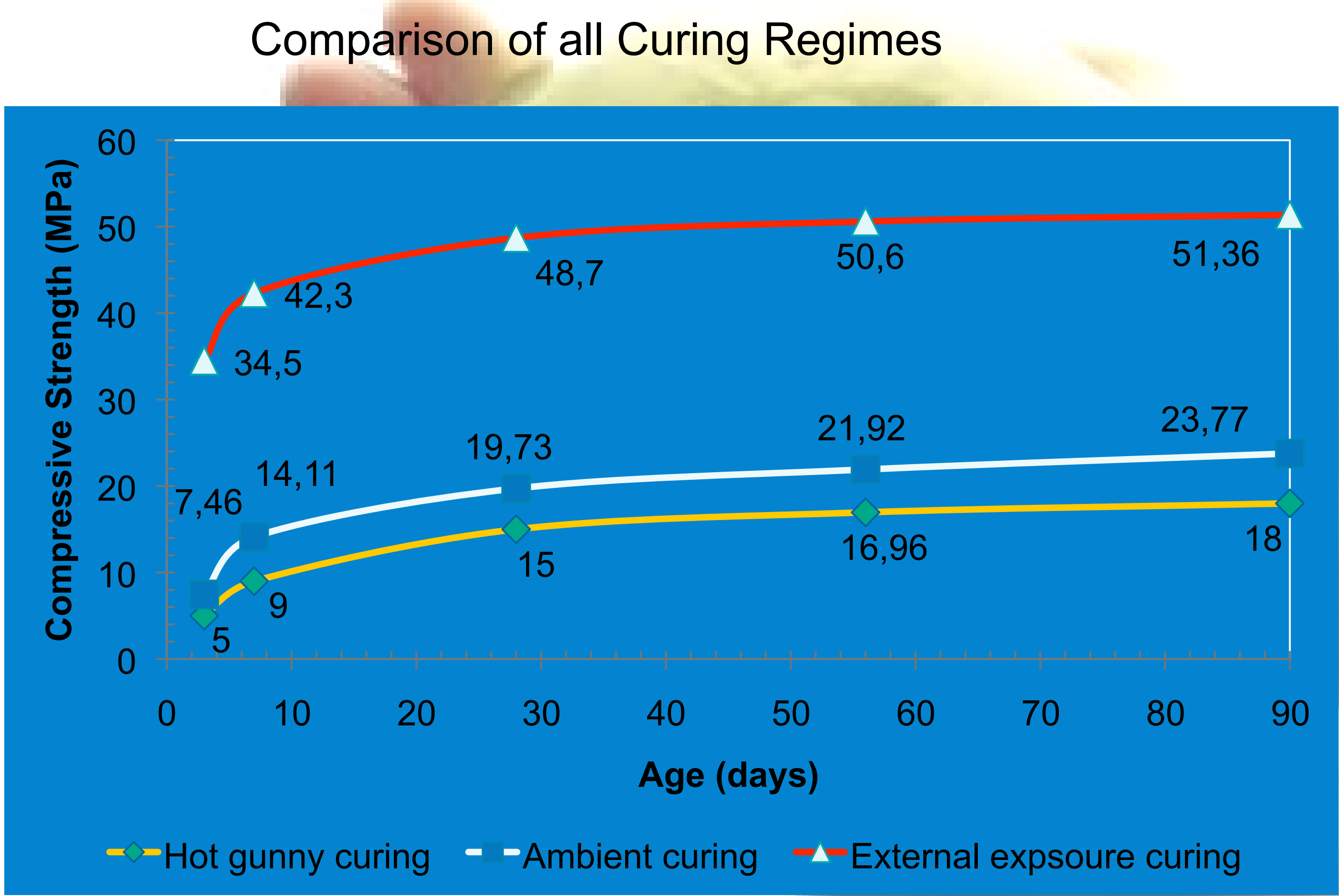
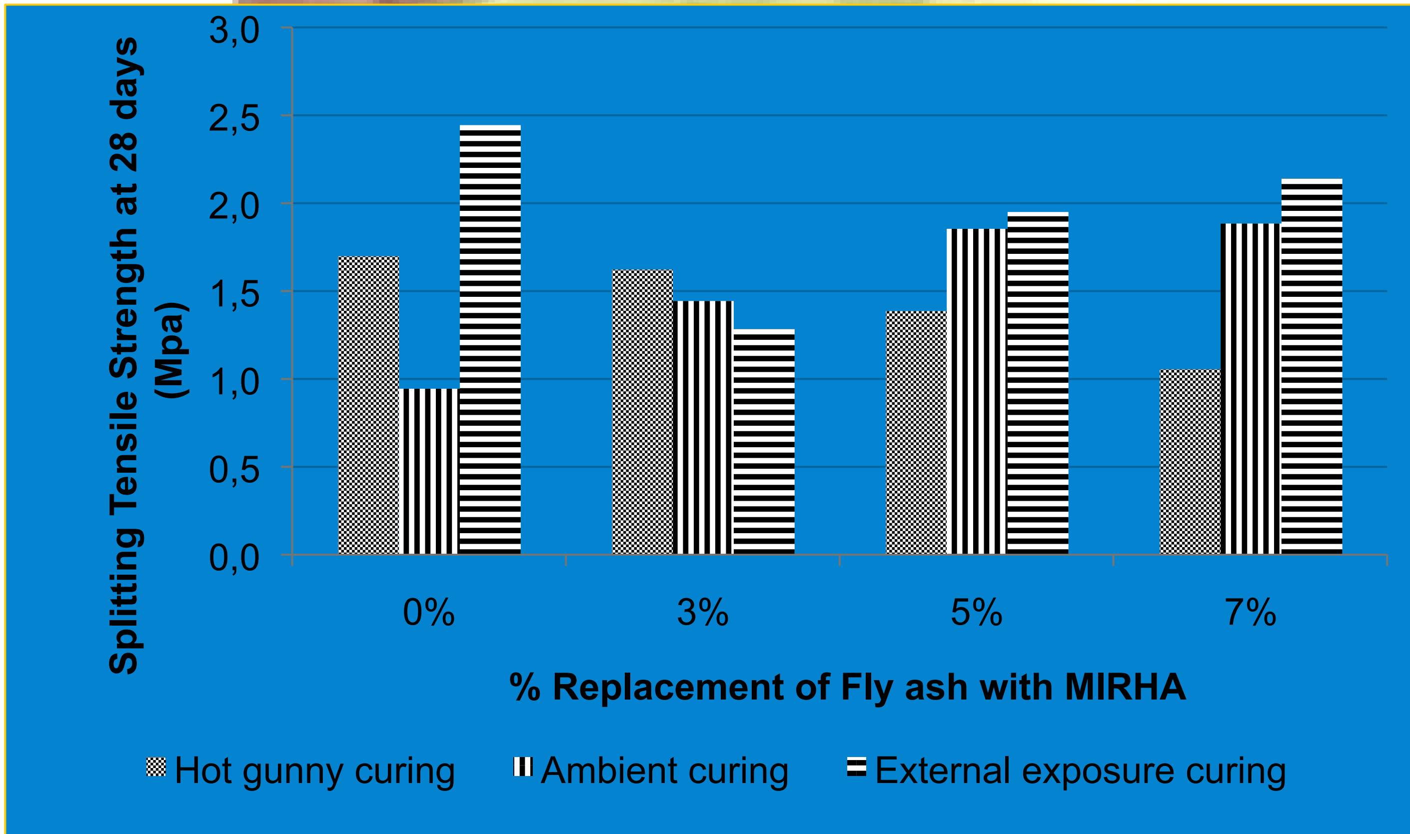


Result and Discussion



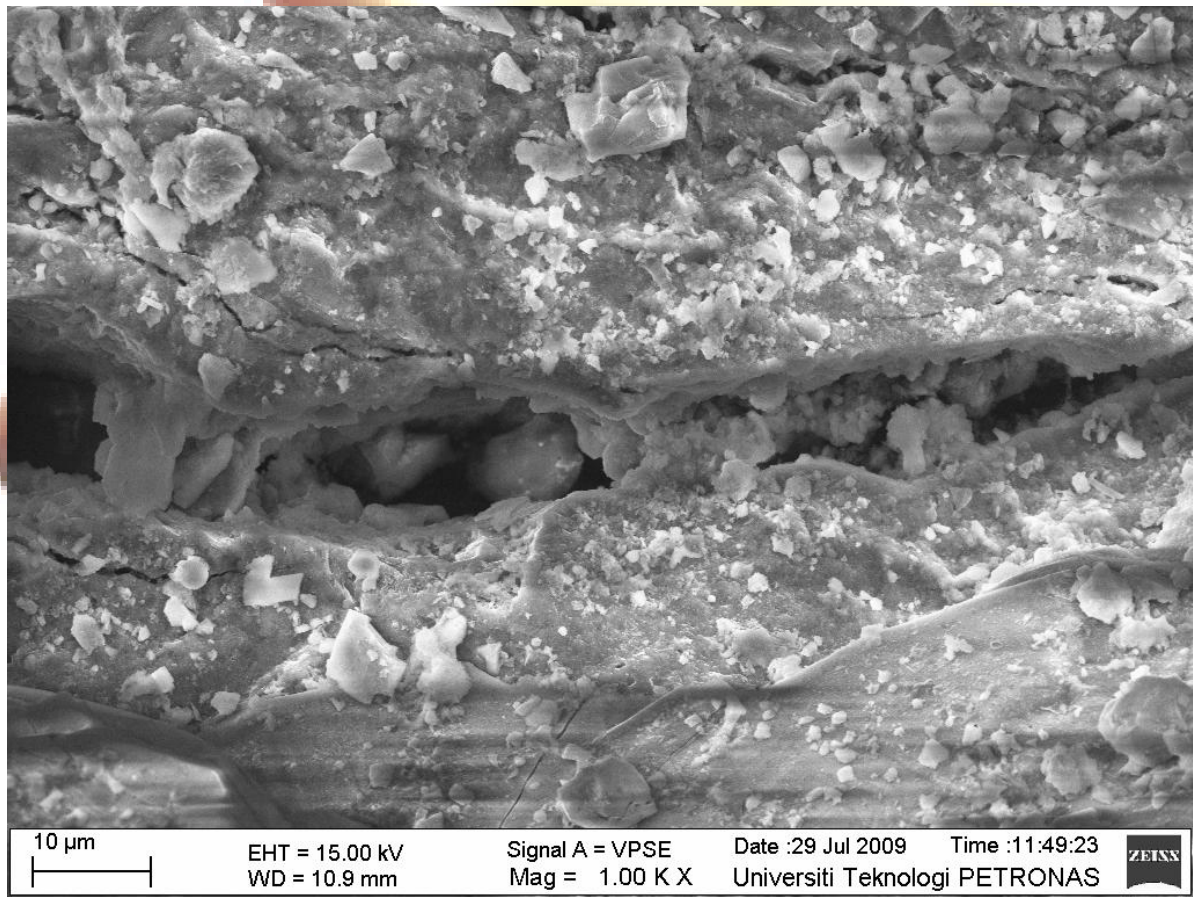
Result and Discussion

Comparison of all Curing Regimes for Splitting Strength



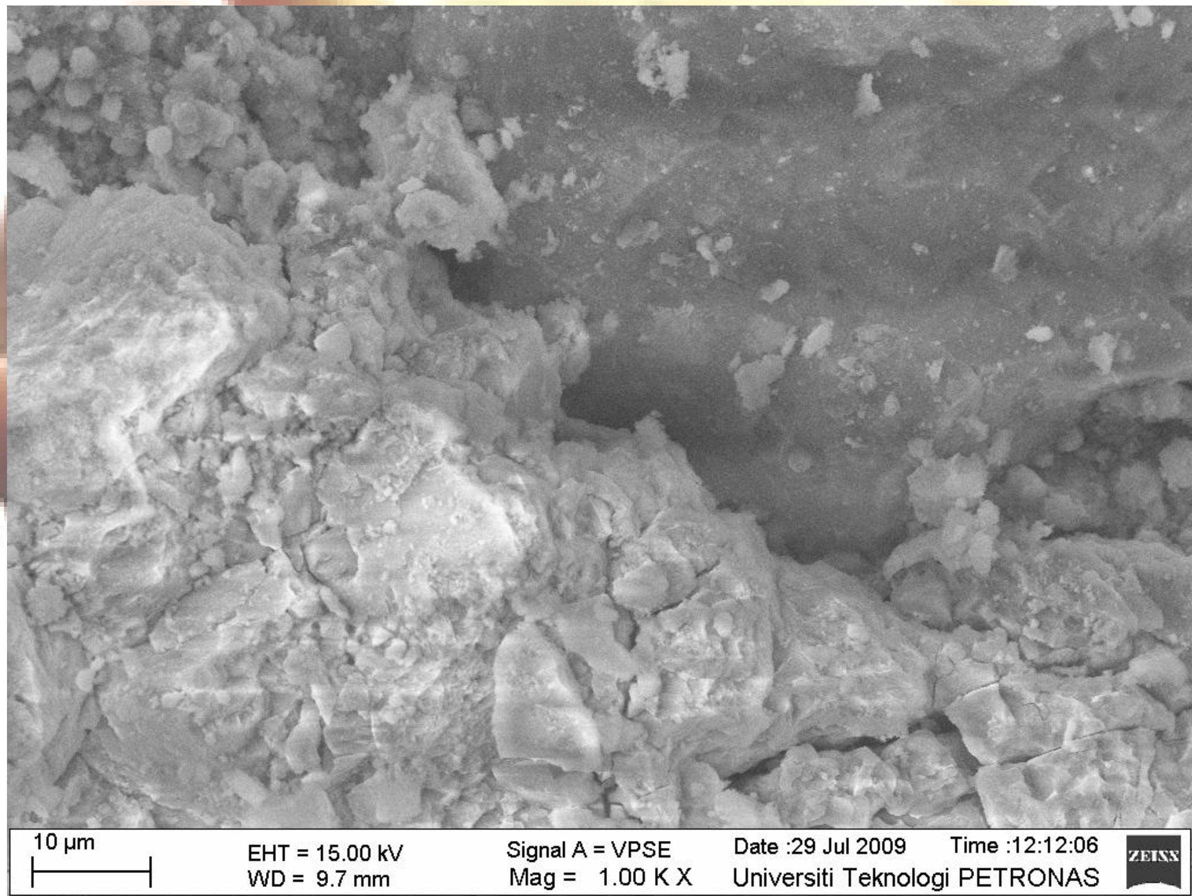
Result and Discussion

SEM Images of Concrete Sample with Hot Gunny Curing



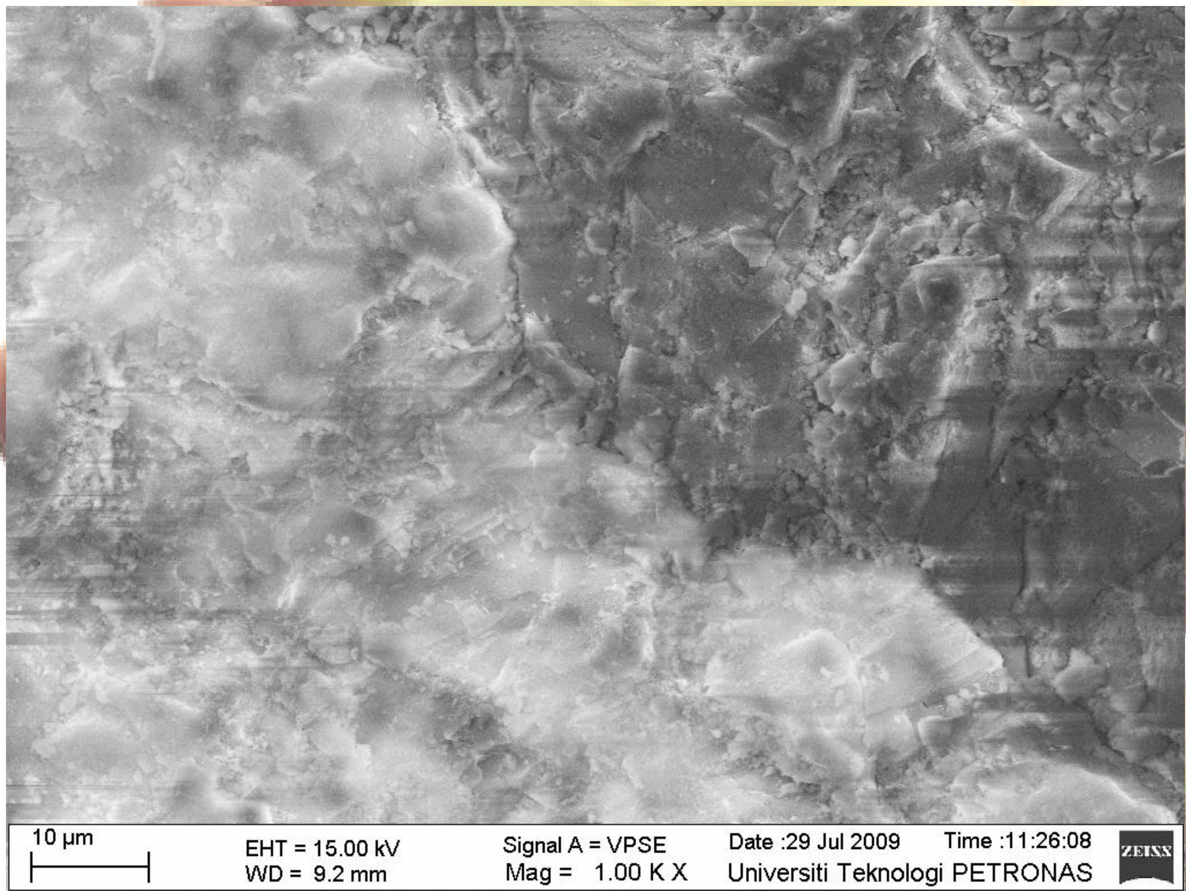
Result and Discussion

SEM Images of Concrete Sample with Ambient Curing



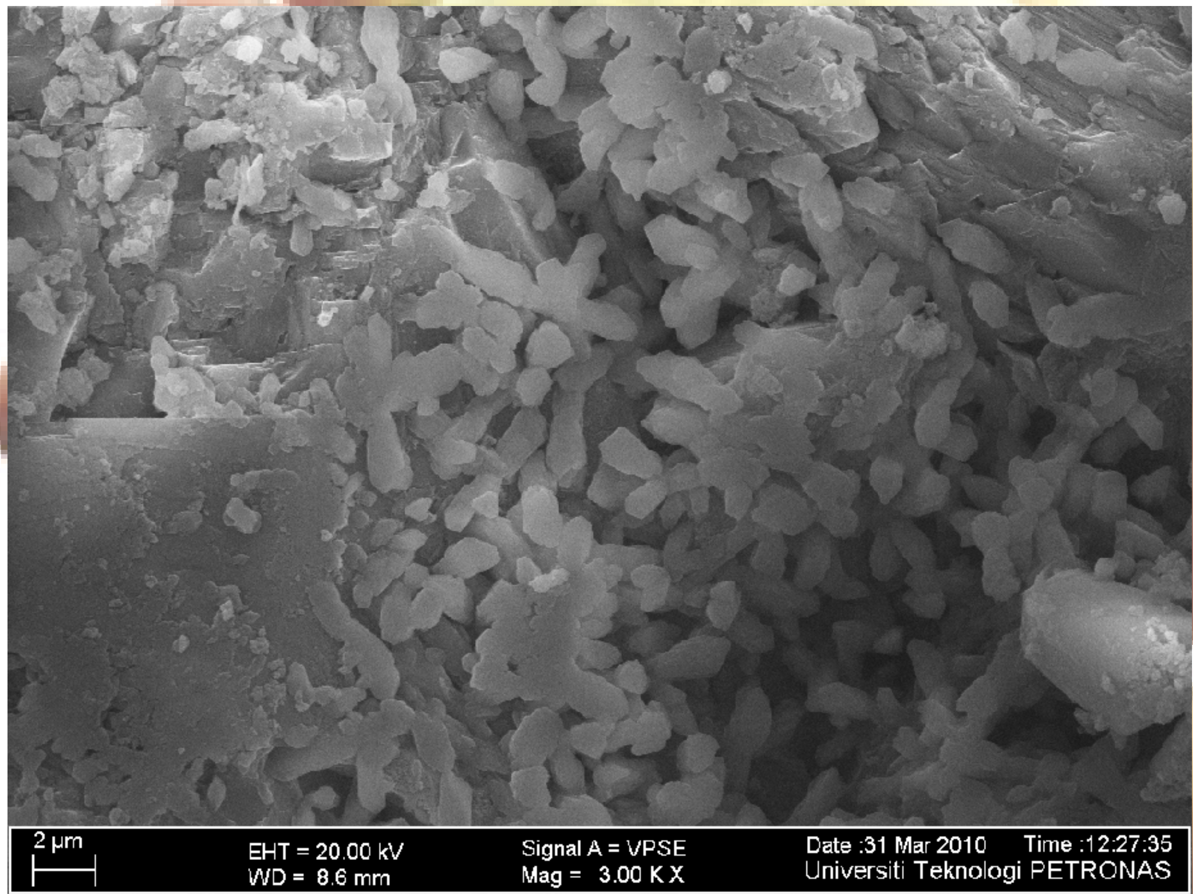
Result and Discussion

SEM Images of Concrete Sample with External Exposure Curing



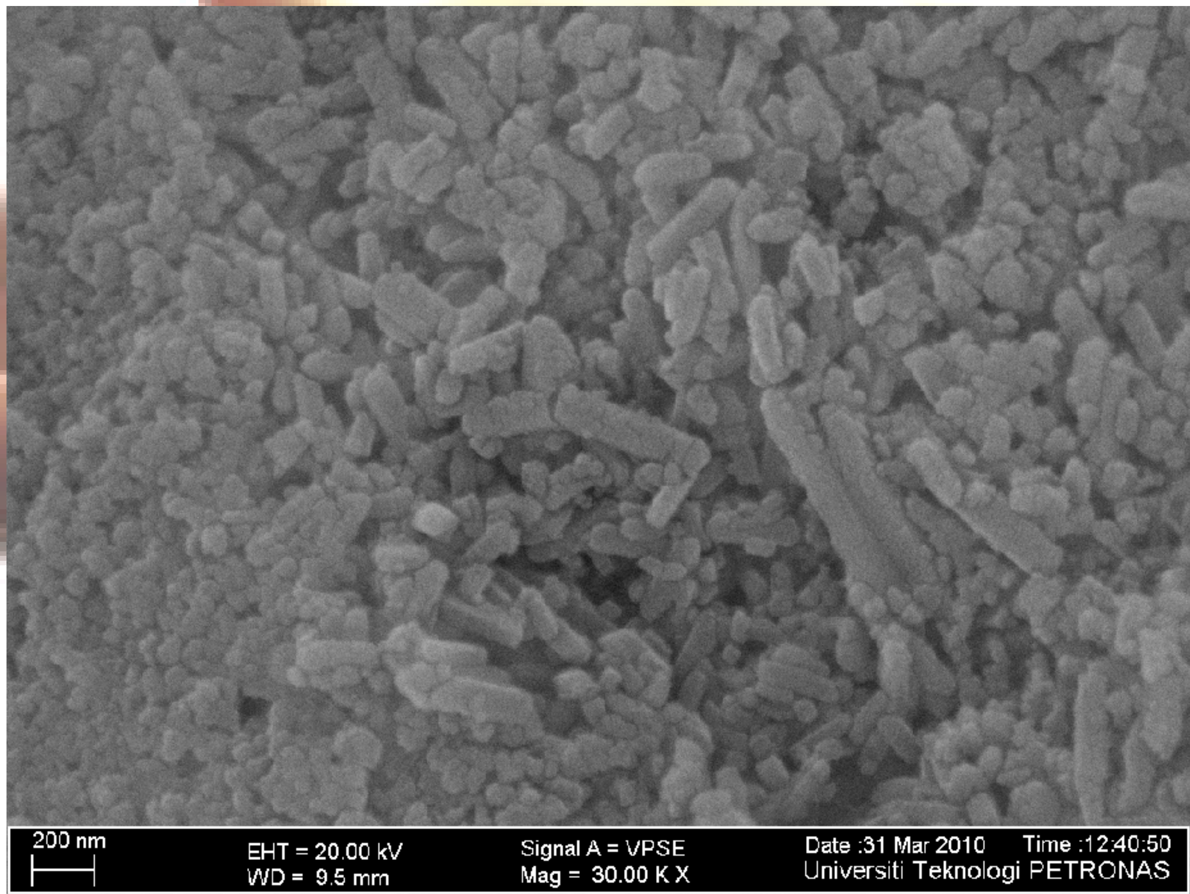
Result and Discussion

SEM Images of Concrete Sample with Oven Curing



Result and Discussion

SEM Images of Geopolymer Micelles



CONCLUSION

Conclusion

The inclusion of glucose as natural retarder has successfully improved fly ash based geopolymer concrete. In ambient curing, 1% addition of glucose to the mixture could improve concrete strength up to 18.79% higher compared to non glucose mixture, while in external exposure curing, 2% inclusion of glucose had compressive strength up to 12.75% higher than non glucose sample.

Between these curing methods, external exposure curing provided the most optimum curing condition to geopolymer concrete. It was believed that gradual increment in the temperature presented an important role to the fly ash based geopolymer concrete performance.

Conclusion (Con't)

Fly ash and MIRHA together with NaOH and Na-Silicate can be a good replacement of cement in concrete.

Strength is developed till 28 days and there is no significant increment in strength with age after 28 days.

5% replacement of Fly ash with MIRHA is optimum amount for hot gunny and ambient curing.

Among all three types of curing, external exposure curing is the best.

SEM analysis showed that by external exposure curing, better dissolution of Si and Al occurred that lead to a compact microstructure and greater strength.