DEVELOPING GEOPOLYMER COMPOSITES USING DRY MIXING TECHNIQUE

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IINTRODUCTION

Sustainability Issues:

- Each ton of cement production-one ton of carbon-dioxide, 1 kg of sulphur dioxide (SO_2), 2 kg oxides of nitrogen (NO_x) and 10 kg dust into the atmosphere (Zhang et al., 2018)
- Shortage of Landfill sites

Optimum Solution:

Geopolymer concrete (GPC)- novel form of concrete, synthesized by the alkali activation of source materials (aluminosilicate rich materials) (Davidovits, 1991).

On Site Feasibility Problems:

- Highly corrosive alkaline solution-based reagents
- Heat Curing

Feasible Solution: Dry Mixing Technique

- Powder-based reagents: required in less quantity
- Source Materials: aluminosilicate rich materials
- No need of heat curing

OBJECTIVE

- Develop cement free binder for the production/development of sustainable engineered composites.
- Geopolymer Technology

$$(Si_2O_5.Al_2O_2)_n + H_2O + OH^- \rightarrow Si(OH)_4 + AL(OH)^{4-}$$

$$Si(OH)_4 + AL(OH)^4 \rightarrow (\text{-Si-O-Al-O-})_n + 4H_2O$$

Geopolymerisation (Komnitsas, 2011)

EXPERIMENTAL WORK

Table 1- Mix Proportions for Geopolymer Composites

Binder*	Mix Designation**	Activator	Activator/ Binder	Activator component ratio	Water/Binder	HRWRA***
FA(C)+ GGBS	M1A1	$Ca(OH)_2$+ $Na_2SiO_3.5H_2O$	0.09	$Na_2SiO_3.5H_2O$/ $Ca(OH)_2$=2.5	0.35	0
	M1A2	$Ca(OH)_2$+ Na_2SO_4	0.12	$Ca(OH)_2$/ Na_2SO_4=2.5	0.35	0.01
FA(F)+ GGBS	M2A1	$Ca(OH)_2$+ $Na_2SiO_3.5H_2O$	0.09	$Na_2SiO_3.5H_2O$/ $Ca(OH)_2$=2.5	0.3	0
	M2A2	$Ca(OH)_2$+ Na_2SO_4	0.12	$Ca(OH)_2$/ Na_2SO_4=2.5	0.35	0
GGBS	M3A1	$Ca(OH)_2$+ $Na_2SiO_3.5H_2O$	0.09	$Na_2SiO_3.5H_2O$/ $Ca(OH)_2$=2.5	0.35	0
	M3A2	$Ca(OH)_2$+ Na_2SO_4	0.12	$Ca(OH)_2$/ Na_2SO_4=2.5	0.35	0.02

All numbers are mass ratios of binder

*Binder denotes supplementary cementitious materials (SCM_S)

** Mix Designation: M-mix, A-activator

*** HRWRA: Poly-carboxylate based super-plasticizer





Figure 1-Sample Preparation


Figure 2- Ambient Temperature Curing Regime



Figure 3-(a) slump flow spread, (b) setting time test, (c) compressive strength test

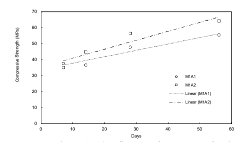
RESULTS AND CONCLUSIONS

Table 1-Density and Compressive Strength

Binder*	Mix Designation	Water/Binder	Days	Density (g/cm^3)	Compressive Strength (MPa)
FA(C)+ GGBS	M1A1	0.35	7/14/28/56	2.1/2/1.97/2.03	37.5/36.6/47.8/55.45
	M1A2	0.35	7/14/28/56	2.14/2.02/2.02/2	35/44.72/56.3/64.2
FA(F)+ GGBS	M2A1	0.3	7/14/28/56	1.85/1.86/1.86/1.87	20.5/25.67/34.05/34.12
	M2A2	0.35	7/14/28/56	1.75/N.A.	8.4/N.A.
GGBS	M3A1	0.35	7/14/28/56	2.08/2/2.02/2	26.15/22.4/29.3/34.1
	M3A2	0.35	7/14/28/56	2.03/2/2.01/2.03	26.75/37.8/34.11/31.77

Table 2-Workability

Binder*	Mix Designation	Water/Binder	HRWRA**	Avg. Flow Dia. (mm)	Relative Slump
FA(C)+ GGBS	M1A1	0.35	0	195	2.8
	M1A2	0.35	0.01	165	1.7
FA(F)+ GGBS	M2A1	0.3	0	170	1.89
	M2A2	0.35	0	N.A.	N.A.
GGBS	M3A1	0.35	0	175	2.06
	M3A2	0.35	0.02	200	3



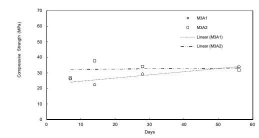


Figure 4- (a) Influence of two types of activators on mix-1, (b) Influence of two types of activators on mix-3

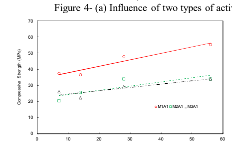
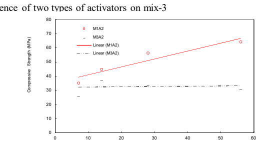



Figure 5- Effect of activator on different source materials (a) A1, (b) A2

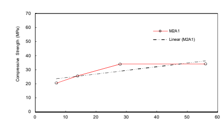
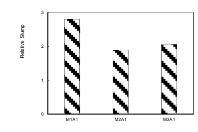


Figure 6- Compressive strength for mix (M2A1)



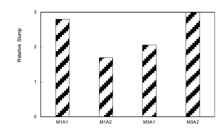


Figure 7- (a) Relative slump of different mixes for activator A1 (b) influence of activators (A1 and A2) on relative slump of different mixes

- The mix combination (M1A2) achieved the highest compressive strength of 64.2 MPa at 56 days.
- The mix M1A1 exhibited a comparable compressive strength of 55.45 MPa at 56 days and higher slump flow than mix M1A2.
- The initial and final setting time of the mix M1A1 was determined to be as 119 minutes and 259 minutes respectively.
- M1A1 was designated as the best performing mix based on slump flow and compressive strength characteristics.

REFERENCES

Zhang, J., Zhang, P., Zheng, Y. and Wang, K. 2018. A review on properties of fresh and hardened geopolymer mortar. *Composites Part B*, Volume 152.

Davidovits, J. 1991. Geopolymers. Journal of Thermal Analysis, 37(8):1633–1656.

Li, V. C., & Kanda, T. (1998). Engineered Cementitious Composites for structural applications. *Journal of Materials in Civil Engineering*, *10*(2), 66–69.

Komnitsas, K. A. (2011) 'Potential of geopolymer technology towards green buildings and sustainable cities', *Procedia Engineering*, 21, pp. 1023–1032. doi: 10.1016/j.proeng.2011.11.2108.

Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)1' (ASTM, 2016). doi: 10.1520/C0109_C0109M-16A.

Standard Test Method for Flow of Hydraulic Cement Mortar 1' (ASTM, 2015). doi: 10.1520/C1437

Designation: C191 − 18a Standard Test Methods for Time of Setting of Hydraulic Cement by Vicat Needle 1' (2018). doi: 10.1520/C0191-18A.

ACKNOWLEDGEMENTS

- CRH Canada
- ATCO Power
- WESTLAB Canada
- NSERC

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