

EACEF-5

The 5th International Conference of
Euro Asia Civil Engineering Forum

EACEF5

The 5th Euro Asia Civil Engineering Forum Conference

Surabaya, Indonesia, 15-18 September 2015

MENU

Home

[+ Program](#)

[+ Announcement](#)

[+ Committee](#)

[+ Participant](#)

[+ Venue & Accomodation](#)

[+ Keynote & Invited Speakers](#)

[+ Post Conference Seminar](#)

[+ Organizers](#)

[+ University Partner](#)

[+ Supporting Organizations](#)

[+ Gallery](#)

COMMITTEE

Steering Committee:

Benjamin Lumantarna, Petra
Christian University,
Surabaya

Harianto Hardjasaputra,
Universitas Pelita Harapan,
Jakarta

Yoyong Arfiadi, Universitas
Atma Jaya Yogyakarta,
Yogyakarta

Timoticin Kwanda, Petra
Christian University,
Surabaya

Manlian A. Ronald,
Universitas Pelita Harapan,
Jakarta

International Scientific Committee

Worsak Kanok-Nukulchai
(Asian Institute of

MORE

PETRA CHRISTIAN UNIVERSITY

 Click to open larger map

IMPORTANT DATES

There are no upcoming events.

[+ Contact Us](#)

PETRA CHRISTIAN UNIVERSITY



Technology, Thailand)
B.V. Rangan (Curtin University, Australia)
Koji Sakai (Kagawa University, Japan)
Takafumi Noguchi (The University of Tokyo, Japan)
Tamon Ueda (Hokkaido University, Japan)
DongUk Choi (Hankyong National University, South Korea)

Tawatchai Tingsanchali (Thailand)

SURABAYA



Piti Sukontasukkul (King Mongkut University of Technology, North Bangkok, Thailand)
Nguyen Van Chanh (Ho Chi Minh City University of Technology, Vietnam)

Chan Weng Tat (National University of Singapore)

Susanto Teng (Nanyang Technological University, Singapore)

Mohd. Warid Hussin (Universiti Teknologi Malaysia)

Prabir K. Sarker (Curtin University, Australia)

Drajat Hoedajanto (HAKI, Indonesia)

Robby Soetanto



NEARBY HOTELS



Yellow Hotel



Rich Palace Hotel



JW Marriott Hotel Surabaya

 Hotel SWK 95

 Ibis Styles Hotel

powered by MapsMarker.com

(Loughborough University,
UK)

Iswandi Imran (Bandung
Institute of Technology,
Indonesia)

Tavio (Institut Teknologi
Sepuluh Nopember,
Indonesia)

Sholihin As'ad (Sebelas
Maret University, Indonesia)

Han Ay Lie (Diponegoro
University, Indonesia)

Gideon Hadi Kusuma
(Australia)

Sugie Prawono (Petra
Christian University,
Indonesia)

Wimpy Santosa
(Parahyangan Catholic
University, Indonesia)

Ade Sjafruddin (Bandung
Institute of Technology,
Indonesia)

Organizing Committee

Chairman

DjwantoroHardjito, Petra
Christian University

Vice-Chairman

Rudy Setiawan, Petra
Christian University

Members

Ima Muljati, Petra Christian

University
Antoni, Petra Christian
University
Gogot Setyo Budi, Petra
Christian University
Jack Widjajakusuma,
Universitas Pelita Harapan
Wiryanto Dewobroto,
Universitas Pelita Harapan
Anastasia Yunika,
Universitas Atma Jaya
Yogyakarta
Johanes Januar Sudjati,
Universitas Atma Jaya
Yogyakarta
Daniel Tjandra, Petra
Christian University
Wong Foek Tjong, Petra
Christian University
Cilcia Kusumastuti, Petra
Christian University
Sandra Loekita, Petra
Christian University
Pamuda Pudjisuryadi, Petra
Christian University
Paravita Sri Wulandari, Petra
Christian University
Effedy Tanojo, Petra
Christian University
Ratna S. Alifen, Petra
Christian University
Indriani Santoso, Petra
Christian University
Irwan Tanuadji, Petra

Christian University
Sri Megawati Hermanto,
Petra Christian University



ORGANIZERS:



UNIVERSITAS
KRISTEN
PETRA



UPH
UNIVERSITAS PELITA HARAPAN



UNIVERSITAS
ATMA JAYA YOGYAKARTA

Petra Christian University (www.petra.ac.id)



The app covers 21,000 journals
from All publishers

**Research
Highlights**

Journals Books

Shopping cart

Sign in

Help

You have **Guest** access to
ScienceDirect Find out more...

Search all fields

Author name

--This Journal/Book--

Volume

Issue

Page

Advanced search



Procedia Engineering

[Open Access](#) | [About this Journal](#)

[Get new article feed](#)

[Subscribe to new volume alerts](#)

[Add to Favorites](#)

Copyright © 2015 Elsevier Ltd. All rights reserved

Procedia Engineering
Volume 125, Pages 1-1156 (2015)
Civil Engineering Innovation for a Sustainable
Edited by Antoni, Ima Muljati and Djwantor Hardjito

[< Previous vol/iss](#) | [No next vol/iss](#)

[No prev art. 1 - 100 of 166](#) [Next >](#)

Volumes 121 - 125 (2015)

Volume 125

pp. 1-1156 (2015)
Civil Engineering Innovation for a Sustainable

Volume 124

pp. 1-356 (2015)
24th International Meshing Roundtable

Volume 123

pp. 1-614 (2015)
Selected papers from Creative Construction Conference 2015

Volume 122

pp. 1-320 (2015)
Innovative solutions in Construction Engineering and Management.Flexible Approach

Volume 121

pp. 1-2240 (2015)
The 9th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC) joint with the 3rd International Conference on Building Energy and Environment (COBEE), 12-15 July 2015, Tianjin, China

Volumes 111 - 120 (2015)

Volumes 101 - 110 (2015)

Volumes 91 - 100 (2014 - 2015)

Volumes 81 - 90 (2014)

Volumes 71 - 80 (2014)

Volumes 61 - 70 (2013 - 2014)

Volumes 51 - 60 (2013)

Volumes 41 - 50 (2012)

Volumes 31 - 40 (2012)

Volumes 21 - 30 (2011 - 2012)

Volumes 11 - 20 (2011)

Volumes 1 - 10 (2009 - 2011)

Export

Open Access articles

- | | | |
|--------------------------|--|-------------|
| <input type="checkbox"/> | Preface
Pages 1-4
Antoni, Ima Muljati, Djwantor Hardjito
PDF (188 K) | Open Access |
| <input type="checkbox"/> | Performance-based Contracting for Roads – Experiences of Australia and Indonesia Original Research Article
Pages 5-11
Reini Wirahadikusumah, Betty Susanti, Vaughan Coffey, Charles Adighibe
Abstract PDF (274 K) | Open Access |
| <input type="checkbox"/> | Sensitivity Analysis of Risk from Stakeholders' Perception Case Study: Semarang-solo Highway Project Section I (Tembalang-Gedawang) Original Research Article
Pages 12-17
Asri Nurdiana, M. Agung Wibowo, Jati Utomo D. Hatmoko
Abstract PDF (246 K) | Open Access |
| <input type="checkbox"/> | Returns to Scale in Buildings Construction Costs: Indonesian Cases Original Research Article
Pages 18-24
Andreas Wibowo
Abstract PDF (285 K) | Open Access |
| <input type="checkbox"/> | The Analysis of Supply Chain Performance Measurement at Construction Project Original Research Article
Pages 25-31
M. Agung Wibowo, Moh Nur Sholeh
Abstract PDF (489 K) | Open Access |
| <input type="checkbox"/> | The Practice of Time Management on Construction Project Original Research Article
Pages 32-39
Lok Siew Chin, Abdul Rahim Abdul Hamid
Abstract PDF (1009 K) | Open Access |
| <input type="checkbox"/> | Analysis of Factors Affecting Design Changes in Construction Project with Partial Least Square (PLS) Original Research Article
Pages 40-45
A.A. Gde Agung Yana, Rusdhi H.A., M. Agung Wibowo
Abstract PDF (400 K) | Open Access |
| <input type="checkbox"/> | Identification and Analyze of Influence Level on Waste Construction Management of Performance Original Research Article
Pages 46-52
Elizar, M. Agung Wibowo, Pinaridi Koestalam | Open Access |

ADVERTISEMENT

EVENTS YOU MAY BE INTERESTED IN

[International Reliability Physics Symposium \(RIPS\)](#)
17–21 Apr 2016
Pasadena, United States

 **3rd International Conference on Structural Nonlinear Dynamics and Diagnosis**
23–25 May 2016
Marrakech, Morocco

INTRACONNEX 2016 (Industrial Trade Conference & Exhibition) Medan – North Sumatra
20–22 Apr 2016
Medan, Indonesia

[More events »](#)

Powered by
GLOBALEVENTSLIST

[Abstract](#) | [PDF \(268 K\)](#)

- [Structural Equation Model for Investigating Risk Factors Affecting Project Success in Surabaya](#) Original Research Article Open Access
Pages 53-59
Herry Pintardi Chandra
[Abstract](#) | [PDF \(405 K\)](#)
- [Proactiveness of Contractors: A study of Indonesia](#) Original Research Article Open Access
Pages 60-67
Harjanto Setiawan, Bilge Erdogan, Stephen O. Ogunlana
[Abstract](#) | [PDF \(308 K\)](#)
- [Competitive Aggressiveness of Contractors: A Study of Indonesia](#) Original Research Article Open Access
Pages 68-74
Harjanto Setiawan, Bilge Erdogan, Stephen O. Ogunlana
[Abstract](#) | [PDF \(314 K\)](#)
- [Low-cost Apartment Program Implementation in Surabaya Metropolitan Area](#) Original Research Article Open Access
Pages 75-82
Farida Rachmawati, Ria A.A. Soemitro, Tri Joko W. Adi, Connie Susilawati
[Abstract](#) | [PDF \(256 K\)](#)
- [Model of Learning/Training of Occupational Safety & Health \(OSH\) Based on Industry in the Construction Industry](#) Original Research Article Open Access
Pages 83-88
Bambang Endroyo, Bambang E. Yuwono, Djemari Mardapi, Soenarto
[Abstract](#) | [PDF \(262 K\)](#)
- [Knowledge Management Maturity in Construction Companies](#) Original Research Article Open Access
Pages 89-94
Mochamad Agung Wibowo, Rudi Waluyo
[Abstract](#) | [PDF \(256 K\)](#)
- [An Analysis of Bidding Strategy, Project Performance and Company Performance Relationship in Construction](#) Original Research Article Open Access
Pages 95-102
Mohamad Agung Wibowo, I. Nyoman Yudha Astana, Rusdi H.A.
[Abstract](#) | [PDF \(318 K\)](#)
- [Initial Investigation for Potential Motivators to Achieve Sustainable Construction Safety and Health](#) Original Research Article Open Access
Pages 103-108
Herry Pintardi Chandra
[Abstract](#) | [PDF \(274 K\)](#)
- [Improving Safety Among Small Organisations in the Construction Industry: Key Barriers and Improvement Strategies](#) Original Research Article Open Access
Pages 109-116
Riza Yosia Sunindijo
[Abstract](#) | [PDF \(269 K\)](#)
- [Risk Analysis of BOT Scheme on Post-construction Toll Road](#) Original Research Article Open Access
Pages 117-123
Yudi Harto Suseno, Muhammad Agung Wibowo, Bagus Hario Setiadji
[Abstract](#) | [PDF \(444 K\)](#)
- [Best Practice for Financial Models of PPP Projects](#) Original Research Article Open Access
Pages 124-132
Fedy Kurniawan, Sri Wiwoho Mudjanarko, Stephen Ogunlana
[Abstract](#) | [PDF \(275 K\)](#)
- [Credit Enhancement and its Risk Factors for IPP Projects in Asia: An Analysis by Network Theory](#) Original Research Article Open Access
Pages 133-142
Abu Naser Chowdhury, Po-Han Chen, Robert Tiong
[Abstract](#) | [PDF \(350 K\)](#)

- Successful Criteria for Large Infrastructure Projects in Malaysia** Original Research Article Open Access
Pages 143-149
Md. Asrul Nasid Masrom, Mohd Hilmi Izwan Abd Rahim, Sulzakimin Mohamed, Goh Kai Chen, Riduan Yunus
[Abstract](#) | [PDF \(256 K\)](#)
- Analysis of Rainfall-runoff Neuron Input Model with Artificial Neural Network for Simulation for Availability of Discharge at Bah Bolon Watershed** Original Research Article Open Access
Pages 150-157
Setiono, Rintis Hadiani
[Abstract](#) | [PDF \(809 K\)](#)
- Self and Artificial Air Entrainment in Steep Channel** Original Research Article Open Access
Pages 158-165
Yeri Sutopo, Budi S. Wignyosukarto, Bambang Yulistyanto, Istiarto
[Abstract](#) | [PDF \(432 K\)](#)
- The Application of Rainfall-Runoff-inundation (RRI) Model for Inundation Case in Upper Citarum Watershed, West Java-Indonesia** Original Research Article Open Access
Pages 166-172
Kania Dewi Nastiti, Yeonsu Kim, Kwansue Jung, Hyunuk An
[Abstract](#) | [PDF \(766 K\)](#)
- Effects of Compost Thickness and Compaction on Methane Emissions in Simulated Landfills** Original Research Article Open Access
Pages 173-178
Gabriel Andari Kristanto, Sesaria Marina Raissa, Evi Novita
[Abstract](#) | [PDF \(287 K\)](#)
- Rainfall Erosivity Estimation for Northern and Southern Peninsular Malaysia using Fournier Indexes** Original Research Article Open Access
Pages 179-184
Zul Azmi Mohtar, Ahmad Shukri Yahaya, Fauziah Ahmad
[Abstract](#) | [PDF \(296 K\)](#)
- Impact of Climate Change on Streamflow in the Tropical Lowland of Kapuas River, West Borneo, Indonesia** Original Research Article Open Access
Pages 185-192
Henny Herawati, Suripin, Suharyanto
[Abstract](#) | [PDF \(1235 K\)](#)
- Royal Commission at Yanbu Environmental Regulations** Original Research Article Open Access
Pages 193-198
Ayedh Al Shehai
[Abstract](#) | [PDF \(286 K\)](#)
- Water Turbidity Impact on Discharge Decrease of Groundwater Recharge in Recharge Reservoir** Original Research Article Open Access
Pages 199-206
Akhmad Azis, Hamzah Yusuf, Zulfiyah Faisal, Muhammad Suradi
[Abstract](#) | [PDF \(432 K\)](#)
- Mathematical Modelling of Injection Wells for Flooding Prevention in Jakarta** Original Research Article Open Access
Pages 207-212
Mohajit
[Abstract](#) | [PDF \(292 K\)](#)
- Application of Large Scale Particle Image Velocimetry (LSPIV) to Identify Flow Pattern in a Channel** Original Research Article Open Access
Pages 213-219
Tommy Ekamitra Sutarto
[Abstract](#) | [PDF \(924 K\)](#)
- Sand Dynamics as a Tool for Coastal Erosion Management: A Case Study in Darwin Harbour, Northern Territory, Australia** Original Research Article Open Access
Pages 220-228
Silvia G. Tonyes, Robert J. Wasson, Niels C. Munksgaard, Ken G. Evans, Richard Brinkman, David K. Williams

[Abstract](#) | [PDF \(898 K\)](#)

- [The Change of Hydrological Regime in Upper Cikapundung Watershed, West Java Indonesia](#) Original Research Article Open Access
Pages 229-235
Hary Pradiko, Arwin, Prayatni Soewondo, Yadi Suryadi
[Abstract](#) | [PDF \(609 K\)](#)
- [Study on Water Balance in Poteran – A Small Island in East Java, Indonesia](#) Original Research Article Open Access
Pages 236-242
Tatas, Agung Budipriyanto, Mohamad Khoiri, Wien Lestari, Askur Rahman
[Abstract](#) | [PDF \(424 K\)](#)
- [Extending Public Water Supply in Peri-Urban Area: Technical-Engineering, Economic, and Environmental Consideration](#) Original Research Article Open Access
Pages 243-249
Sri Maryati, An Nisaa' Siti Humaira
[Abstract](#) | [PDF \(389 K\)](#)
- [The Presence of Jeringau \(Acorus Calamus\) as Flexible Vegetation Type in the Channel Against Flow Resistance](#) Original Research Article Open Access
Pages 250-256
Maimun Rizalikhadi, Dian Safiana
[Abstract](#) | [PDF \(564 K\)](#)
- [The Influence of Single Zigzag Type Porous Groin in the Change of Beach Profile](#) Original Research Article Open Access
Pages 257-262
Eldina Fatimah, Zouhrawaty, A. Ariff, Teuku Budi Aulia
[Abstract](#) | [PDF \(934 K\)](#)
- [Evaluation of Drainage Channels Capacity in Ambon City: A Case Study on Wai Batu Merah Watershed Flooding](#) Original Research Article Open Access
Pages 263-269
Cilcia Kusumastuti, Ruslan Djajadi, Angel Rumihin
[Abstract](#) | [PDF \(1558 K\)](#)
- [Experimental Assessment of Integrated Technology Application Used to Rain \(WM4RR\) & Floods Reduction \(AR-DWIS\) in Jakarta](#) Original Research Article Open Access
Pages 270-276
Raden Djoko Goenawan, Ridwan Ridwan, Muhammad Sadly, Teddy Sudinda, Mahally Kudsy, Tri Handoko Seto, Budi Harsoyo
[Abstract](#) | [PDF \(372 K\)](#)
- [Log Jams at a Bridge with a Pier and a Bridge without Pier](#) Original Research Article Open Access
Pages 277-283
Muhammad Islamy Rusyda
[Abstract](#) | [PDF \(475 K\)](#)
- [The Submerged Breakwater as Prototype of Coastal Protection in Gili Trawangan, Lombok, Indonesia](#) Original Research Article Open Access
Pages 284-290
Eko Pradjoko, Imam Bachtiar, Nanang Matalatta, Gatot Sugihartono
[Abstract](#) | [PDF \(1125 K\)](#)
- [Mapping of Ozone Gas \(O₃\) Concentrations in Padang City](#) Original Research Article Open Access
Pages 291-297
Vera Surtia Bachtiar, Slamet Raharjo, Yenni Ruslinda, Fitra Hayati, Desi Ratna Komala
[Abstract](#) | [PDF \(1083 K\)](#)
- [Correlation Equation to Predict HHV of Tropical Peat Based on its Ultimate Analyses](#) Original Research Article Open Access
Pages 298-303
Wiwiek Setyawati, Enri Damanhuri, Puji Lestari, Kania Dewi
[Abstract](#) | [PDF \(338 K\)](#)
- [Identification of Extreme Events in Climate Data from Multiple Sites](#) Original Research Article Open Access
Pages 304-310

Heri Kuswanto, Shofi Andari, Erma Oktania Permatasari

[Abstract](#) | [PDF \(441 K\)](#)

- [Prediction of Liquefaction Potential Study at Bantul Regency the Province of Special Region of Yogyakarta Indonesia](#) Original Research ArticleOpen Access

Pages 311-316
John T. Hatmoko, Hendra Suryadharna

[Abstract](#) | [PDF \(303 K\)](#)
- [Strength Performance of Iowa Soils Stabilized with Biofuel Industry Co-product](#) Original Research ArticleOpen Access

Pages 317-323
Halil Ceylan, Sungwan Kim, Ali Ulvi Uzer, Bo Yang

[Abstract](#) | [PDF \(762 K\)](#)
- [Physical Properties and Mineral Content of Sidoarjo Mud Volcano](#) Original Research ArticleOpen Access

Pages 324-330
Luky Handoko, Ahmad Rifa'i, Noriyuki Yasufuku, Ryohei Ishikura

[Abstract](#) | [PDF \(348 K\)](#)
- [Effect of Area Development on the Stability of Cut Slopes](#) Original Research ArticleOpen Access

Pages 331-337
Yulindasari Sutejo, Nurly Gofar

[Abstract](#) | [PDF \(786 K\)](#)
- [The Shape of Slide Surface of Gravity Retaining Walls Construction on Sand by Small Scale Sinusoidal Dynamic Load Tests](#) Original Research ArticleOpen Access

Pages 338-344
Anissa Maria Hidayati, Sri Prabandiyani RW, I. Wayan Redana

[Abstract](#) | [PDF \(702 K\)](#)
- [Determination of Shear Wave Velocity Using Multi-channel Analysis of Surface Wave Method and Shear Modulus Estimation of Peat Soil at Western Johore](#) Original Research ArticleOpen Access

Pages 345-350
Adnan Zainorabidin, Mohd Jazlan Mad Said

[Abstract](#) | [PDF \(401 K\)](#)
- [Stress-path on the Hydraulic Fracturing Test of the Clay Core of Rock Fill Dams in the Laboratory](#) Original Research ArticleOpen Access

Pages 351-357
Didiek Djarwadi, Kabul B. Suryolelono, Bambang Suhendro, Hary C. Hardiyatmo

[Abstract](#) | [PDF \(605 K\)](#)
- [Analysis of Geotextile Reinforced Road Embankment Using PLAXIS 2D](#) Original Research ArticleOpen Access

Pages 358-362
Paravita Sri Wulandari, Daniel Tjandra

[Abstract](#) | [PDF \(618 K\)](#)
- [Analysis of Piled Raft Foundation on Soft Soil Using PLAXIS 2D](#) Original Research ArticleOpen Access

Pages 363-367
Paravita Sri Wulandari, Daniel Tjandra

[Abstract](#) | [PDF \(284 K\)](#)
- [A Combined Flume-imaging Technique for Measuring Fluvial Erosion of Cohesive Stream Bank Soils](#) Original Research ArticleOpen Access

Pages 368-375
Tommy E. Sutarto

[Abstract](#) | [PDF \(700 K\)](#)
- [Determination of Unsaturated Soil Properties and Slope Deformation Analysis Due to the Effect of Varies Rainfall](#) Original Research ArticleOpen Access

Pages 376-382
Sony Pramusandi, Ahmad Rifa'i, Kabul B. Suryolelono

[Abstract](#) | [PDF \(984 K\)](#)
- [Investigation of the Consolidation Drainage of High Water Content Clay by Siphon Method through Unsaturated](#)Open Access

[Filter](#) Original Research Article

Pages 383-389

Shodai Soda, Ryohei Ishikura, Noriyuki Yasufuku, Luky Handoko

[Abstract](#) | [PDF \(928 K\)](#)

- [Dynamic Soil Compaction—recent Methods and Research Tools for Innovative Heavy Equipment Approaches](#) Original Research ArticleOpen Access

Research Article
Pages 390-396
Holger Pankrath, Marco Barthel, Alexander Knut, Matteo Bracciale, Ralf Thiele

[Abstract](#) | [PDF \(1506 K\)](#)
- [Innovative Reinforced Soil Structures for High Walls and Slopes Combining Polymeric and Metallic Reinforcements](#) Original Research ArticleOpen Access

Pages 397-405
Matteo Lelli, Riccardo Laneri, Pietro Rimoldi

[Abstract](#) | [PDF \(1128 K\)](#)
- [Bearing Capacity of Pile Foundations Embedded in Clays and Sands Layer Predicted Using PDA Test and Static Load Test](#) Original Research ArticleOpen Access

Pages 406-410
Gogot Setyo Budi, Melisa Kosasi, Dewi Hindra Wijaya

[Abstract](#) | [PDF \(1038 K\)](#)
- [Generalized Additive Models for Estimating Motorcycle Collisions on Collector Roads](#) Original Research ArticleOpen Access

Pages 411-416
Machus Machsus, Rachmad Basuki, Amalia Firdaus Mawardi

[Abstract](#) | [PDF \(511 K\)](#)
- [Predicting the Remaining Service Life of Road Using Pavement Condition Index](#) Original Research ArticleOpen Access

Pages 417-423
Ary Setyawan, Jolis Nainggolan, Arif Budiarto

[Abstract](#) | [PDF \(512 K\)](#)
- [The Effect of Pavement Condition on Vehicle Speeds and Motor Vehicles Emissions](#) Original Research ArticleOpen Access

Pages 424-430
Ary Setyawan, Irvan Kusdiantoro, Syafi'i

[Abstract](#) | [PDF \(289 K\)](#)
- [Study on BIM Utilization for Design Improvement of Infrastructure Project](#) Original Research ArticleOpen Access

Pages 431-437
Masaru Minagawa, Shunji Kusayanagi

[Abstract](#) | [PDF \(1097 K\)](#)
- [Needs Analysis of the Bridge Infrastructures Crossing over the Musi River of Palembang](#) Original Research ArticleOpen Access

Pages 438-444
Joni Arliansyah, Adi Taruna, Rhaptyalyani, Astri Yuli Kurnia

[Abstract](#) | [PDF \(630 K\)](#)
- [Trip Attraction Model Using Radial Basis Function Neural Networks](#) Original Research ArticleOpen Access

Pages 445-451
Joni Arliansyah, Yusuf Hartono

[Abstract](#) | [PDF \(396 K\)](#)
- [Using Advanced Materials of Granular BRA Modifier Binder to Improve the Flexural Fatigue Performance of Asphalt Mixtures](#) Original Research ArticleOpen Access

Pages 452-460
Muhammad Karami, Hamid Nikraz

[Abstract](#) | [PDF \(577 K\)](#)
- [Traffic Performance Analysis of u-turn and Fly Over u-turn Scenario; A Case Study at Soekarno Hatta Road, Palembang, Indonesia](#) Original Research ArticleOpen Access

Pages 461-466
Rhaptyalyani H. Della, Hanafiah, Joni Arliansyah, Riga Artiansyah

[Abstract](#) | [PDF \(579 K\)](#)
- [Modelling Road Traffic Noise for Collector Road \(Case Study of Denpasar City\)](#) Original Research ArticleOpen Access

Pages 467-473
Putu Aliit Suthanaya
[Abstract](#) | [PDF \(440 K\)](#)

- [Development of Asphalt Pavement Temperature Model for Tropical Climate Conditions in West Bali Region](#) Original Research Article Open Access
Pages 474-480
I. Made Agus Ariawan, Bambang Sugeng Subagio, Bagus Hario Setiadji
[Abstract](#) | [PDF \(1369 K\)](#)

- [Does Demographic Pattern Matter for Sustainable Infrastructure Policy?](#) Original Research Article Open Access
Pages 481-488
Ferry Hermawan, Tutik Rachmawati, Herry Ludiro Wahyono
[Abstract](#) | [PDF \(279 K\)](#)

- [Applying Input-output Model to Estimate the Broader Economic Benefits of Cipularang Tollroad Investment to Bandung District](#) Original Research Article Open Access
Pages 489-497
Ridwan Anas, Ofyar Z. Tamin, Sony S. Wibowo
[Abstract](#) | [PDF \(296 K\)](#)

- [Optimization of River Transport to Strengthen Multimodal Passenger Transport System in Inland Region](#) Original Research Article Open Access
Pages 498-503
Saïd
[Abstract](#) | [PDF \(624 K\)](#)

- [An Analysis of Out-of-home Non-work Activity Time Use and Timing Behaviour Based on Work Schedule and Trip Time](#) Original Research Article Open Access
Pages 504-511
Melawaty Agustien, Ade Sjafruddin, Harun Al Rasyid S. Lubis, Sony S. Wibowo
[Abstract](#) | [PDF \(300 K\)](#)

- [Transportation Demand Management: A Park and Ride System to Reduce Congestion in Palembang City Indonesia](#) Original Research Article Open Access
Pages 512-518
Erika Buchari
[Abstract](#) | [PDF \(266 K\)](#)

- [The Importance of Human Resources Development and its Impact in Increasing of National Port Productivity](#) Original Research Article Open Access
Pages 519-525
Erika Buchari, Hasan Basri
[Abstract](#) | [PDF \(367 K\)](#)

- [The Delays for Signalized Intersection Using ATCS Data and Field Survey Method at Kerten-Intersection of Surakarta](#) Original Research Article Open Access
Pages 526-533
Alfia Magfirona, Nurul Hidayati, Ika Setyaningsih, Gotot Slamet
[Abstract](#) | [PDF \(341 K\)](#)

- [Simultaneous in-situ Stiffness and Anomalies Measurement on Pavement Subgrade Using Tomography Surface Waves Technique](#) Original Research Article Open Access
Pages 534-540
Sri Atmaja P. Rosyidi
[Abstract](#) | [PDF \(485 K\)](#)

- [The Effective Strategy in the Management of "Pantura" Lane Road, Java - Indonesia](#) Original Research Article Open Access
Pages 541-546
Hary Agus Rahardjo, Dwi Dinariana, Fitri Suryani
[Abstract](#) | [PDF \(802 K\)](#)

- [Railway Track Subgrade Failure Mechanisms Using a Fault Chart Approach](#) Original Research Article Open Access
Pages 547-555
Kristianto Usman, Michael Burrow, Gurmel Ghataora
[Abstract](#) | [PDF \(855 K\)](#)

- [Analysis of Hub-and-spoke Airport Networks in Java Island, Based on Cargo Volume and Freight Ratio](#) Original Research Article
Pages 556-563
Gito Sugiyanto, Purwanto Bektu Santosa, Aris Wibowo, Mina Yumei Santi
[Abstract](#) | [PDF \(711 K\)](#) Open Access
- [Traffic Flow Quality as Part of Network Quality for a Sparse Road Network](#) Original Research Article
Pages 564-570
Hitapriya Suprayitno
[Abstract](#) | [PDF \(772 K\)](#) Open Access
- [Effect of Habit and Car Access on Student Behavior Using Cars for Traveling to Campus](#) Original Research Article
Pages 571-578
Rudy Setiawan, Wimpy Santosa, Ade Sjafruddin
[Abstract](#) | [PDF \(278 K\)](#) Open Access
- [A Case Study of Low Compressive Strength of Concrete Containing Fly Ash in East Java Indonesia](#) Original Research Article
Pages 579-586
M. Sigit Darmawan, Ridho Bayuaji, Nur Ahmad Husin, Chomaedhi, Ismail Saud
[Abstract](#) | [PDF \(782 K\)](#) Open Access
- [Experimental Investigation on the Properties of Lightweight Concrete Containing Waste Oil Palm Shell Aggregate](#) Original Research Article
Pages 587-593
Kim Hung Mo, U. Johnson Alengaram, Mohd Zamin Jumaat
[Abstract](#) | [PDF \(453 K\)](#) Open Access
- [Drying Shrinkage of Slag Blended Fly Ash Geopolymer Concrete Cured at Room Temperature](#) Original Research Article
Pages 594-600
Partha Sarathi Deb, Pradip Nath, Prabir Kumar Sarker
[Abstract](#) | [PDF \(262 K\)](#) Open Access
- [Early Age Properties of Low-calcium Fly Ash Geopolymer Concrete Suitable for Ambient Curing](#) Original Research Article
Pages 601-607
Pradip Nath, Prabir Kumar Sarker, Vijaya B. Rangan
[Abstract](#) | [PDF \(283 K\)](#) Open Access
- [Improvement of Concrete Durability by Nanomaterials](#) Original Research Article
Pages 608-612
Saloma, Amrinsyah Nasution, Iswandi Imran, Mikrajuddin Abdullah
[Abstract](#) | [PDF \(214 K\)](#) Open Access
- [Building a Green Swimming Pool by Using Concrete with Aggregates from Demolition Waste](#) Original Research Article
Pages 613-616
Gerard H.P. Hol
[Abstract](#) | [PDF \(457 K\)](#) Open Access
- [Mechanical Behavior of Reactive Powder Concrete with Glass Powder Substitute](#) Original Research Article
Pages 617-622
Widodo Kushartomo, Ika Bali, Budi Sulaiman
[Abstract](#) | [PDF \(558 K\)](#) Open Access
- [Corrosion Behaviours of High Strength TMT Steel Bars for Reinforcing Cement Concrete Structures](#) Original Research Article
Pages 623-630
Md. Aminul Islam
[Abstract](#) | [PDF \(1249 K\)](#) Open Access
- [Improving Microstructures of Concrete Using \$\text{Ca}\(\text{C}_{18}\text{H}_{35}\text{O}_2\)_2\$](#) Original Research Article
Pages 631-637
Agus Maryoto
[Abstract](#) | [PDF \(685 K\)](#) Open Access
- [Influence of Prestressed Force in the Waste Tire Reinforced](#) Open Access

Concrete Original Research Article

Pages 638-643

Agus Maryoto, Nor Intang Setyo Hermanto, Yanuar Haryanto, Sugeng Waluyo, Nur Alvi Anisa

[Abstract](#) | [PDF \(1006 K\)](#)

Flexural Capacity of Concrete Beams Strengthened Using GFRP Sheet after Seawater Immersion Original Research Article Open Access

Pages 644-649

Mufti Amir Sultan, Rudy Djameluddin, Wihardi Tjaronge, Herman Parung

[Abstract](#) | [PDF \(449 K\)](#)

The Strength of Alkali-activated Slag/fly Ash Mortar Blends at Ambient Temperature Original Research Article Open Access

Pages 650-656

Arie Wardhono, David W. Law, Anthony Strano

[Abstract](#) | [PDF \(411 K\)](#)

Compressive Strength of Asphalt Concrete Binder Course (AC-BC) Mixture Using Buton Granular Asphalt (BGA) Original Research Article Open Access

Pages 657-662

Abdul Gaus, Tjaronge M.W., Nur Ali, Rudy Djameluddin

[Abstract](#) | [PDF \(841 K\)](#)

The Control of Response Time in Self-healing of Granulated Cementitious Material by Water-soluble Film Coating Original Research Article Open Access

Pages 663-668

Yong-Soo Lee, Hong-Gi Kim, Tae-Han Song, Jae-Suk Ryou

[Abstract](#) | [PDF \(609 K\)](#)

Optimization of the Use of Volcanic Ash of Mount Sinabung Eruption as the Substitution for Fine Aggregate Original Research Article Open Access

Pages 669-674

Rahmi Karolina, Syahrizal, M. Agung Putra, Tito Agung Prasetyo

[Abstract](#) | [PDF \(242 K\)](#)

Authenticity Principle in Conservation of De Javasche Bank of Surabaya: Materials, Substance and Form Original Research Article Open Access

Pages 675-684

Timoticin Kwanda

[Abstract](#) | [PDF \(1523 K\)](#)

Use of Biofuel Co-product for Pavement Geo-materials Stabilization Original Research Article Open Access

Pages 685-691

Ali Ulvi Uzer

[Abstract](#) | [PDF \(710 K\)](#)

Identification of Source Factors of Carbon Dioxide (CO₂) Emissions in Concreting of Reinforced Concrete Original Research Article Open Access

Pages 692-698

Hermawan, Puti F. Marzuki, Muhamad Abduh, R. Driejana

[Abstract](#) | [PDF \(321 K\)](#)

[< Previous vol/iss](#) | [No next vol/iss](#)

[No prev art. 1 - 100 of 166](#) [Next >](#)

[About ScienceDirect](#)

[Contact and support](#)

[Terms and conditions](#)

[Privacy policy](#)

Copyright © 2015 Elsevier B.V. or its licensors or contributors. ScienceDirect® is a registered trademark of Elsevier B.V.

Cookies are used by this site. To decline or learn more, visit our [Cookies](#) page.

[Switch to Mobile Site](#)



The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)

The strength of alkali-activated slag/fly ash mortar blends at ambient temperature

Arie Wardhono^{a,*}, David W. Law^b, Anthony Strano^b

^aUniversitas Negeri Surabaya, Kampus UNESA Ketintang, Surabaya 60231, Indonesia

^bRMIT University, RMIT City Campus, Melbourne VIC 3000, Australia

Abstract

The implementation of sustainable development in civil engineering society has led to the use of new materials with low environmental impact. Ordinary Portland cement (OPC) is the primary material in the production of traditional concrete. However, the manufacturing of OPC has led to environmental concerns over the production of CO₂. The use of fly ash and slag, the most commonly used industrial by-products, as replacements for PC, has helped to reduce these CO₂ emission. Recent research has also shown that it is possible to use fly ash or slag as a sole binder in concrete by activating them with alkali components through a polymerization process. However, the main issue of the use of fly ash as a replacement material for cement is the need of heat curing regime to achieve structural integrity. While, the standard curing regime used for OPC concrete can be applied to the alkali-activated slag (AAS) due to the similar characteristic of the hydration product.

This paper reports the detail of the experimental work that has been undertaken to investigate the strength of AAS/fly ash (AASF) mortar blends. The AASF specimens were prepared using a mix of ground granulated blast-furnace slag (GGBS) and low calcium class F fly ash activated by high alkaline solution. The mix compositions of slag to fly ash were 1:0, 0.9:0.1, 0.8:0.2, 0.7:0.3, 0.6:0.4 and 0.5:0.5, respectively. The standard curing regime at ambient temperature was applied.

The results showed that the mix proportion of 0.5 slag : 0.5 fly ash produced the best strength results. The standard deviation values also reduced along with the increase of fly ash content indicating an improved stability of the specimens. It also suggested that 0.5 slag : 0.5 fly ash blend could provide a solution for the need of heat curing for fly ash-based geopolymer.

© 2015 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of organizing committee of The 5th International Conference of Euro Asia Civil Engineering Forum (EACEF-5)

Keywords: Alkali activated material; GGBS; fly ash; strength development; ambient temperature

* Corresponding author. Tel.: +62-81333371173; fax: +62-31-8299342.

E-mail address: ariewardhono@unesa.ac.id

1. Introduction

Concrete is the most commonly used construction material in society, which is conventionally produced by using the ordinary Portland Cement (OPC). As primary binder of concrete, the ratio of OPC in traditional concrete is approximately 10% – 15% by the mass of concrete. However, the production of OPC has resulted in the environmental problems over the production of CO₂ with approximately 1 ton of CO₂ produced per 1 ton OPC [1, 2]. This has led to the adoption of industrial waste materials, such as fly ash and ground granulated blast furnace slag (GGBS), as replacement materials for OPC due to their ability to enhance the physical, chemical and mechanical properties of cements and concretes [3,4].

Recent research has shown that it is possible to use fly ash or slag as a sole binder in concrete by activating them with alkali components through a polymerization process [5-8]. The activation of fly ash involves the activation of material containing primarily silicate and aluminates with a highly alkaline solution and forms an inorganic binder through a geopolymeric reaction [9,10]. While the activation of slag involves the activation by low to mild alkali of a material containing primarily silicate and calcium and produces calcium silicate hydrate gel (C-S-H gel) similar to that formed in OPC [11]. The products of geopolymeric reaction are different from other type of alkali activated materials (slag reaction) since the products are a polymer rather than C-S-H gel.

As cement replacement materials, both fly ash and slag have been observed to have a comparable compressive strength. However, the main issue of the use of fly ash as cement replacement materials is the need of heat curing regime to achieve structural integrity. While, the standard curing regime used for OPC concrete can be applied to the alkali activated slag (AAS) due to the similar characteristic of the hydration product (C-S-H gel), fly ash requires heat curing. This paper reports the results of experimental research on the development of alkali activated slag and fly ash (AASF) blends mortars cured at ambient temperature. The properties of AASF mortars were assessed in the form of compressive strength.

2. Experimental procedures

2.1. Materials

The primary materials used for this study were a low calcium class F fly ash with high silicate (Si) content combined with ground granulated blast-furnace slag (GGBS), a construction grade slag type. The chemical composition breakdown of the fly ash and GGBS are shown in Table 1.

Table 1. Chemical compositions of fly ash and GGBS (mass %)

Composition	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	K ₂ O	Na ₂ O	TiO ₂	P ₂ O ₅	Mn ₂ O ₃	SO ₃
GGBS*	36.87	14.23	0.32	36.0	5.05	0.05	0.00	0.63	0.36	0.39	6.08
Fly ash	66.65	25.06	1.68	2.03	0.01	1.01	0.39	1.25	1.23	0.05	0.62

Note: * Wardhono, 2012 [12]

The fly ash used in this study was class F fly ash. It had a CaO of 2.03% (< 10%), SiO₂+Al₂O₃+Fe₂O₃ of 93.39% (>70%) and SO₃ composition of 0.62 as in accordance with ASTM C618 [13]. The GGBS used satisfies the requirement for an AAS. It had a CaO/SiO₂ ratio of 0.98 (between 0.5 and 2.0) and an Al₂O₃/SiO₂ ratio of 0.39 (between 0.1 and 0.6). The hydration modulus which was defined as the ratio of CaO+MgO+Al₂O₃ to SiO₂ was 1.5 (> 1.4) to ensure good hydration properties [8,14]. The fineness of the fly ash and GGBS materials were measured using a Malvern Particle Size Analyzer Instruments Mastersizer X and had a fineness of 67.22% and 90.90% (passing 45 μm), respectively. The fine aggregate used to make the specimens was blended concrete sand from Langwarrin, Victoria, Australia, with the fineness modulus of 2.0 and the coarse aggregates were from Mawson Lake Cooper quarry with the specific gravity of 2.9

The alkaline activator solutions were formulated by blending sodium silicate with sodium hydroxide (NaOH) to achieve a Na₂O dosage of 15% and activator modulus (Ms) of 1.25. A sodium silicate with alkali modulus (AM) of

approximately 2.0 ($\text{Na}_2\text{O} = 14.7\%$ and $\text{SiO}_2 = 29.4\%$) and a high concentration of sodium hydroxide, 15 M NaOH in liquid form were used.

2.2. Mix proportions

In accordance to ASTM C109, the sand to binder (a combination of slag and fly ash) ratio was 2.75 : 1 [15]. A water to binder ratio was 0.66 (the water from the alkali activator solutions was not included) was used to prepare the AASF mortars. The alkali activator present was 0.163 by the weight of mortar mix. The mix design of the AASF mortars was developed from the previous research [12]. The mix compositions of slag to fly ash were: 100% : 0%, 90% : 10%, 80% : 20%, 70% : 30%, 60% : 40% and 50% : 50%, respectively. Table 2 summarizes the mix design while Table 3 shows the summary of activator modulus of AASF mortar specimens.

Table 2. Mix design of AASF mortars

Mix	GGBS : FA Ratio	GGBS (kg)	Fly ash (kg)	Sodium silicate (kg)	NaOH (kg)	Water (kg)	Fine sand (kg)
M1	1.0 : 0.0	1.03	---	0.53	0.24	0.068	2.84
M2	0.9 : 0.1	0.93	0.10	0.53	0.24	0.068	2.84
M3	0.8 : 0.2	0.83	0.20	0.53	0.24	0.068	2.84
M4	0.7 : 0.3	0.72	0.31	0.53	0.24	0.068	2.84
M5	0.6 : 0.4	0.62	0.41	0.53	0.24	0.068	2.84
M6	0.5 : 0.5	0.52	0.51	0.53	0.24	0.068	2.84

Table 3. Activator modulus of AASF mortars

Mix	Na_2O from sodium silicate	Na_2O from NaOH	Total Na_2O content	SiO_2 from sodium silicate	SiO_2 from NaOH	SiO_2 from GGBS	Total SiO_2 content	Activator Modulus (Ms) $\text{SiO}_2/\text{Na}_2\text{O}$
M1	0.077	0.046	12.32	0.155	0.000	0.345	0.500	4.06
M2	0.077	0.046	12.32	0.155	0.051	0.310	0.516	4.19
M3	0.077	0.046	12.32	0.155	0.102	0.276	0.533	4.32
M4	0.077	0.046	12.32	0.155	0.153	0.241	0.549	4.46
M5	0.077	0.046	12.32	0.155	0.204	0.207	0.566	4.59
M6	0.077	0.046	12.32	0.155	0.255	0.172	0.582	4.72

2.3. Specimen preparation and testing

The mixing for AASF mortar specimens was performed using a 5 liter Hobart mixer. The mixtures were cast in $50 \times 50 \times 50 \text{ mm}^3$ cubes moulds and vibrated for 1 minute to ensure no air/voids were present in the specimens. The mortar specimens were cured at room temperature for one day (Note: no heat curing treatment was applied to the AASF specimens) prior to being demoulded. The mortar specimens were then kept in water at a temperature of $20 \pm 2^\circ\text{C}$ until time of testing.

It should be noted that due to the high viscosity and fast setting rate of AASF mortar specimens, the workability of the AASF paste was low and it was difficult to ensure the mortar specimens was compact properly thus, the specimens were vibrated to ensure good quality mortar specimens. The mixing procedure was in accordance to the previous research [16] with a total mixing time of 9 minutes, with the casting process taking approximately 10 minutes. Thus,

the relative setting time of AASF specimens was approximately 15-18 minutes. However, it was difficult to differentiate the relative setting time and workability of the mixtures for different slag/fly ash ratios.

Compressive strength measurement of $50 \times 50 \times 50 \text{ mm}^3$ cube mortars were carried out on a Universal Testing Machine, UH-F500 kNI Shimadzu, under a load control regime with a loading rate of 1 kN/s, within 0.9 to 1.8 kN/s as outlined in ASTM C109 [15]. Three mortar cubes were tested for each data point. The mortar specimens were tested at 3, 7, 14, and 28 day after casting. The test was completed until failure of the mortar specimens.

3. Results and discussions

Table 4 and Figure 1 give the compressive strength results reported for the AASF mortar specimens for all mixes. The AASF mortars demonstrates a good performance of strength at early age with all mixes producing compressive strength above 20 MPa during the first three days after casting. All mixes demonstrate a continual improvement on strength throughout 28 days, with the exception of AASF Mix 1 which lost strength between 14 and 28 days.

Table 4. Compressive strength test results of AASF (MPa)

Mix	Age of concrete			
	3	7	14	28
M1	32.92 ± 6.98	42.81 ± 2.95	43.86 ± 4.85	39.55 ± 8.42
M2	29.41 ± 0.52	31.08 ± 2.81	40.99 ± 1.84	48.17 ± 8.08
M3	23.69 ± 5.05	33.60 ± 4.97	31.15 ± 0.57	53.28 ± 6.11
M4	23.25 ± 3.35	40.64 ± 3.15	41.94 ± 2.80	47.32 ± 4.64
M5	31.04 ± 1.47	32.04 ± 4.40	34.92 ± 2.42	55.63 ± 1.71
M6	28.65 ± 2.41	46.84 ± 0.55	48.76 ± 2.69	62.49 ± 0.77

Table 5. Strength development of AASF mortar specimens up to 28 days (%)

Mix	Age of concrete			
	3 to 28 days	7 to 28 days	14 to 28 days	28 days
M1	83.24%	108.24%	110.90%	100%
M2	61.05%	64.52%	85.09%	100%
M3	44.46%	63.06%	58.46%	100%
M4	49.13%	85.88%	88.63%	100%
M5	55.80%	57.59%	62.77%	100%
M6	45.85%	74.96%	78.03%	100%

The strength development of AASF Mix 1 demonstrates the highest initial strength with 32.92 MPa at 3 days age (83.24% final strength) and slightly increased from 7 to 14 days age of 42.81 MPa and 43.86 MPa, respectively. However, beyond that, the compressive strength of AASF Mix 1 does not display any significant increase with time, but shows a slight reduction in strength at 28 days to 39.55 MPa. A similar finding was also found by other researchers [17,18]. According to Collins and Sanjayan [17], the deteriorating behavior of a specimen made by 100% slag material can be attributed to the growth of micro-cracking within the specimens. They found that the micro-cracking became progressively larger over time. In addition, Wardhono et al [18] also found a decrease of AAS concrete strength which is attributed to the growth of the micro-cracks with time. The authors found that the decreasing strength was coupled with an increase in the permeable voids ratio, as demonstrated by an increase of porosity and water absorption and decrease in ultrasonic pulse velocity.

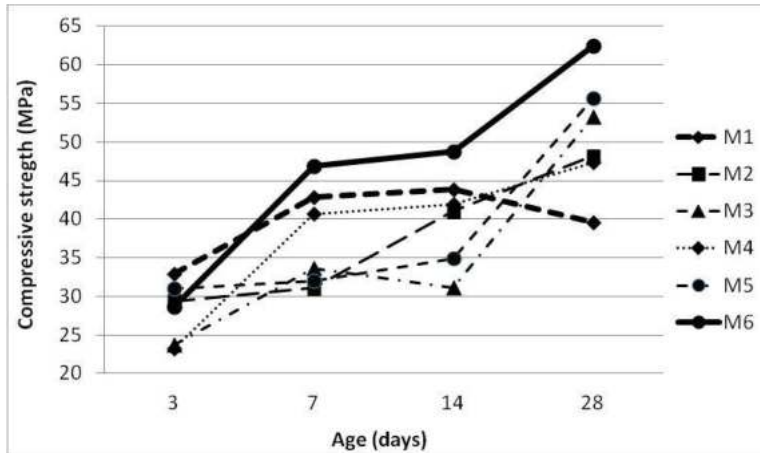


Fig. 1. Compressive strength of AASF mortars

AASF Mix 6, which is made by 50% slag and 50% fly ash, exhibits the highest compressive strength compared to other mixes with a strength of 62.49 MPa at 28 days. In contrast to AASF Mix 1, AASF Mix 6 displayed a low initial compressive strength with 28.65 MPa at 3 days, which only represents 45.85% of the final strength. However, it shows a significant increase of strength of 46.84 MPa (74.96% final strength) and 48.76 MPa (78.03% final strength) at 14 days and 21 days, respectively.

Overall the results show a general decrease in initial strength and increase in final strength as the fly ash content increases, though considerable variability is found within the results. This would suggest that the GGBS is the primary contributor to the initial strength with the fly ash contributing to the strength gain with time. This is consistent with the reported data for AAS materials, which have been observed to give a high initial strength, which generally gains little further strength before showing a reduction in strength with time. While 100% fly ash materials generally require heat curing to achieve high strength, often not achieving structural integrity at ambient temperatures.

This most likely suggests that the hydration reaction has two possible mechanisms: (1) the hydration reaction of slag and the polymerization of fly ash are occurring separately from one another, or (2) the two reactions are occurring simultaneously [19]. In the first case it is hypothesized that the GGBS reacts first to form a matrix around the fly ash and the fly ash then fills in the pores, to provide the increased strength. In the second mechanism the two reactions occur simultaneously with the GGBS reaction activating the fly ash at the ambient temperature.

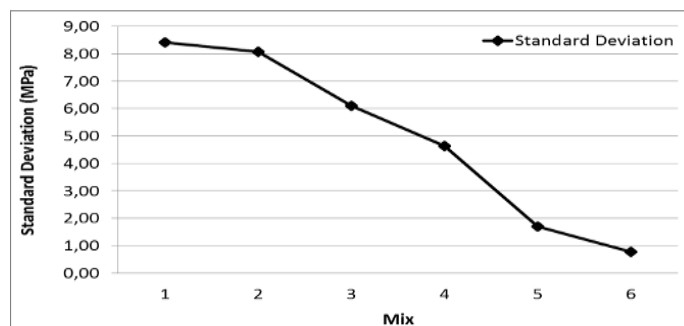


Fig. 2. Standard deviation developments of AASF mortars at 28 days age

Table 4 and Figure 2 show the standard deviation for each test of each mix design. This table shows that as the percentage of fly ash added to the mixture increases, the standard deviations for the tests reduce, and the consistency of the mix designs increase. The decreasing trend in the standard deviations as the mixture approaches 50:50 composition of slag and fly ash shows that the addition of fly ash resulted in a more stable product. Current research shows that AAS has an issue with long term durability due to the development of the micro-cracking [17]. It is possible

that fly ash increases the stability of AAS because the polymerization process of the fly ash geopolymer fill the pores present in the AAS mortar. As a result the pores in the AAS mortar will have less water in them and in turn will shrink less and micro-cracking will be reduced. The variability in the results and the stabilizing effects of the fly ash suggest the second mechanism is the more probable.

Figure 3 displays the strength development of AASF mortar specimens with slag addition at 28 days age. The result shows a similar performance to other researcher with slag addition up to 30% [20]. The AASF specimen demonstrates a higher strength compared to Nath et al specimens at 10% and 20% of slag addition. However, Nath et al specimen shows a better strength performance at 30% addition. The AASF specimen achieves a comparable strength performance with Nath et al specimen at 50% slag addition. The slow rate strength development of AASF specimen might attributed to the high molarity of NaOH (15M) solution. According to Nath et al, increasing the alkaline solution cause reduction of strength while increasing setting time. This is because of higher water to solid ratio of mixture having higher liquid content. Excess alkali solution causes an increase in the amount of water in the system which hinders polymerization. This promotes an increase of poorly polymerized reaction products [20].

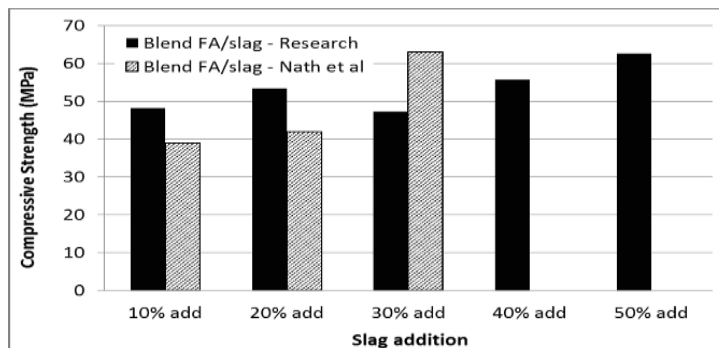


Fig. 3. Strength development of AASF mortars at 28 days age compred to Nath et al. [20]

All mixes were cured in ambient conditions and were able to be successfully removed from the casts after 24 hours. This was particularly interesting for AASF Mix 5 and 6 which contained higher percentages of fly ash (40% and 50%, respectively) which were expected to require heat curing to rapidly gain strength. Current research generally recommends heat curing for fly ash geopolymer specimen for the first 24 hours, with the initial 24 hours of heat curing resulting in rapid strength gain [16, 21]. Beyond this however, the gain in strength is only moderate and not necessary for practical applications of the concrete. These results do show promising signs for improving the durability of cement less concrete, however the mix designs researched in this paper cannot provide direct evidence to support this idea due to time constraints.

4. Conclusions

The following conclusions may be drawn based on this study:

- 1) The ability of slag and fly ash to replace ordinary Portland cement in concrete can potentially reduce the environmental impact over the production of CO₂.
- 2) AASF Mix 1 (made by 100% slag) demonstrates the highest initial compressive strength, however, it shows a reduction in strength over periods of time and reaches the lowest compressive strength at 28 days.
- 3) Although it demonstrates the low initial strength, AASF mix 6 (made by 50% slag and 50% fly ash) exhibits the highest compressive strength at 28 days.
- 4) AASF specimen test results suggest that the hydration reaction of slag and the polymerization reaction of fly ash could occur separately or simultaneously. The results suggest that the simultaneous reaction is the most likely with the GGBS reation activating the fly ash, enabling it to react at room temperature.
- 5) The addition of fly ash to the mixes resulting in lower standard deviations which means improved stability of AASF mortar specimens.

- 6) AASF mixes containing higher percentages of fly ash are still able to be successfully cured under ambient condition. This suggests that the blending of slag and fly ash could provide a solution for the need for heat in the curing of fly ash based-geopolymer concrete.

Acknowledgements

The authors would like to acknowledge the facilities, and the scientific and technical assistance, of the Australian Microscopy & Microanalysis Research Facility at the RMIT Microscopy & Microanalysis Facility, at RMIT University, Melbourne, Australia. Materials support from the Independence Cement Pty. Ltd. Australia and PQ Australia for carrying out this research project is gratefully acknowledged.

References

- [1] Davidovits, J., Global warming impact on the cement and aggregates industries, *World Resource Review*, 6(2) (1994) 263-278.
- [2] Berry, M., D. Cross, and J. Stephens, *Changing the environment: An alternative "green" concrete produced without Portland cement in World of Coal Ash (WOCA)*, Lexington, KY, USA, 2009.
- [3] Law, D.W., et al., Durability assessment of alkali activated slag (AAS) concrete, *Materials and Structures*, 45 (2012) 1425-1437.
- [4] Neville, A.M., *Properties of Concrete*, 5th ed, Harlow, England; New York: Pearson, 2011.
- [5] Davidovits, J., Geopolymers. *New Inorganic polymeric new materials*, *Journal of Thermal Analysis*, 37 (1991) 1633-1656.
- [6] Davidovits, J., *Properties of geopolymer cements in First International Conference on Alkaline Cements and Concretes*, Scientific Research, Kiev, Ukraine, 1994.
- [7] Bakharev, T., J.G. Sanjayan, and Y.B. Cheng, Alkali activation of Australian slag cements, *Cement and Concrete Research*, 29 (1999) 113-120.
- [8] Taling, B. and J. Brandstetr, Present state and future of alkali activated slag concretes, *American Concrete Institute*, 114 (1989) 1519-1546.
- [9] Barbosa, V.F.F., K.J.D. MacKenzie, and C. Thaumaturgo, Synthesis and characterisation of materials based on inorganic polymers of alumina and silica: sodium polysialate polymers, *International Journal of Inorganic Materials*, 2 (2000) 309-317.
- [10] Xu, H. and J.S.J.v. Deventer, The geopolymerisation of alumino-silicate minerals, *International Journal of Mineral Processing*, 59 (2000) 247-266.
- [11] Brough, A.R. and A. Atkinson, Sodium silicate-based, alkali-activated slag mortars. Part I. Strength, hydration and microstructure, *Cement and Concrete Research*, 32 (2002) 865-879.
- [12] Wardhono, A., D.W. Law, and T.C.K. Molyneaux, Strength of alkali activated slag and fly ash-based geopolymer mortar, in *Microdurability 2012 "The 2nd International Conference on Microstructural-related Durability of Cementitious Composites"*, Amsterdam, Netherlands: RILEM Publications, 2012.
- [13] ASTM C618-03, Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete, ASTM International: USA, 2003.
- [14] Chang, J.J., A study on the setting characteristics of sodium silicate-activated slag pastes, *Cement and Concrete Research*, 33 (2003) 1005-1011.
- [15] ASTM C109/C109M-07, Standard test method for compressive strength of hydraulic cement mortars, ASTM International: USA, 2008.
- [16] Adam, A.A., Strength and durability properties of alkali-activated slag and fly ash-based geopolymer concrete, in *School of Civil, Environment and Chemical Engineering*, RMIT University: Melbourne, Australia, 2009.
- [17] Collins, F. and J.G. Sanjayan, Microcracking and strength development of alkali activated slag concrete, *cement and Concrete Composites*, 23 (2001) 345-352.
- [18] Wardhono, A., D.W. Law, and T.C.K. Molyneaux, Long term performance of alkali activated slag concrete, *Journal of Advanced Concrete Technology*, 13 (2015) 187-192.
- [19] Wardhono, A., D.W. Law, and T.C.K. Molyneaux, The mechanical properties of fly ash geopolymer in long term performance in *The CIC 2014 "Concrete Innovation Conference"*, Oslo, Norway, 2014.
- [20] Nath, P. and P.K. Sarker, Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition, *Construction and Building Materials*, 66 (2014) 163-171.
- [21] Bakharev, T., Geopolymeric materials prepared using Class F fly ash and elevated temperature curing, *Cement and Concrete Research*, 35 (2005) 1224-132.