PERFORMANCE PROPERTIES OPTIMIZATION OF TRIAXIAL CERAMIC-PALM OIL FUEL ASH BY EMPLOYING TAGUCHI DESIGN AND FLOWER POLLINATION ALGORITHM

AZLAN BIN ZAINUDIN

A thesis submitted in
fulfillment of the requirement for the award of the
Doctor of Philosophy in Mechanical Engineering

Faculty of Mechanical and Manufacturing Engineering
Universiti Tun Hussein Onn Malaysia

DECEMBER 2018

Every challenging work needs self-efforts as well as
guidance of elders especially those who
were very close
to our heart

My humble effort I dedicate to my sweet and loving

Mother and Late Father
Kamariah binti Yaacob and Zainudin bin Abdullah

Whose affection, love,
encouragement and prays of day and
might make me able to get such success and honor

ACKNOWLEDGEMENT

Foremost, I would like to express my sincere gratitude to my main supervisor, Assoc. Prof. Dr. Sia Chee Kiong and co-supervisor Assoc. Prof. Dr. Ong Pauline for the continuous support of my doctoral research, for their patience, motivation, and immense knowledge. Their guidance helped me in all aspects of research works including writing of this doctoral thesis.

The special and deepest appreciation go to my mother (Kamariah binti Yaacob), my late father (Zainudin bin Abdullah), and my siblings (Siti Munirah binti Zainudin and Muhammad Shahrul bin Zainudin). Their constant inspiration, understanding, patience, and support help me to complete my doctoral thesis and no words are adequate to express my special appreciation to them.

Besides, I would like to thank the laboratory committee: Mr. Anuar bin Ismail, Hj Mohd Tarmizi bin Nasir, Mr. Shahrul Mahadi bin Samsudin, Mr. Fazlannuddin Hanur bin Harith, Hj Abu Bakar bin Ahmad, Mr. Mohd Bahtiar bin Mohd Basri, and Mr. Mohd Azman bin Mohd Sadikin for their assistance for the experimental works. My sincere thanks also go to the fellow friends which involved in this doctoral research. The discussions and supports from them are appreciated as it also improves some parts of my doctoral research.

Finally, I would like to express my sincere thanks to the Ministry of Education Malaysia and Universiti Tun Hussein Onn Malaysia for the financial supports and facilities. The grants involved are Knowledge Transfer Programme (KTP) (Vote 1279), Fundamental Research Grant Scheme (FRGS) (Vote 1490), and Postgraduate Research Grant (GPPS) (Vote U751).

ABSTRACT

The combustion of wasted palm oil materials leads to the formation of Palm Oil Fuel Ash (POFA). The lack of use of POFA for beneficial applications causes environmental problems. The introduction of new raw material in an original composition can affect original optimal parameters. The excessive cost and time consumed is a main issue if high number of experiments need to be performed. Primarily, this research is about the optimization of triaxial ceramic employing the POFA process by the Taguchi design and Flower Pollination Algorithm (FPA). The recycled POFA was evaluated through the POFA layer formation method where selected POFA layers were employed as filler raw material. This research also provided the chronology of Taguchi design and FPA regarding the production of triaxial ceramic product. The research was then continued with the development of optimal parameters of the triaxial ceramic process containing POFA, specifically the following performance properties: shrinkage, water absorption, apparent porosity, bulk density, and flexural strength. Mainly, the Taguchi L_{18} orthogonal array was used as the design of experiment. Primarily, this research successfully attained the POFA layer formation for the triaxial ceramics. It was concluded that POFA could be successfully applied as filler material in triaxial ceramic application. Besides that, the Taguchi design and FPA were also successfully employed in this research field through the effectiveness of developed optimal design parameters. Taguchi Grey Relational Analysis (GRA) developed following optimal parameters: 15 wt.% of unground POFA, pressed at 2 t, and sintered at 1200 °C for 300 min of soaking time. In the meantime, both linear and interaction approach of FPA developed following optimal parameters: 5 wt.% of ground POFA, pressed at 4 t, and sintered at 1200 °C for 300 min of soaking time. It was successfully validated by the confirmation experiments including through crystalline phase and morphology analyses.

.

ABSTRAK

Proses pembakaran bahan terbuang minyak kelapa sawit membawa kepada pembentukan *Palm Oil Fuel Ash* (POFA). Kekurangan penggunaan POFA untuk aplikasi yang bermanfaat menyebabkan masalah alam sekitar. Pengenalan bahan mentah baru dalam komposisi asal dapat mempengaruhi parameter optimum yang asal. Kos yang tinggi dan masa yang digunakan adalah isu utama jika jumlah eksperimen yang banyak perlu dilakukan. Penyelidikan ini adalah mengenai pengoptimuman proses seramik tiga paksi yang menggunakan POFA oleh reka bentuk Taguchi dan *Flower Pollination Algorithm* (FPA). POFA yang dikitar semula dinilai melalui kaedah pembentukan lapisan POFA dengan lapisan POFA yang dipilih telah digunakan sebagai bahan mentah pengisi. Penyelidikan ini juga menyediakan kronologi reka bentuk Taguchi dan FPA mengenai pengeluaran produk seramik tiga paksi. Penyelidikan kemudiannya diteruskan dengan pembangunan parameter optimum proses seramik tiga paksi yang mengandungi POFA, khususnya ciri-ciri prestasi berikut: pengecutan, penyerapan air, porositi ketara, ketumpatan pukal, dan kekuatan lenturan. Ortogonal Taguchi L_{18} digunakan sebagai reka bentuk eksperimen. Penyelidikan ini berjaya mencapai pembentukan lapisan POFA untuk seramik tiga paksi. Kesimpulannya, POFA dapat digunakan sebagai bahan pengisi dalam aplikasi seramik tiga paksi. Selain itu, reka bentuk Taguchi dan FPA juga berjaya digunakan dalam bidang penyelidikan ini melalui keberkesanan parameter reka bentuk optimum yang dibangunkan. Taguchi *Grey Relational Analysis* (GRA) memberi parameter optimum seperti berikut: 15 wt.% daripada unground POFA, ditekan pada 2 t, dan disinter pada 1200 °C bagi 300 minit waktu perendaman. Sementara itu, kedua-dua pendekatan linear dan interaksi daripada FPA memberi parameter optimum seperti berikut: 5 wt.% daripada ground POFA, ditekan pada 4 t, dan disinter pada 1200 °C bagi 300 minit waktu perendaman. Ia telah berjaya disahkan oleh eksperimen pengesahan termasuk melalui analisis fasa kristal dan morfologi.

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABBREVIATIONS

°C	-	Degree Celsius
ANOVA	-	Analysis of Variance
AP	-	Apparent Porosity
ASTM	-	American Society for Testing and Materials
BD	-	Bulk Density
DOF	-	Degree of freedom
EDX	-	Energy-Dispersive X-ray
FPA	-	Flower Pollination Algorithm
FS	-	Flexural Strength
g	-	gram
GPOFA	-	Ground Palm Oil Fuel Ash
GRA	-	Grey Relational Analysis
GRC	-	Grey Relational Coefficient
GRG	-	Grey Relational Grade
h	-	hour
ICDD	-	International Center for Diffraction Data
kN	-	kilo Newton
min	-	minute
MPOB	-	Malaysian Palm Oil Board
OA	-	Orthogonal Array
POFA	-	Palm Oil Fuel Ash
rpm	-	Revolution per minute
SEM	-	Scanning Electron Microscope
SH	-	Shrinkage
SNR	-	Signal to Noise Ratio
UGPOFA	-	Unground Palm Oil Fuel Ash
UPOFA	-	Ultrafine Palm Oil Fuel Ash
t	-	ton

TPOFA	-	Treated Palm Oil Fuel Ash
μm	-	micrometers
WA	-	Water Absorption
wt.%	-	weight percent
XRD	-	X-ray Diffraction
XRF	-	X-ray fluorescence

LIST OF APPENDICES

LIST OF PUBLICATIONS

1) **Zainudin, A.**, Sia, C. K., Ong, P., Ching, N. O. L., & Nor, N. H. M. (2017). Potential of Palm Oil Fuel Ash (POFA) Layers as Secondary Raw Material in Porcelain Stoneware Application. Journal of Mechanical Engineering, 2(2), 71–81.
2) **Zainudin, A.**, Sia, C. K., Ong, P., Narong, O. L. C., & Nor, N. H. M. (2017). Taguchi design and flower pollination algorithm application to optimize the shrinkage of triaxial porcelain containing palm oil fuel ash. IOP Conference Series: Materials Science and Engineering, 165(1), 12036
3) Narong, O. L. C., Sia, C. K., Yee, S. K., Ong, P., **Zainudin, A.**, Nor, N. H. M., & Hassan, M. F. (2018). Optimisation of EMI shielding effectiveness: Mechanical and physical performance of mortar containing POFA for plaster work using Taguchi Grey method. Construction and Building Materials, 176, 509–518.
4) Ching, N. O. L., Sia, C. K., **Zainudin, A.**, Nor, N. H. M., & Yee, S. K. (2017). Exploring the Potential of Palm Oil Fuel Ash (POFA) in EMI Shielding Effectiveness. Journal of Mechanical Engineering, 2(1), 101–111.
5) Narong, O. L. C., Sia, C. K., Yee, S. K., Ong, P., **Zainudin, A.**, Nor, N. H. M., & Kasim, N. A. (2017). Optimization of the EMI shielding effectiveness of fine and ultrafine POFA powder mix with OPC powder using Flower Pollination Algorithm. IOP Conference Series: Materials Science and Engineering, 165(1), 12035.
6) Narong, O. L. C., Sia, C. K., Yee, S. K., Ong, P., **Zainudin, A**., Nor, N. H. M., & Hassan, M. F. (2018). Optimization of EMI shielding effectiveness plaster mortar containing POFA using Taguchi design and Flower Pollination Algorithm method. International Journal of Integrated Engineering, 10(3), 93-101.
7) Hassan, M. F., **Zainudin, A**., Sia, C. K., Ong, P., Narong, O. L. C., Yee, S. K., & Katimon, M. N. (2019). Interaction of Taguchi Design with Quantitative Analysis of Crystalline Phase in Triaxial Ceramic Employing

Palm Oil Fuel Ash Application. IOP Conference Series: Materials Science and Engineering. (Publication process)

8) **Zainudin, A**., Sia, C. K., Ong, P., Narong, O. L. C., Azlan, M. A., & Lee, W. K. (2019). Performance Properties Optimization of Triaxial Ceramic-Palm Oil Fuel Ash By Employing Taguchi Grey Relational Analysis. International Journal of Integrated Engineering. (Review process)

CHAPTER 1

INTRODUCTION

This chapter deals with the introduction of research. The chapter starts with a research background, followed by problem statements, objectives, scopes, significant of research, and outline of the thesis.

1.1. Research background

Ceramic application can be classified into advanced and traditional ceramics. Advanced ceramics are made from artificial and chemically modified raw materials. They include five major industry segments which are structural, electrical, coatings, chemical and environmental ceramics. Meanwhile, traditional ceramics are mainly made from natural raw materials such as porcelain, stoneware, earthenware, whitewares, concretes, refractories, and structural clay products. The traditional ceramic is simply called triaxial ceramic because of the triaxial composition (Bhattacharyya & Snehesh, 2015; Bó & Hotza, 2013; Conconi et al., 2014; Ngun et al., 2014; Serra et al., 2015). It is basically composed of plasticity material (clay or kaolin), fluxing agent (feldspar), and filler material (silica or quartz) (Barry Carter & Grant Norton, 2013).

Industrial activity produces huge industrial waste, including any material regarded useless during the manufacturing processes such as in factories, industries, mills, and mining operations. Some examples of industrial wastes are chemical solvents, pigments, sludge, metals, ash, paper products, industrial by-products, and radioactive wastes. Recently, most of these wastes are found to have potential for use in certain applications. The motivation for using those wastes is to reduce the agricultural and industrial wastes that are uncontrollably dumped in landfills.

One of the industrial wastes is from the palm oil industry. Currently, Malaysia is surrounded by 5.81 million hectares of oil palm planted area as reported by MPOB (2017). Malaysia is one of the world's largest producers of palm oil. Due to the operations, Malaysia generates a huge quantity of wastes including trunks, fronds, empty fruit bunches, palm kernel shell, palm mesocarp fiber, and palm kernel cake. Other than trunks and fronds, wasted materials have been recycled as a combusted material in the palm oil mill boilers to generate electrical energy. The ash produced from this burning is called Palm Oil Fuel Ash (POFA) (Awal & Hussin, 1997). With hundreds of palm oil mills operating in Malaysia, thousands of tons of ash are produced annually as reported in studies about previous POFA usages (Abdul Shukor Lim et al., 2015; Altwair et al., 2012; Chandara et al., 2010; Khalid et al., 2016; Megat Johari et al., 2012; Salih et al., 2014; Yusuf, Megat Johari, et al., 2014a).

POFA in respective application are normally presented as unground POFA (UGPOFA), ground POFA (GPOFA), treated POFA (TPOFA), and ultrafine POFA (UPOFA). Generally, collected POFAs are obtained in the form of irregular, porous, and large shapes. Researchers initially sieve the collected POFA to remove excessive size particles called UGPOFA. If these UGPOFAs are grounded and re-sieved, GPOFA is then produced. Furthermore, when it is heated at the right temperature, TPOFA is produced. Meanwhile, if TPOFA is re-grounded and re-sieved, UPOFA is produced. However, various chemical composition of POFA have been reported from different POFA that were used by various researchers (Thomas et al., 2017). Hence, each particle part of established POFA is highly present in various significant levels for a respective application. This means, only a few parts of POFA particles are needed in the respective application. In a review process by Thomas et al. (2017), there are researchers who explained that carbon does not help in the strength developments of concrete. However, higher silica content during the burning process is highly needed. It shows that POFA contains both significant and insignificant parts. Therefore, a process for separating these two parts of POFA are considered in this research to collect just the significant POFA.

The modifications of triaxial ceramic products are evaluated in terms of performance properties. The performance properties present both physical and mechanical properties. Those performance properties are continually improved from various areas of triaxial ceramic research. Shrinkage, water absorption, apparent porosity, and bulk density are the physical properties in this research. Meanwhile, flexural strength represents the mechanical property. Shrinkage is frequently applied to a ceramic product as quality and process control parameters, where it controls the dimension of that ceramic product. Water absorption is also a character of a triaxial ceramic specimen where it points to the lower water absorption condition. It means that the specimen is frost resistant and able to prevent liquid from permeating. Meanwhile, apparent porosity relates to a condition of open pore where it is a cavity that communicates with the surface of the ceramic body. Following that, maximum bulk density and flexural strength is desired. Flexural strength represents the highest stress experienced by the ceramic product at its moment of yield.

The substitution of new material causes a change of the optimal parameter. To obtain a new optimal parameter, the design of experiment tools is usually applied. Recently, a mixture design tool has been used in a triaxial ceramic application to obtain an optimized composition of the three raw materials (Coronado et al., 2014, 2015; Dal Bó et al., 2014; Ngun et al., 2014). However, other parameters like sintering temperature, soaking time, molding pressure, and heating rate have been controlled as constant parameters. Following that, optimization represents a process to obtain the new optimal condition for process. In this research, optimization process is performed to obtain optimal condition for the highest performance properties.

Jurków & Stiernstedt (2014) had applied the Taguchi design to optimize many parameters by considering cost and time-consuming factors. The Taguchi design orthogonal array (OA) is the familiar generalized optimization tools that was introduced by Taguchi a long time ago. Taguchi design is still widely used among researchers from various fields today. Furthermore, Taguchi design was also found in POFA study which is a study of geopolymer product using treated POFA (TPOFA) (Mijarsh et al., 2014). Traditional Taguchi design analysis is specifically used to optimize single objective, while Taguchi Grey Relational Analysis (GRA) is used for multiple objectives. Theoretically, single objective represents that the property is individually targeted such as to produce the largest flexural strength specimen without considering other properties. Meanwhile, multi-objective involves several properties or at least two properties. This research involves the five single objectives and one multiple objective condition.

REFERENCES

Abdelaziz, A. Y., Ali, E. S., & Abd Elazim, S. M. (2016). Combined economic and emission dispatch solution using Flower Pollination Algorithm. International Journal of Electrical Power & Energy Systems, 80, 264–274.

Abdul Shukor Lim, N. H., Ismail, M. A., Lee, H. S., Hussin, M. W., Sam, A. R. M., & Samadi, M. (2015). The effects of high volume nano palm oil fuel ash on microstructure properties and hydration temperature of mortar. Construction and Building Materials, 93, 29–34.

Ahmad, N., Kamal, S., Raza, Z. A., Hussain, T., & Anwar, F. (2016). Multi-response optimization in the development of oleo-hydrophobic cotton fabric using Taguchi based grey relational analysis. Applied Surface Science, 367, 370–381.

Aineto, M., Acosta, A., & Iglesias, I. (2006). The role of a coal gasification fly ash as clay additive in building ceramic. Journal of the European Ceramic Society, 26, 3783–3787.

Akarsu, M., Burunkaya, E., Tunalı, A., Selli, N. T., & Arpaç, E. (2014). Enhancement of hybrid sol–gel coating and industrial application on polished porcelain stoneware tiles and investigation of the performance. Ceramics International, 40, 6533–6540.

Akpinar, S., Evcin, A., & Ozdemir, Y. (2017). Effect of calcined colemanite additions on properties of hard porcelain body. Ceramics International, 43, 8364–8371.

Allegretta, I., Eramo, G., Pinto, D., & Hein, A. (2014). The effect of temper on the thermal conductivity of traditional ceramics: Nature, percentage and granulometry. Thermochimica Acta, 581, 100–109.

Allegretta, I., Eramo, G., Pinto, D., & Hein, A. (2017). The effect of mineralogy, microstructure and firing temperature on the effective thermal conductivity of traditional hot processing ceramics. Applied Clay Science, 135, 260–270.

Alsubari, B., Shafigh, P., & Jumaat, M. Z. (2016). Utilization of high-volume treated palm oil fuel ash to produce sustainable self-compacting concrete. Journal of Cleaner Production, 137, 982–996.

Altwair, N. M., Megat Johari, M. A., & Saiyid Hashim, S. F. (2012). Flexural performance of green engineered cementitious composites containing high volume of palm oil fuel ash. Construction and Building Materials, 37, 518–525.

Álvaro Guzmán, A., Marisol Gordillo, S., Silvio Delvasto, A., María Francisca Quereda, V., & Enrique Sánchez, V. (2016). Optimization of the technological properties of porcelain tile bodies containing rice straw ash using the design of experiments methodology. Ceramics International, 42, 15383–15396.

Alyasseri, Z. A. A., Khader, A. T., Al-Betar, M. A., Awadallah, M. A., & Yang, X.-S. (2018). Variants of the Flower Pollination Algorithm: A Review. In X.-S. Yang (Ed.), Nature-Inspired Algorithms and Applied Optimization (pp. 91–118). Cham: Springer International Publishing.

ASTM C1161. (2003). Standard Test Method for Flexural Strength of Advanced Ceramics at Ambient Temperature. ASTM International.

ASTM C326. (2003). Standard Test Method for Drying and Firing Shrinkages of Ceramic Whiteware Clays. ASTM International.

ASTM C373. (2014). Standard Test Method for Water Absorption, Bulk Density, Apparent Porosity, and Apparent Specific Gravity of Fired Whiteware Products, Ceramic Tiles, and Glass Tiles. ASTM International.

ASTM C618. (2012). Standard Specification for Coal Fly Ash and Raw or Calcined Natural Pozzolan for Use in Concrete. ASTM International.

Awaad, M., Naga, S. M., & El-Mehalawy, N. (2015). Effect of replacing weathered feldspar for potash feldspar in the production of stoneware tiles containing fish bone ash. Ceramics International, 41, 7816–7822.

Awal, A. S. M. A., & Hussin, M. W. (1997). The effectiveness of palm oil fuel ash in preventing expansion due to alkali-silica reaction. Cement and Concrete Composites, 19, 367–372.

Awal, A. S. M. A., & Shehu, I. A. (2013). Evaluation of heat of hydration of concrete containing high volume palm oil fuel ash. Fuel, 105, 728–731.

Awal, A. S. M. A., & Shehu, I. A. (2015). Performance evaluation of concrete containing high volume palm oil fuel ash exposed to elevated temperature. Construction and Building Materials, 76, 214–220.

Awal, A. S. M. A., Shehu, I. A., & Ismail, M. (2015). Effect of cooling regime on the residual performance of high-volume palm oil fuel ash concrete exposed to high temperatures. Construction and Building Materials, 98, 875–883.

Azadi, R., & Rostamiyan, Y. (2015). Experimental and analytical study of buckling strength of new quaternary hybrid nanocomposite using Taguchi method for optimization. Construction and Building Materials, 88, 212–224.

Bafghi, M. S., Emami, A. H., Vahdati Khaki, J., & Zakeri, A. (2009). Development of a mathematical expression for the variation of amorphization phenomenon during intensive milling of minerals. International Journal of Mineral Processing, 93(2), 149–154.

Balak, Z., & Zakeri, M. (2016). Application of Taguchi L32 orthogonal design to optimize flexural strength of ZrB2-based composites prepared by spark plasma sintering. International Journal of Refractory Metals and Hard Materials, 55, 58–67.

Barry Carter, C., & Grant Norton, M. (2013). Ceramic Materials: Science and Engineering (3rd ed.). New York: Springer Science & Business Media.

Bashar, I. I., Alengaram, U. J., Jumaat, M. Z., Islam, A., Santhi, H., & Sharmin, A. (2016). Engineering properties and fracture behaviour of high volume palm oil fuel ash based fibre reinforced geopolymer concrete. Construction and Building Materials, 111, 286–297.

Bayer Ozturk, Z., & Eren Gultekin, E. (2015). Preparation of ceramic wall tiling derived from blast furnace slag. Ceramics International, 41, 12020–12026.

Bekdaş, G., Nigdeli, S. M., & Yang, X. S. (2015). Sizing optimization of truss structures using flower pollination algorithm. Applied Soft Computing, 37, 322–331.

Bernasconi, A., Diella, V., Pagani, A., Pavese, A., Francescon, F., Young, K., Stuardt, J., & Tunnicliffe, L. (2011). The role of firing temperature, firing time and quartz grain size on phase-formation, thermal dilatation and water absorption in sanitary-ware vitreous bodies. Journal of the European Ceramic Society, 31, 1353–1360.

Bhattacharyya, S., & Snehesh, T. S. (2015). Effect of cobalt oxide additive on the fired properties of tri-axial ceramic. Ceramics International, 41, 61–67.

Bó, M. D., & Hotza, D. (2013). Using Recycled Ceramics to make new Triaxial Ceramics. Refractories and Industrial Ceramics, 54(3), 243–250.

Bruker. (2008). X-Ray Spectrometry S4 Pioneer. Retrieved April 22, 2018, from https://www.brukersupport.com/ProductDetail/751

Chamoli, S., Yu, P., & Kumar, A. (2016). Multi-response optimization of geometric and flow parameters in a heat exchanger tube with perforated disk inserts by Taguchi grey relational analysis. Applied Thermal Engineering, 103, 1339–1350.

Chandara, C., Mohd Azizli, K. A., Ahmad, Z. A., Saiyid Hashim, S. F., & Sakai, E. (2012). Heat of hydration of blended cement containing treated ground palm oil fuel ash. Construction and Building Materials, 27, 78–81.

Chandara, C., Sakai, E., Azizli, K. A. M., Ahmad, Z. A., & Hashim, S. F. S. (2010). The effect of unburned carbon in palm oil fuel ash on fluidity of cement pastes containing superplasticizer. Construction and Building Materials, 24, 1590–1593.

Chen, C. H., & Huang, C. Y. (2017). Improve electromagnetic interference of electronic products with Taguchi parametric design. Measurement, 102, 200–207.

Chindaprasirt, P., Rukzon, S., & Sirivivatnanon, V. (2008). Resistance to chloride penetration of blended Portland cement mortar containing palm oil fuel ash, rice husk ash and fly ash. Construction and Building Materials, 22, 932–938.

Conconi, M. S., Gauna, M. R., Serra, M. F., Suarez, G., Aglietti, E. F., Rendtorff, N. M., & Gonnet, M. B. (2014). Quantitative firing transformations of a triaxial ceramic by X-ray diffraction methods. CerâMica, 60, 524–531.

Conserva, L. R. S., Melchiades, F. G., Nastri, S., Boschi, A. O., Dondi, M., Guarini, G., Raimondo, M., & Zanelli, C. (2017). Pyroplastic deformation of porcelain stoneware tiles: Wet vs. dry processing. Journal of the European Ceramic Society, 37(1), 333–342.

Coronado, M., Segadães, A. M., & Andrés, A. (2014). Combining mixture design of experiments with phase diagrams in the evaluation of structural ceramics containing foundry by-products. Applied Clay Science, 101, 390–400.

Coronado, M., Segadães, A. M. M., & Andrés, A. (2015). Using mixture design of experiments to assess the environmental impact of clay-based structural ceramics containing foundry wastes. Journal of Hazardous Materials, 299, 529–539.

Dal Bó, M., Bernardin, A. M., & Hotza, D. (2014). Formulation of ceramic engobes with recycled glass using mixture design. Journal of Cleaner Production, 69, 243–249.

Dal Bó, M., Cantavella, V., Sanchéz, E., Gilabert, F. A., Boschi, A. O., & Hotza, D. (2017). An estimate of quartz content and particle size in porcelain tiles from young's modulus measurements. Ceramics International, 43, 2233–2238.

Dao, T. P., Huang, S. C., & Thang, P. T. (2017). Hybrid Taguchi-cuckoo search algorithm for optimization of a compliant focus positioning platform. Applied Soft Computing Journal, 57, 526–538.

Deepanraj, B., Sivasubramanian, V., & Jayaraj, S. (2017). Multi-response optimization of process parameters in biogas production from food waste using Taguchi-Grey relational analysis. Energy Conversion and Management, 141, 429–438.

Deng, J. (1989). Introduction to Grey System Theory. The Journal of Grey System, 1, 1–24.

Dias, F. G., Segadães, A. M., Perottoni, C. A., & Cruz, R. C. D. (2017). Assessment of the fluxing potential of igneous rocks in the traditional ceramics industry. Ceramics International, 43, 16149–16158.

Dondi, M., Raimondo, M., & Zanelli, C. (2014). Clays and bodies for ceramic tiles: Reappraisal and technological classification. Applied Clay Science, 96, 91–109.

Draa, A. (2015). On the performances of the flower pollination algorithm – Qualitative and quantitative analyses. Applied Soft Computing, 34, 349–371.

Echeverrigaray, S. G., Emiliano, J. V., Segadães, A. M., & Cruz, R. C. D. (2016). Low-valued raw materials challenge the common eligibility criteria for triaxial ceramics. Ceramics International, 42, 10671–10681.

El-Maghraby, H. F., El-Omla, M. M., Bondioli, F., & Naga, S. M. (2011). Granite as flux in stoneware tile manufacturing. Journal of the European Ceramic Society, 31, 2057–2063.

Eren Gültekin, E. (2018). The effect of heating rate and sintering temperature on the elastic modulus of porcelain tiles. Ultrasonics, 83, 120–125.

Farzadnia, N., Noorvand, H., Yasin, A. M., & Aziz, F. N. A. (2015). The effect of nano silica on short term drying shrinkage of POFA cement mortars. Construction and Building Materials, 95, 636–646.

Ferreira, A., Fagnani, K. C., Alves, H. J., Colpini, L. M. S., Kunh, S. S., Nastri, S., Conserva, L. R. S., & Melchiades, F. G. (2018). Effect of incorporating sludge from poultry slaughterhouse wastewater treatment system in ceramic mass for tile production. Environmental Technology & Innovation, 9, 294–302.

Galán-Arboledas, R. J., Álvarez de Diego, J., Dondi, M., & Bueno, S. (2017). Energy, environmental and technical assessment for the incorporation of EAF stainless steel slag in ceramic building materials. Journal of Cleaner Production, 142, 1778–1788.

González, I., Campos, P., Barba-Brioso, C., Romero, A., Galán, E., & Mayoral, E. (2016). A proposal for the formulation of high-quality ceramic "green" materials with traditional raw materials mixed with Al-clays. Applied Clay Science, 131, 113–123.

Gouvêa, D., Tisse Kaneko, T., Kahn, H., Souza Conceição, E. de, & Antoniassi, J. L. (2015). Using bone ash as an additive in porcelain sintering. Ceramics International, 41, 487–496.

Gültekin, E. E., Topateş, G., & Kurama, S. (2017). The effects of sintering temperature on phase and pore evolution in porcelain tiles. Ceramics International, 43, 11511–11515.

Güngör, F., & Ay, N. (2018). The effect of particle size of body components on the processing parameters of semi transparent porcelain. Ceramics International, 44, 10611–10620.

Harabi, A., Guerfa, F., Harabi, E., Benhassine, M.-T., Foughali, L., & Zaiou, S. (2016). Preparation and characterization of new dental porcelains, using K-feldspar and quartz raw materials. Effect of B_2O_3 additions on sintering and mechanical properties. Materials Science and Engineering: C, 65, 33–42.

Iqbal, Y., & Lee, W. E. (2000). Microstructural Evolution in Triaxial Porcelain. Journal of the American Ceramic Society, 83, 3121–3127.

Islam, A., Alengaram, U. J., Jumaat, M. Z., & Bashar, I. I. (2014). The development of compressive strength of ground granulated blast furnace slag-palm oil fuel ash-fly ash based geopolymer mortar. Materials & Design, 56, 833–841.

Islam, M. M. U., Mo, K. H., Alengaram, U. J., & Jumaat, M. Z. (2016). Mechanical and fresh properties of sustainable oil palm shell lightweight concrete incorporating palm oil fuel ash. Journal of Cleaner Production, 115, 307–214.

Jamo, H. U., & Maharaz, M. N. (2014). Influence of Mould Pressure and Substitution of Quartz by Palm Oil Fuel Ash on The Hardness of Porcelain Body. Science World Journal, 9(4), 23–28.

Jamo, H. U., Noh, M. Z., & Ahmad, Z. A. (2013). Structural analysis and surface morphology of a treated palm oil fuel ash. Prosiding Seminar Kebangsaan Aplikasi Sains Dan Matematik.

Jamo, H. U., Noh, M. Z., & Ahmad, Z. A. (2014). Effects of palm oil fuel ash composition on the properties and morphology of porcelain-palm oil fuel ash composite. Jurnal Teknologi, 70(5), 5–10.

Jaturapitakkul, C., Tangpagasit, J., Songmue, S., & Kiattikomol, K. (2011). Filler effect and pozzolanic reaction of ground palm oil fuel ash. Construction and Building Materials, 25, 4287–4293.

Ji, R., Wu, S., Yan, C., Wang, H., He, Y., Zhao, D., & Wang, X. (2017). Preparation and characterization of the one-piece wall ceramic board by using solid wastes. Ceramics International, 43, 8564–8571.

Jurków, D., & Stiernstedt, J. (2014). Investigation of High Temperature Co-fired Ceramics sintering conditions using Taguchi Design of the experiment. Ceramics International, 40, 10447–10455.

Karabulut, Ş. (2015). Optimization of surface roughness and cutting force during AA7039/Al2O3 metal matrix composites milling using neural networks and Taguchi method. Measurement, 66, 139–149.

Karim, M. R., Zain, M. F. M., Jamil, M., & Lai, F. C. (2013). Fabrication of a non-cement binder using slag, palm oil fuel ash and rice husk ash with sodium hydroxide. Construction and Building Materials, 49, 894–902.

Kayabekir, A. E., Bekda\cs, G., Nigdeli, S. M., & Yang, X.-S. (2018). A Comprehensive Review of the Flower Pollination Algorithm for Solving Engineering Problems. In X.-S. Yang (Ed.), Nature-Inspired Algorithms and Applied Optimization (pp. 171–188). Cham: Springer International Publishing.

Ke, S., Wang, Y., Pan, Z., Ning, C., & Zheng, S. (2016). Recycling of polished tile waste as a main raw material in porcelain tiles. Journal of Cleaner Production, 115, 238–244.

Khalid, N. H. A., Hussin, M. W., Mirza, J., Ariffin, N. F., Ismail, M. A., Lee, H.-S., Mohamed, A., & Jaya, R. P. (2016). Palm oil fuel ash as potential green micro-filler in polymer concrete. Construction and Building Materials, 102, 950–960.

Khankhaje, E., Hussin, M. W., Mirza, J., Rafieizonooz, M., Salim, M. R., Siong, H. C., & Warid, M. N. M. (2016). On blended cement and geopolymer concretes containing palm oil fuel ash. Materials & Design, 89, 385–398.

Kim, K., Kim, K., & Hwang, J. (2015). LCD waste glass as a substitute for feldspar in the porcelain sanitary ware production. Ceramics International, 41, 7097–7102.

Kim, K., Kim, K., & Hwang, J. (2016). Characterization of ceramic tiles containing LCD waste glass. Ceramics International, 42, 7626–7631.

Kockal, N. U. (2015). Optimizing production parameters of ceramic tiles incorporating fly ash using response surface methodology. Ceramics International, 41, 14529–14536.

Kokunešoski, M., Šaponjić, A., Maksimović, V., Stanković, M., Pavlović, M., Pantić, J., & Majstorović, J. (2014). Preparation and characterization of clay-based porous ceramics with boric acid as additive. Ceramics International, 40, 14191–14196.

Lazim, D., Zain, A. M., Bahari, M., & Omar, A. H. (2017). Review of modified and hybrid flower pollination algorithms for solving optimization problems. Artificial Intelligence Review, 1–31.

Lee, W. E., & Iqbal, Y. (2001). Influence of mixing on mullite formation in porcelain. Journal of the European Ceramic Society, 21, 2583–2586.

Lerdprom, W., Chinnam, R. K. K., Jayaseelan, D. D. D., & Lee, W. E. E. (2016). Porcelain production by direct sintering. Journal of the European Ceramic Society, 36, 4319–4325.

Lerdprom, W., Zapata-Solvas, E., Jayaseelan, D. D., Borrell, A., Salvador, M. D., & Lee, W. E. (2017). Impact of microwave processing on porcelain microstructure. Ceramics International, 43, 13765–13771.

Lim, S. K., Tan, C. S., Lim, O. Y., & Lee, Y. L. (2013). Fresh and hardened properties of lightweight foamed concrete with palm oil fuel ash as filler. Construction and Building Materials, 46, 39–47.

Luo, Y., Zheng, S., Ma, S., Liu, C., & Wang, X. (2017). Ceramic tiles derived from coal fly ash : Preparation and mechanical characterization. Ceramics International, 43(15), 11953–11966.

Magagnin, D., dos Santos, C. M. F., Wanderlind, A., Jiusti, J., & De Noni, A. (2014). Effect of kaolinite, illite and talc on the processing properties and mullite content of porcelain stoneware tiles. Materials Science and Engineering: A, 618, 533–539.

Manikandan, N., Kumanan, S., & Sathiyanarayanan, C. (2017). Multiple performance optimization of electrochemical drilling of Inconel 625 using

Taguchi based Grey Relational Analysis. Engineering Science and Technology, an International Journal, 20, 662–671.

Manivel, D., & Gandhinathan, R. (2016). Optimization of surface roughness and tool wear in hard turning of austempered ductile iron (grade 3) using Taguchi method. Measurement, 93, 108–116.

Márquez, J. M., Rincón, J. M., & Romero, M. (2008). Effect of firing temperature on sintering of porcelain stoneware tiles. Ceramics International, 34, 1867–1873.

Márquez, J. M., Rincón, J. M., & Romero, M. (2010). Effect of microstructure on mechanical properties of porcelain stoneware. Journal of the European Ceramic Society, 30, 3063–3069.

Megat Johari, M. A., Zeyad, A. M., Muhamad Bunnori, N., & Ariffin, K. S. (2012). Engineering and transport properties of high-strength green concrete containing high volume of ultrafine palm oil fuel ash. Construction and Building Materials, 30, 281–288.

Mijarsh, M. J. A., Megat Johari, M. A., & Ahmad, Z. A. (2014). Synthesis of geopolymer from large amounts of treated palm oil fuel ash: Application of the Taguchi method in investigating the main parameters affecting compressive strength. Construction and Building Materials, 52, 473–481.

Mijarsh, M. J. A., Megat Johari, M. A., & Ahmad, Z. A. (2015). Compressive strength of treated palm oil fuel ash based geopolymer mortar containing calcium hydroxide, aluminum hydroxide and silica fume as mineral additives. Cement and Concrete Composites, 60, 65–81.

Mohammadi, F., & Mohammadi, T. (2017). Optimal conditions of porous ceramic membrane synthesis based on alkali activated blast furnace slag using Taguchi method. Ceramics International, 43, 14369–14379.

Mohanty, S. K., Mishra, G. P., & Mangaraj, B. B. (2014). Implementing Taguchi and cuckoo search to optimize LAA. In 2014 Annual IEEE India Conference (INDICON) (pp. 1–5).

Montoya, N., Serrano, F. J., Reventós, M. M., Amigo, J. M., & Alarcón, J. (2010). Effect of TiO_2 on the mullite formation and mechanical properties of alumina porcelain. Journal of the European Ceramic Society, 30, 839–846.

MPOB. (2017). Overview of the Malaysian Oil Palm Industry 2017. Retrieved April 18, 2018, from http://www.mpob.gov.my/

Mujah, D. (2016). Compressive strength and chloride resistance of grout containing ground palm oil fuel ash. Journal of Cleaner Production, 112, 712–722.

Mujah, D., Rahman, M. E., & Zain, N. H. M. (2015). Performance evaluation of the soft soil reinforced ground palm oil fuel ash layer composite. Journal of Cleaner Production, 95, 89–100.

Naga, S. M., Bondioli, F., Wahsh, M. M. S., & El-Omla, M. (2012). Utilization of granodiorite in the production of porcelain stoneware tiles. Ceramics International, 38, 6267–6272.

Nagaratnam, B. H., Rahman, M. E., Mirasa, A. K., Mannan, M. A., & Lame, S. O. (2016). Workability and heat of hydration of self-compacting concrete incorporating agro-industrial waste. Journal of Cleaner Production, 112, 882–894.

Nandi, V. S., Raupp-Pereira, F., Montedo, O. R. K., & Oliveira, A. P. N. (2015). The use of ceramic sludge and recycled glass to obtain engobes for manufacturing ceramic tiles. Journal of Cleaner Production, 86, 461–470.

Nelabhotla, D. M., Jayaraman, T. V., Asghar, K., & Das, D. (2016). The optimization of chemical mechanical planarization process-parameters of c-plane gallium-nitride using Taguchi method and grey relational analysis. Materials & Design, 104, 392–403.

Ngun, B. K., Mohamad, H., Katsumata, K., Okada, K., & Ahmad, Z. A. (2014). Using design of mixture experiments to optimize triaxial ceramic tile compositions incorporating Cambodian clays. Applied Clay Science, 87, 97–107.

Noh, M. Z., Jamo, H. U., & Ahmad, Z. A. (2017). The bending strength of the porcelain with the substitution of quartz by palm oil fuel ash. Materials Science Forum, 888, 112–116.

Noorvand, H., Ali, A. A. A., Demirboga, R., Noorvand, H., & Farzadnia, N. (2013). Physical and chemical characteristics of unground palm oil fuel ash cement mortars with nanosilica. Construction and Building Materials, 48, 1104–1113.

Olupot, P. W., Jonsson, S., & Byaruhanga, J. K. (2010). Development and characterisation of triaxial electrical porcelains from Ugandan ceramic minerals. Ceramics International, 36, 1455–1461.

Pant, S., Kumar, A., & Ram, M. (2017). Flower pollination algorithm development: a state of art review. International Journal of System Assurance Engineering and Management, 8(2), 1858–1866.

Pérez, J. M., Rincón, J. M., & Romero, M. (2012). Effect of moulding pressure on microstructure and technological properties of porcelain stoneware. Ceramics International, 38, 317–325.

Pérez, J. M., & Romero, M. (2014). Microstructure and technological properties of porcelain stoneware tiles moulded at different pressures and thicknesses. Ceramics International, 40, 1365–1377.

Pinheiro, B. C. A., & Holanda, J. N. F. (2013). Reuse of solid petroleum waste in the manufacture of porcelain stoneware tile. Journal of Environmental Management, 118, 205–210.

Porras, A., Maranon, A., & Ashcroft, I. A. (2016). Optimal tensile properties of a Manicaria-based biocomposite by the Taguchi method. Composite Structures, 140, 692–701.

Pourakbar, S., Asadi, A., Huat, B. B. K., & Fasihnikoutalab, M. H. (2015). Stabilization of clayey soil using ultrafine palm oil fuel ash (POFA) and cement. Transportation Geotechnics, 3, 24–35.

Praveen, A. S., Sarangan, J., Suresh, S., & Channabasappa, B. H. (2016). Optimization and erosion wear response of NiCrSiB/WC–Co HVOF coating using Taguchi method. Ceramics International, 42, 1094–1104.

Rahaman, M. N. (2003). Ceramic Processing and Sintering (2nd Ed.). New York: Marcel Dekker, Inc.

Ranganathan, S., Tebbe, J., Wiemann, L. O., & Sieber, V. (2016). Optimization of the lipase mediated epoxidation of monoterpenes using the design of experiments—Taguchi method. Process Biochemistry, 51, 1479–1485.

Ranjbar, N., Behnia, A., Alsubari, B., Moradi Birgani, P., & Jumaat, M. Z. (2016). Durability and mechanical properties of self-compacting concrete incorporating palm oil fuel ash. Journal of Cleaner Production, 112, 723–730.

Ranjbar, N., Mehrali, M., Alengaram, U. J., Metselaar, H. S. C., & Jumaat, M. Z. (2014). Compressive strength and microstructural analysis of fly ash/palm oil fuel ash based geopolymer mortar under elevated temperatures. Construction and Building Materials, 65, 114–121.

Ranjbar, N., Mehrali, M., Behnia, A., Alengaram, U. J., & Jumaat, M. Z. (2014). Compressive strength and microstructural analysis of fly ash/palm oil fuel ash based geopolymer mortar. Materials & Design, 59, 532–539.

Reddy, P. D. P., Reddy, V. C. V., & Manohar, T. G. (2016). Application of flower pollination algorithm for optimal placement and sizing of distributed generation in Distribution systems. Journal of Electrical Systems and Information Technology, 3, 14–22.

Ross, P. J. (1996). Taguchi Techniques for Quality Engineering: Loss Function, Orthogonal Experiments, Parameter and Tolerance Design. McGraw-Hill.

Sahu, P. K., & Pal, S. (2015). Multi-response optimization of process parameters in friction stir welded AM20 magnesium alloy by Taguchi grey relational analysis. Journal of Magnesium and Alloys, 3, 36–46.

Salem, A., Jazayeri, S. H., Rastelli, E., & Timellini, G. (2010). Kinetic model for isothermal sintering of porcelain stoneware body in presence of nepheline syenite. Thermochimica Acta, 503–504, 1–7.

Salih, M. A., Abang Ali, A. A., & Farzadnia, N. (2014). Characterization of mechanical and microstructural properties of palm oil fuel ash geopolymer cement paste. Construction and Building Materials, 65, 592–603.

Salih, M. A., Farzadnia, N., Abang Ali, A. A., & Demirboga, R. (2015). Effect of different curing temperatures on alkali activated palm oil fuel ash paste. Construction and Building Materials, 94, 116–125.

Senthilkumar, N., Tamizharasan, T., & Anandakrishnan, V. (2014). Experimental investigation and performance analysis of cemented carbide inserts of different geometries using Taguchi based grey relational analysis. Measurement, 58, 520–536.

Serra, M. F., Conconi, M. S., Gauna, M. R., Suárez, G., Aglietti, E. F., & Rendtorff, N. M. (2016). Mullite ($3Al_2O_3 \cdot 2SiO_2$) ceramics obtained by reaction sintering of rice husk ash and alumina, phase evolution, sintering and microstructure. Journal of Asian Ceramic Societies, 4, 61–67.

Serra, M. F., Conconi, M. S., Suarez, G., Aglietti, E. F., & Rendtorff, N. M. (2015). Volcanic ash as flux in clay based triaxial ceramic materials, effect of the firing temperature in phases and mechanical properties. Ceramics International, 41, 6169–6177.

Shanmugarajan, B., Shrivastava, R., Sathiya, P., & Buvanashekaran, G. (2016). Optimisation of laser welding parameters for welding of P92 material using Taguchi based grey relational analysis. Defence Technology, 12, 343–350.

Shilaja, C., & Ravi, K. (2017). Optimization of emission/economic dispatch using euclidean affine flower pollination algorithm (eFPA) and binary FPA (BFPA) in solar photo voltaic generation. Renewable Energy, 107, 550–566.

Shinde, A. B., & Pawar, P. M. (2017). Multi-objective optimization of surface textured journal bearing by Taguchi based Grey relational analysis. Tribology International, 114, 349–357.

Sokolar, R., Kersnerová, L., & Sveda, M. (2017). The effect of different fluxing agents on the sintering of dry pressed porcelain bodies. Journal of Asian Ceramic Societies, 5, 290–294.

Sowinska, M. (2014). In-operando hard X-ray photoelectron spectroscopy study on the resistive switching physics of HfO_2 -based RRAM. PhD Thesis, Brandenburg University of Technology.

Srirangan, A. K., & Paulraj, S. (2016). Multi-response optimization of process parameters for TIG welding of Incoloy 800HT by Taguchi grey relational analysis. Engineering Science and Technology, an International Journal, 19, 811–817.

Sultana, M. S., Ahmed, A. N., Zaman, M. N., Rahman, M. A., Biswas, P. K., & Nandy, P. K. (2015). Utilization of hard rock dust with red clay to produce roof tiles. Journal of Asian Ceramic Societies, 3, 22–26.

Taguchi, G., Chowdhury, S., & Wu, Y. (2005). Taguchi's Quality Engineering Handbook. Wiley.

Tangchirapat, W., & Jaturapitakkul, C. (2010). Strength, drying shrinkage, and water permeability of concrete incorporating ground palm oil fuel ash. Cement and Concrete Composites, 32, 767–774.

Tangchirapat, W., Jaturapitakkul, C., & Chindaprasirt, P. (2009). Use of palm oil fuel ash as a supplementary cementitious material for producing high-strength concrete. Construction and Building Materials, 23, 2641–2646.

Tarhan, B., Tarhan, M., & Aydin, T. (2017). Reusing sanitaryware waste products in glazed porcelain tile production. Ceramics International, 43, 3107–3112.

Tarhan, M., Tarhan, B., & Aydin, T. (2016). The effects of fine fire clay sanitaryware wastes on ceramic wall tiles. Ceramics International, 42, 17110–17115.

Teo, P.-T., Seman, A. A., Basu, P., & Sharif, N. M. (2014). Recycling of Malaysia's electric arc furnace (EAF) slag waste into heavy-duty green ceramic tile. Waste Management, 34, 2697–708.

Thomas, B. S., Kumar, S., & Arel, H. S. (2017). Sustainable concrete containing palm oil fuel ash as a supplementary cementitious material – A review. Renewable and Sustainable Energy Reviews, 80, 550–561.

Tsai, T.-N., & Liukkonen, M. (2016). Robust parameter design for the micro-BGA stencil printing process using a fuzzy logic-based Taguchi method. Applied Soft Computing, 48, 124–136.

Wang, H., Zhu, M., Sun, Y., Ji, R., Liu, L., & Wang, X. (2017). Synthesis of a ceramic tile base based on high-alumina fly ash. Construction and Building Materials, 155, 930–938.

Xi, X., Xiong, H., Zou, C., Zuo, F., Huang, R., & Lin, H. T. (2017). Oxidation protection of SiC in porcelain tile ceramics by adding Si powder. Journal of the European Ceramic Society, 37, 2753–2756.

Xi, X., Xu, L., Shui, A., Wang, Y., & Naito, M. (2014). Effect of silicon carbide particle size and CaO content on foaming properties during firing and microstructure of porcelain ceramics. Ceramics International, 40, 12931–12938.

Xu, S., & Wang, Y. (2017). Parameter estimation of photovoltaic modules using a hybrid flower pollination algorithm. Energy Conversion and Management, 144, 53–68.

Yang, X.-S. (2012). Flower Pollination Algorithm for Global Optimization. Unconventional Computation and Natural Computation 2012, Lecture Notes in Computer Science, 7445, 240–249.

Yang, X.-S., Karamanoglu, M., & He, X. (2013). Multi-objective flower algorithm for optimization. Procedia Computer Science, 18, 861–868.

Yusuf, M. O. (2015). Performance of slag blended alkaline activated palm oil fuel ash mortar in sulfate environments. Construction and Building Materials, 98, 417–424.

Yusuf, M. O., Azmi, M., Johari, M., Ahmad, Z. A., & Maslehuddin, M. (2014). Evolution of alkaline activated ground blast furnace slag-ultrafine palm oil fuel ash based concrete. Materials and Design, 55, 387–393.

Yusuf, M. O., Megat Johari, M. A., Ahmad, Z. A., & Maslehuddin, M. (2014a). Influence of curing methods and concentration of NaOH on strength of the synthesized alkaline activated ground slag-ultrafine palm oil fuel ash mortar/concrete. Construction and Building Materials, 66, 541–548.

Yusuf, M. O., Megat Johari, M. A., Ahmad, Z. A., & Maslehuddin, M. (2014b). Shrinkage and strength of alkaline activated ground steel slag/ultrafine palm oil fuel ash pastes and mortars. Materials and Design, 63, 710–718.

Yusuf, M. O., Megat Johari, M. A., Ahmad, Z. A., & Maslehuddin, M. (2014c). Strength and microstructure of alkali-activated binary blended binder containing palm oil fuel ash and ground blast-furnace slag. Construction and Building Materials, 52, 504–510.

Zeyad, A. M., Megat Johari, M. A., Tayeh, B. A., & Yusuf, M. O. (2017). Pozzolanic reactivity of ultrafine palm oil fuel ash waste on strength and durability performances of high strength concrete. Journal of Cleaner Production, 144, 511–522.

Zhou, J., Li, T., Zhang, Q., Wang, Y., & Shu, Z. (2013). Direct-utilization of sewage sludge to prepare split tiles. Ceramics International, 39(8), 9179–9186.