THE EFFECT OF ELEVATED TEMPERATURE AND HEATING DURATION ON HIGH STRENGTH CONCRETE WITH STEEL SLAG AS CEMENT REPLACEMENT

HO CHIA MIN

MASTER OF SCIENCE

UNIVERSITI MALAYSIA PAHANG

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this thesis and in our opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

(Supervisor's Signature)

Full Name : ASSOCIATE PROF. DR. DOH SHU ING

Position : ASSOCIATE PROFESSOR

Date : 06 JULY 2023

(Co-supervisor's Signature)

Full Name : ASSOCIATE PROF. IR. DR. CHIN SIEW CHOO

Position : ASSOCIATE PROFESSOR

Date : 06 JULY 2023

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

____

(Student's Signature)

Full Name : HO CHIA MIN

ID Number : MAH 21007

Date : 06 JULY 2023

THE EFFECT OF ELEVATED TEMPERATURE AND HEATING DURATION ON HIGH STRENGTH CONCRETE WITH STEEL SLAG AS CEMENT REPLACEMENT

HO CHIA MIN

Thesis submitted in fulfillment of the requirements
for the award of the degree of
Master of Science

Faculty of Civil Engineering Technology

UNIVERSITI MALAYSIA PAHANG

JULY 2023

ACKNOWLEDGEMENTS

My utmost gratitude goes to Associate Professor Dr. Doh Shu Ing, my supervisor, and Associate Professor Ir. Dr. Chin Siew Choo, for their remarkable patience and constructive suggestions that proved invaluable throughout this project. I also owe a debt of gratitude to my defence committee, whose knowledge and expertise were indispensable in enabling me to undertake this journey, and whose support and guidance were immensely appreciated. Lastly, I extend my sincere thanks to the Institute of Postgraduate Students (IPS) for their generous backing of my research.

I wish to express my appreciation to my lab technician and collaborator, particularly Li Xiaofeng, my lab partner, for their valuable aid and technical expertise. I am also grateful to the university's librarians, research assistants, and study participants, whose contributions had a profound impact on me and served as a source of inspiration.

Furthermore, I would like to acknowledge my family, most notably my parents and siblings, for their unwavering faith in me, which sustained my enthusiasm and determination throughout this endeavor. Finally, I would like to thank Li Xiaofeng for providing guidance and a sounding board, in addition to the emotional support they offered.

ABSTRAK

Permintaan konkrit yang signifikan telah menyumbang kepada pengeluaran simen dalam kuantiti yang banyak di mana simen adalah bahan utama dalam pembuatan konkrit. Selain itu, sisa industri seperti sisa keluli (SS) dihasilkan dalam kuantiti yang besar dan kebanyakannya dibuang ke tapak pelupusan, akhirnya menyebabkan impak negatif terhadap alam sekitar. Penggunaan SS sebagai pengganti sebahagian simen dalam pembuatan konkrit akan mengurangkan penggunaan simen dan kuantiti sisa yang dilupuskan. Di samping itu, konkrit berkekuatan tinggi (HSC) adalah komposit heterogen yang mengalami perubahan sifat fizikal, kimia, dan mekanikal yang rumit apabila terdedah kepada suhu tinggi. Penggunaan produk sampingan industri sebagai bahan tambahan dalam HSC telah mempengaruhi sifatnya selepas terdedah kepada suhu tinggi. Oleh itu, penyelidikan ini dilakukan untuk mengkaji kesan suhu tinggi yang berbeza dan tempoh pemanasan terhadap HSC dengan saiz zarah SS yang berbeza sebagai pengganti simen, berdasarkan sifat fizikal, kimia, dan mekanikalnya. Dua saiz zarah SS yang berbeza telah digunakan sebagai pengganti sebahagian simen, iaitu SS halus (FSS-0.075mm) dan SS kasar (CSS-0.15mm). Pada peringkat awal penyelidikan, campuran percubaan telah dijalankan untuk mengenal pasti nisbah air-simen optimum dan nisbah penggantian SS. Satu spesimen kawalan dan SS-HSC telah dibancuh menjadi (100 x 100 x 100) mm kuib, dan (dia. 100 x 300) mm. Selepas 28 hari, spesimen tersebut diletakkan dalam relau elektrik pada suhu 200 ℃, 400 ℃, 600 ℃, dan 800 ℃ selama 1, 2, dan 3 jam. Sifat fizikokimia SS-HSC telah diperiksa melalui kehilangan jisim, perubahan warna, pengimbasan mikrokop elektron (SEM), difraksi X-Ray (XRD), dan analisis termogravimetrik (TGA). Sifat mekanikal SS-HSC juga telah disiasat melalui ujian kekuatan mampatan dan modulus keanjalan. Keputusan daripada ujian tersebut digunakan dalam pemodelan matematik, menggunakan Response surface methodology (RSM) telah dijalankan untuk membangunkan model matematik dengan pelbagai pembolehubah bebas dan bergantung. Hasil kajian menunjukkan bahawa struktur mikro HSC menjadi lebih padat apabila dipanaskan sehingga 400°C, manakala retakan mikro ditemui apabila terdedah kepada suhu 600°C dan ke atas. Kekuatan mampatan sisa HSC meningkat sehingga 400°C, tetapi berkurangan setelah terdedah kepada suhu 600°C dan ke atas. Selain itu, CSS10 mendapati kekuatan mampatan relatif yang lebih tinggi daripada FSS10 apabila dipanaskan pada suhu yang tinggi. Fenomena yang diperhatikan boleh dikaitkan dengan saiz zarah SS yang lebih kasar yang bertindak sebagai bahan simen tambahan serta agregat dalam HSC. Daripada pemodelan RSM, HSC yang dikenakan suhu yang tinggi selama 2 jam mengekalkan prestasi mekanikal yang baik manakala CSS10 menunjukkan kelakuan selepas kebakaran yang lebih baik berbanding dengan FSS10. Pekali penentuan terlaras (R2 terlaras) bagi kedua-dua ujian adalah 0.9648 dan 0.9126. Secara keseluruhan, kajian menunjukkan bahawa HSC yang mengandungi CSS berpotensi untuk digunakan sebagai aplikasi struktur dalam rintangan api.

ABSTRACT

A vast demand for concrete contributes to an enormous cement production where cement is the primary constituent in concrete manufacturing. Besides, the industry waste such as steel slag (SS) has produced in a large quantity and a large portion of it is disposed of on landfilling which causing a serious environmental impact. Utilization of the SS as partial cement replacement in producing concrete would reduce the cement consumption and amount of waste disposed. In addition, high strength concrete (HSC) is a heterogeneous composite which undergoes a transformation of physical, chemical, and mechanical behavior in a complicated way when subjected to elevated temperatures. The use of industrial by-products as supplementary cementitious materials in HSC has influenced the performance of itself after exposure to high temperature Thus, this research was conducted to investigate the effect of different heating temperatures and heating durations on HSC with the different particle sizes of SS as cement replacement based on the physical, chemical, and mechanical properties. Two different SS particle sizes were used as partial cement replacements which are fine SS (0.075mm) and coarse SS (0.15mm). At the early stage of the research, trial mix was conducted to identify the optimum water-cement ratio and SS replacement ratio. A control specimen and SS-HSC was cast into (100 x 100 x 100) mm cube, and (dia. 100 x 300) mm. After 28 days, the specimens were placed in the electrical furnace at temperature of 200℃, 400℃, 600℃ and 800℃ for 1, 2 and 3 hours. The physicochemical characteristic of the SS-HSC was examined by mass loss, color change, scanning electron microcopy (SEM), X-Ray diffraction (XRD), and thermogravimetric analysis (TGA). While the mechanical properties of SS-HSC were investigated by compressive strength test and modulus of elasticity. Besides, the results from compressive strength test and modulus of elasticity were used in mathematical modelling. In this study, Response surface methodology (RSM) was conducted to develop the mathematical model with various independent and dependent variables. The findings show that microstructure of HSC becomes denser when heated up to 400°C while the microcracks are found when subjected to 600°C and above. The residual compressive strength of SS-HSC is increased up to 400°C and decreased after exposure to 600°C and above. Furthermore, CSS10 obtained slightly higher relative residual compressive strength than FSS10 when heated at elevated temperature. The observed phenomenon could be attributed to the coarser particles size of SS acting as supplementary cementitious materials as well as aggregate in the HSC. From the RSM modelling, HSC subjected to elevated temperatures for 2 hours retains a significantly good performance on the mechanical properties while CSS10 presents a better post-fire behavior as compared to FSS10. The adjusted coefficient of determination (predicted R^2) of the models are 0.9648 and 0.9126, respectively. Finally, the study showed that HSC that containing CSS has the potential to be used as structural application in fire resistance.

TABLE OF CONTENT

REFERENCES

Abd AlRahman, D. Y. A. (2019). *The Use of Steel Slag in Manufacturing of Portland cement*.

ACI Committee 211. (1993). Guide for Selecting Proportions for High-Strength Concrete with Portland Cement and Fly Ash. In *ACI Materials Journal* (Vol. 90, Issue 3). https://doi.org/10.14359/9754

Adesanya, E., Sreenivasan, H., Kantola, A. M., Telkki, V. V., Ohenoja, K., Kinnunen, P., & Illikainen, M. (2018). Ladle slag cement – Characterization of hydration and conversion. *Construction and Building Materials*, *193*, 128–134. https://doi.org/10.1016/j.conbuildmat.2018.10.179

Afroughsabet, V., & Ozbakkaloglu, T. (2015). Mechanical and durability properties of high-strength concrete containing steel and polypropylene fibers. *Construction and Building Materials*, *94*, 73–82. https://doi.org/10.1016/j.conbuildmat.2015.06.051

Aïtcin, P. C. (2016). Portland cement. In *Science and Technology of Concrete Admixtures*. Woodhead Publishing. https://doi.org/10.1016/B978-0-08-100693-1.00003-5

Akbarzadeh Bengar, H., Shahmansouri, A. A., Akkas Zangebari Sabet, N., Kabirifar, K., & W.Y. Tam, V. (2020). Impact of elevated temperatures on the structural performance of recycled rubber concrete: Experimental and mathematical modeling. *Construction and Building Materials*, *255*, 119374. https://doi.org/10.1016/j.conbuildmat.2020.119374

Akca, A. H., & Zihnioğlu, N. Ö. (2013). High performance concrete under elevated temperatures. *Construction and Building Materials*, *44*, 317–328. https://doi.org/10.1016/j.conbuildmat.2013.03.005

Akhtar, M. N., Ibrahim, Z., Bunnori, N. M., Jameel, M., Tarannum, N., & Akhtar, J. N. (2021). Performance of sustainable sand concrete at ambient and elevated temperature. *Construction and Building Materials*, *280*, 122404. https://doi.org/10.1016/j.conbuildmat.2021.122404

Al-Oraimi, S. K., Taha, R., & Hassan, H. F. (2006). The effect of the mineralogy of coarse aggregate on the mechanical properties of high-strength concrete. *Construction and Building Materials*, *20*(7), 499–503. https://doi.org/10.1016/j.conbuildmat.2004.12.005

Ali, N., Jaffar, A., Anwer, M., Alwi, S. K. K., Anjum, M. N., Ali, N., Raja, M. R., Hussain, A., & Ming, X. (2015). The Greenhouse Gas Emissions Produced by Cement Production and Its Impact on Environment A Review of Global Cement Processing. *International Journal of Research*, *2*(2), 488–500. http://edupediapublications.org/journals/index.php/ijr/article/view/1455

Almeida, W., Ae, M., Pereira Gonçalves, J., Mô Nica Batista, A. E., & Lima, L. (2007). Copper slag waste as a supplementary cementing material to concrete. *Journal of Materials Science*, *42*, 2226–2230. https://doi.org/10.1007/s10853-006-0997-4

Alrekabi, S. (2011). *Engineering properties of concrete containing steel slag aggregate exposed to elevated temperatures* (Master's thesis) Retrived from https://doi.org/10.13140/2.1.4398.9761

Alsadey, S. (2012). Influence of Superplasticizer on Strength of Concrete. *International Journal of Research in Engineering and Technology*, *1*(3), 164–166.

Alsadey, S. (2015). Effect of Superplasticizer on Fresh and Hardened Properties of Concrete. *Journal of Agricultural Science and Engineering*, *1*(2), 70–74.

Amran, M., Murali, G., Khalid, N. H. A., Fediuk, R., Ozbakkaloglu, T., Lee, Y. H., Haruna, S., & Lee, Y. Y. (2021). Slag uses in making an ecofriendly and sustainable concrete: A review. *Construction and Building Materials*, *272*, 121942. https://doi.org/10.1016/j.conbuildmat.2020.121942

Anastasiou, E. K., Papayianni, I., & Papachristoforou, M. (2014). Behavior of self compacting concrete containing ladle furnace slag and steel fiber reinforcement. *Materials and Design*, *59*, 454–460. https://doi.org/10.1016/j.matdes.2014.03.030

Annadurai, A., & Ravichandran, A. (2014). Development of mix design for high strength Concrete with Admixtures. *IOSR Journal of Mechanical and Civil Engineering*, *10*(5), 22–27. www.iosrjournals.org

Aslani, F., & Bastami, M. (2011). Constitutive relationships for normal-and high-strength concrete at elevated temperatures. *ACI Materials Journal*, *108*(4), 355–364. https://doi.org/10.14359/51683106

Babalola, O. E., Awoyera, P. O., Le, D.-H., & Bendezú Romero, L. M. (2021). A review of residual strength properties of normal and high strength concrete exposed to elevated temperatures: Impact of materials modification on behaviour of concrete composite. *Construction and Building Materials*, *296*, 123448. https://doi.org/10.1016/j.conbuildmat.2021.123448

Bangi, M. R., & Horiguchi, T. (2012). Effect of fibre type and geometry on maximum pore pressures in fibre-reinforced high strength concrete at elevated temperatures. *Cement and Concrete Research*, *42*(2), 459–466. https://doi.org/10.1016/j.cemconres.2011.11.014

Bashandy, A. A. (2015). Performance of self-curing concrete at elevated temperatures. *Indian Journal of Engineering and Materials Sciences*, *22*(February), 93–104.

Bastami, M., Baghbadrani, M., & Aslani, F. (2014). Performance of nano-Silica modified high strength concrete at elevated temperatures. *Construction and Building Materials*, *68*, 402–408. https://doi.org/10.1016/j.conbuildmat.2014.06.026

Beaucour, A.-L., Pliya, P., Faleschini, F., Njinwoua, R., Pellegrino, C., & Noumowé, A. (2020). Influence of elevated temperature on properties of radiation shielding concrete with electric arc furnace slag as coarse aggregate. *Construction and Building Materials*, *256*, 119385. https://doi.org/10.1016/j.conbuildmat.2020.119385

Bediako, M., & Amankwah, E. O. (2015). *Analysis of Chemical Composition of Portland Cement in Ghana: A Key to Understand the Behavior of Cement*. https://doi.org/10.1155/2015/349401

Behnood, A., & Ziari, H. (2008). Effects of silica fume addition and water to cement ratio on the properties of high-strength concrete after exposure to high temperatures. *Cement and Concrete Composites*, *30*(2), 106–112. https://doi.org/10.1016/j.cemconcomp.2007.06.003

Belhadj, E., Diliberto, C., & Lecomte, A. (2012). Characterization and activation of Basic Oxygen Furnace slag. *Cement and Concrete Composites*, *34*(1), 34–40. https://doi.org/10.1016/j.cemconcomp.2011.08.012

Beushausen, H., & Dittmer, T. (2015). The influence of aggregate type on the strength and elastic modulus of high strength concrete. *Construction and Building Materials*, *74*, 132–139. https://doi.org/10.1016/j.conbuildmat.2014.08.055

Bi, J., Liu, P., & Gan, F. (2020). Effects of the cooling treatment on the dynamic behavior of ordinary concrete exposed to high temperatures. *Construction and Building Materials*, *248*, 118688. https://doi.org/10.1016/j.conbuildmat.2020.118688

Bingöl, A. F., & Tohumcu, I. (2013). Effects of different curing regimes on the compressive strength properties of self compacting concrete incorporating fly ash and silica fume. *Materials & Design*, *51*, 12–18. https://doi.org/10.1016/j.matdes.2013.03.106

Brand, A. S., & Fanijo, E. O. (2020). A review of the influence of steel furnace slag type on the properties of cementitious composites. *Applied Sciences (Switzerland)*, *10*(22), 1–27. https://doi.org/10.3390/app10228210

Caldarone, M. A. (2014). High-Strength Concrete: A Practical Guide. In *Taylor & Francis*.

Carvalho, S. Z., Vernilli, F., Almeida, B., Demarco, M., & Silva, S. N. (2017). The recycling effect of BOF slag in the portland cement properties. *Resources, Conservation and Recycling*, *127*(June), 216–220. https://doi.org/10.1016/j.resconrec.2017.08.021

Chang, Y. F., Chen, Y. H., Sheu, M. S., & Yao, G. C. (2006). Residual stress–strain relationship for concrete after exposure to high temperatures. *Cement and Concrete Research*, *36*(10), 1999–2005. https://doi.org/10.1016/j.cemconres.2006.05.029

Chi, M. C., Chi, J. H., & Wu, C. H. (2018). Effect of GGBFS on Compressive Strength and Durability of Concrete. *Advanced Materials Research*, *1145*, 22–26. https://doi.org/10.4028/www.scientific.net/amr.1145.22

Chithra, S., Senthil Kumar, S. R. R., & Chinnaraju, K. (2016). The effect of Colloidal Nano-silica on workability, mechanical and durability properties of High Performance Concrete with Copper slag as partial fine aggregate. *Construction* *and Building Materials*, *113*, 794–804. https://doi.org/10.1016/j.conbuildmat.2016.03.119

Choe, G., Kim, G., Yoon, M., Hwang, E., Nam, J., & Guncunski, N. (2019). Effect of moisture migration and water vapor pressure build-up with the heating rate on concrete spalling type. *Cement and Concrete Research*, *116*(August 2017), 1–10. https://doi.org/10.1016/j.cemconres.2018.10.021

Choi, S. J., Lee, S. S., & Monteiro, P. J. M. (2012). Effect of Fly Ash Fineness on Temperature Rise, Setting, and Strength Development of Mortar. *Journal of Materials in Civil Engineering*, *24*(5), 499–505. https://doi.org/10.1061/(asce)mt.1943-5533.0000411

Christina Mary, V., & Kishore, C. H. (2015). Experimental investigation on strength and durability characteristics of high performance concrete using GGBS and msand. *ARPN Journal of Engineering and Applied Sciences*, *10*(11), 4852–4856.

Cleetus, A., Shibu, R., Paul, V. K., & Jacob, B. (2018). Analysis and Study of the Effect of GGBFS on Concrete Structures. *International Research Journal of Engineering and Technology (IRJET)*, *5*(3), 3033–3037.

Demirel, B., Gultekin, E., & Alyamac, K. E. (2019). Performance of Structural Lightweight Concrete containing Metakaolin after Elevated Temperature. *KSCE Journal of Civil Engineering*, *23*(7), 2997–3004. https://doi.org/10.1007/s12205-019-1192-x

Dhoble, Y. N., & Ahmed, S. (2018). Study on cementitious properties of steel slag by partial replacement of cement. *Global Journal of Engineering Science and Researches*, *5*(7), 213–220.

Dinakar, P., & Manu, S. N. (2014). Concrete mix design for high strength self-compacting concrete using metakaolin. *Materials & Design*, *60*, 661–668. https://doi.org/10.1016/j.matdes.2014.03.053

Domagała, L. (2015). The effect of lightweight aggregate water absorption on the reduction of water-cement ratio in fresh concrete. *Procedia Engineering*, *108*, 206–213. https://doi.org/10.1016/j.proeng.2015.06.139

Douara, T. H., & Guettala, S. (2019). Effects of curing regimes on the physico-mechanical properties of self-compacting concrete made with ternary sands. *Construction and Building Materials*, *195*, 41–51. https://doi.org/10.1016/j.conbuildmat.2018.11.043

Draper, N. R., & Smith, H. (1998). Applied regression analysis (3rd ed.). New York, NY: Wiley.

Du, H. X., Wu, H. P., Wang, F. J., & Yan, R. Z. (2015). The detection of high-strength concrete exposed to high temperatures using infrared thermal imaging technique. *Materials Research Innovations*, *19*(sup1), S1-162-S1-167. https://doi.org/10.1179/1432891715Z.0000000001396

Du, Y., Qi, H. H., Huang, S. S., & Richard Liew, J. Y. (2020). Experimental study on the spalling behaviour of ultra-high strength concrete in fire. *Construction and Building Materials*, *258*, 120334. https://doi.org/10.1016/j.conbuildmat.2020.120334

Ducman, V., & Mladenovič, A. (2011). The potential use of steel slag in refractory concrete. *Materials Characterization*, *62*(7), 716–723. https://doi.org/10.1016/j.matchar.2011.04.016

Dunuweera, S. P., Rajapakse, R. M. G., & Wang, J. (2018). *Cement Types, Composition, Uses and Advantages of Nanocement, Environmental Impact on Cement Production, and Possible Solutions*. https://doi.org/10.1155/2018/4158682

Dwivedi, A., & Jain, M. K. (2014). Fly ash – waste management and overview : A Review. *Science and Technology*, *6*(1), 30–35.

Edalati, M., & Namdari, F. (2014). Management of Air Pollution Control in Cement Industry. *Journal of Middle East Applied Science and Technology (JMEAST) Issue*, *1*(2), 12–15. https://www.researchgate.net/publication/270759021

Edwin, R. S., De Schepper, M., Gruyaert, E., & De Belie, N. (2016). Effect of secondary copper slag as cementitious material in ultra-high performance mortar. *Construction and Building Materials*, *119*, 31–44. https://doi.org/10.1016/j.conbuildmat.2016.05.007

El-Hassan, H., Shehab, E., & Al-Sallamin, A. (2018). Influence of Different Curing Regimes on the Performance and Microstructure of Alkali-Activated Slag Concrete. *Journal of Materials in Civil Engineering*, *30*(9), 04018230. https://doi.org/10.1061/(asce)mt.1943-5533.0002436

Elsanadedy, H. M. (2019). Residual Compressive Strength of High-Strength Concrete Exposed to Elevated Temperatures. *Advances in Materials Science and Engineering*, *2019*. https://doi.org/10.1155/2019/6039571

Fares, A. I., Sohel, K. M. A., Al-Jabri, K., & Al-Mamun, A. (2021). Characteristics of ferrochrome slag aggregate and its uses as a green material in concrete–A review. *Construction and Building Materials*, 294, 123552. https://doi.org/10.1016/j.conbuildmat.2021.123552

Feng, Y., Kero, J., Yang, Q., Chen, Q., Engström, F., Samuelsson, C., & Qi, C. (2019). Mechanical Activation of Granulated Copper Slag and Its Influence on Hydration Heat and Compressive Strength of Blended Cement. *Materials*, *12*, 772. https://doi.org/10.3390/ma12050772

Gabasiane, T. S., Bhero, S., & Danha, G. (2019). Waste Management and Treatment of Copper Slag BCL, Selebi Phikwe Botswana: Review. *Procedia Manufacturing*, *35*, 494–499. https://doi.org/10.1016/j.promfg.2019.05.071

Gagg, C. R. (2014). Cement and concrete as an engineering material : An historic appraisal and case study analysis. *Engineering Failure Analysis*, *40*, 114–140. https://doi.org/10.1016/j.engfailanal.2014.02.004

Gallucci, E., Zhang, X., & Scrivener, K. L. (2013). Effect of temperature on the microstructure of calcium silicate hydrate (C-S-H). *Cement and Concrete Research*, *53*, 185–195. https://doi.org/10.1016/j.cemconres.2013.06.008

Gao, X., Zhang, J., & Su, Y. (2019). Influence of vibration-induced segregation on mechanical property and chloride ion permeability of concrete with variable rheological performance. *Construction and Building Materials*, *194*, 32–41. https://doi.org/10.1016/j.conbuildmat.2018.11.019

Gencel, O., Karadag, O., Hulusi, O., & Bilir, T. (2021). Steel slag and its applications in cement and concrete technology : A review. *Construction and Building Materials*, *283*, 122783. https://doi.org/10.1016/j.conbuildmat.2021.122783

Gong, W. (2018). *Mechanical Properties and Durability Performance of Concrete Subjected to High Temperature Heating* (Issue July). http://dx.doi.org/10.1016/j.cemconcomp.2014.06.001

Guo, H., Yin, S., Yu, Q., Yang, X., Huang, H., Yang, Y., & Gao, F. (2018). Iron recovery and active residue production from basic oxygen furnace (BOF) slag for supplementary cementitious materials. *Resources, Conservation and Recycling*, *129*(October 2017), 209–218. https://doi.org/10.1016/j.resconrec.2017.10.027

Guo, J., Bao, Y., & Wang, M. (2018). Steel slag in China: Treatment, recycling, and management. *Waste Management*, *78*, 318–330. https://doi.org/10.1016/j.wasman.2018.04.045

Guo, Z., & Shi, X. (2011). Experiment and Calculation of Reinforced Concrete at Elevated Temperatures. In *Elsevier*. https://doi.org/10.1016/C2010-0-65988-8

Gupta, T., Siddique, S., Sharma, R. K., & Chaudhary, S. (2017). Effect of elevated temperature and cooling regimes on mechanical and durability properties of concrete containing waste rubber fiber. *Construction and Building Materials*, *137*, 35–45. https://doi.org/10.1016/j.conbuildmat.2017.01.065

Hager, I. (2013). Behaviour of cement concrete at high temperature. *Bulletin of the Polish Academy of Sciences: Technical Sciences*, *61*(1), 145–154. https://doi.org/10.2478/bpasts-2013-0013

Hager, I. (2014). Colour Change in Heated Concrete. *Fire Technology*, *50*(4), 945–958. https://doi.org/10.1007/s10694-012-0320-7

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2010). Multivariate data analysis (7th ed.). Upper Saddle River, NJ: Prentice Hall.

Harison, A., Srivastava, V., & Herbert, A. (2014). Effect of Fly Ash on Compressive Strength of Portland Pozzolona Cement Concrete. *Journal of academia and industrial research (JAIR), 2*(8), 476–479.

Hemalatha, T., & Ramaswamy, A. (2017). A review on fly ash characteristics – Towards promoting high volume utilization in developing sustainable concrete. *Journal of Cleaner Production*, *147*, 546–559.

https://doi.org/10.1016/j.jclepro.2017.01.114

Ho, J. C. M., Liang, Y., Wang, Y. H., Lai, M. H., Huang, Z. C., Yang, D., & Zhang, Q. L. (2022). Residual properties of steel slag coarse aggregate concrete after exposure to elevated temperatures. *Construction and Building Materials*, *316*, 125751. https://doi.org/10.1016/j.conbuildmat.2021.125751

Hoe, K. W., & Ramli, M. (2010). Rational mix design approach for high strength concrete using sand with very high fineness modulus. *American Journal of Applied Sciences*, *7*(12), 1562–1568. https://doi.org/10.3844/ajassp.2010.1562.1568

Huang, H., Zhang, L., & Li, Y. (2015). Experimental study on mechanical and thermal properties of high performance concrete subjected to high temperatures. *Construction and Building Materials, 93,* 496-504. https://doi.org/10.1016/j.conbuildmat.2015.05.097

Huang, K., Zhang, X., Lu, D., Xu, N., Gan, Y., & Han, X. (2021). The Role of Iron Tailing Powder in Ultra-High-Strength Concrete Subjected to Elevated Temperatures. *Advances in Civil Engineering*, *2021*, 1–11. https://doi.org/10.1155/2021/6681429

Huang, Z., Liew, J. Y. R., & Li, W. (2017). Evaluation of compressive behavior of ultra-lightweight cement composite after elevated temperature exposure. *Construction and Building Materials*, *148*, 579–589. https://doi.org/10.1016/j.conbuildmat.2017.04.121

Husem, M. (2006). The effects of high temperature on compressive and flexural strengths of ordinary and high-performance concrete. *Fire Safety Journal*, *41*(2), 155–163. https://doi.org/10.1016/j.firesaf.2005.12.002

Hussin, M. W., Bhutta, M. A. R., Azreen, M., Ramandhansyah, P. J., & Mirza, J. (2015). Performance of blended ash geopolymer concrete at elevated temperatures. *Materials and Structures*, *48*, 709–720.

Iacobescu, R. I., Koumpouri, D., Pontikes, Y., Saban, R., & Angelopoulos, G. N. (2011). Valorisation of electric arc furnace steel slag as raw material for low energy belite cements. *Journal of Hazardous Materials*, *196*, 287–294. https://doi.org/10.1016/j.jhazmat.2011.09.024

Jiang, Y., Ling, T. C., Shi, C., & Pan, S. Y. (2018). Characteristics of steel slags and their use in cement and concrete—A review. *Resources, Conservation and Recycling*, *136*(April), 187–197. https://doi.org/10.1016/j.resconrec.2018.04.023

Kanadasan, J., Ahmad Fauzi, A.F., Abdul Razak, H., Selliah, P., Subramaniam, V. and Yusoff, S. (2015). Feasibility studies of palm oil mill waste aggregates for the construction industry. *Materials*, 8(9), 6508-6530. https://doi.org/10.3390/ma8095319

Karakoç, M. B. (2013). Effect of cooling regimes on compressive strength of concrete with lightweight aggregate exposed to high temperature. *Construction and Building Materials*, *41*, 21–25. https://doi.org/10.1016/j.conbuildmat.2012.11.104

Kayali, O., & Sharfuddin Ahmed, M. (2013). Assessment of high volume replacement fly ash concrete – Concept of performance index. *Construction and Building Materials*, *39*, 71–76. https://doi.org/10.1016/j.conbuildmat.2012.05.009

Khaliq, W., & Kodur, V. (2011). Thermal and mechanical properties of fiber reinforced high performance self-consolidating concrete at elevated temperatures. *Cement and Concrete Research*, *41*(11), 1112–1122. https://doi.org/10.1016/j.cemconres.2011.06.012

Khaliq, W., & Taimur. (2018). Mechanical and physical response of recycled aggregates high-strength concrete at elevated temperatures. *Fire Safety Journal*, *96*, 203–214. https://doi.org/10.1016/j.firesaf.2018.01.009

Khaliq, W., & Waheed, F. (2017). Mechanical response and spalling sensitivity of air entrained high-strength concrete at elevated temperatures. *Construction and Building Materials*, *150*, 747–757. https://doi.org/10.1016/j.conbuildmat.2017.06.039

Khan, M. I., Asce, M., Fares, G., Mourad, S., & Abbass, W. (2015). *Optimized Fresh and Hardened Properties of Strain-Hardening Cementitious Composites : Effect of Sand Size and Workability*. 1–13. https://doi.org/10.1061/(asce)mt.1943-5533

Khurram, N., Khan, K., Saleem, M. U., Amin, M. N., & Akmal, U. (2018). Effect of Elevated Temperatures on Mortar with Naturally Occurring Volcanic Ash and Its Blend with Electric Arc Furnace Slag. *Advances in Materials Science and Engineering*. https://doi.org/10.1155/2018/5324036

Kim, K. Y., Yun, T. S., & Park, K. P. (2013). Evaluation of pore structures and cracking in cement paste exposed to elevated temperatures by X-ray computed tomography. Cement and Concrete Research, 50, 34-40. https://doi.org/10.1016/j.cemconres.2013.03.020

Kim, J., & Jeong, S. (2017). Economic and environmental cost analysis of incineration and recovery alternatives for flammable industrial waste: The case of South Korea. *Sustainability (Switzerland)*, *9*(9). https://doi.org/10.3390/su9091638

Kong, D. L. Y., & Sanjayan, J. G. (2010). Effect of elevated temperatures on geopolymer paste, mortar and concrete. *Cement and Concrete Research*, *40*(2), 334–339. https://doi.org/10.1016/j.cemconres.2009.10.017

Kou, S. C., Poon, C. S., & Etxeberria, M. (2014). Residue strength, water absorption and pore size distributions of recycled aggregate concrete after exposure to elevated temperatures. *Cement and Concrete Composites*, *53*, 73–82. https://doi.org/10.1016/j.cemconcomp.2014.06.001

Kumar, C. B. K. R. R. (2015). A Study on Behaviour of Normal Strength Concrete and High Strength Concrete Subjected to Elevated Temperatures. *International Journal of Civil and Environmental Engineering*, *9*(3), 283–287.

Kumar Karri, S., Rao, G. V. R., & Raju, P. M. (2015). Strength and Durability Studies on GGBS Concrete. *International Journal of Civil Engineering*, *2*(10), 34–41.

https://doi.org/10.14445/23488352/ijce-v2i10p106

Kumar Tiwari, M., Bajpai, S., & Kumar Dewangan, U. (2016). Fly Ash Utilization: A Brief Review in Indian Context. *International Research Journal of Engineering and Technology*, *3*(4), 949–956. www.irjet.net

Kuo, W. Ten, Wang, H. Y., & Shu, C. Y. (2014). Engineering properties of cementless concrete produced from GGBFS and recycled desulfurization slag. *Construction and Building Materials*, *63*, 189–196. https://doi.org/10.1016/j.conbuildmat.2014.04.017

Laskar, A. I. (2011). Mix design of high-performance concrete. *Materials Research*, *14*(4). https://doi.org/10.1590/S1516-14392011005000088

Latif, S. N. A., Chiong, M. S., Rajoo, S., Takada, A., Chun, Y. Y., Tahara, K., & Ikegami, Y. (2021). The trend and status of energy resources and greenhouse gas emissions in the Malaysia power generation mix. *Energies*, *14*(8), 1–26. https://doi.org/10.3390/en14082200

Lee, J.-Y., Choi, J.-S., Yuan, T.-F., Yoon, Y.-S., & Mitchell, D. (2019). Comparing Properties of Concrete Containing Electric Arc Furnace Slag and Granulated Blast Furnace Slag. *Materials*, *12*(9), 1371. https://doi.org/10.3390/ma12091371

Li, L., Jia, P., Dong, J., Shi, L., Zhang, G., & Wang, Q. (2017). Effects of cement dosage and cooling regimes on the compressive strength of concrete after post-fire-curing from 800 °C. *Construction and Building Materials*, *142*, 208–220. https://doi.org/10.1016/j.conbuildmat.2017.03.053

Li, Y., Lu, X., Guan, H., Ying, M., & Yan, W. (2016). A Case Study on a Fire-Induced Collapse Accident of a Reinforced Concrete Frame-Supported Masonry Structure. *Fire Technology*, *52*(3), 707–729. https://doi.org/10.1007/s10694-015-0491-0

Li, Y., Yang, E. H., Zhou, A., & Liu, T. (2021). Pore pressure build-up and explosive spalling in concrete at elevated temperature: A review. *Construction and Building Materials*, *284*, 122818. https://doi.org/10.1016/j.conbuildmat.2021.122818

Li, Z., Li, L., Wang, J., & Wu, X. (2018). Effect of Elevated Temperature on Meso- and Micro-Structure and Compressive Strength of High-Strength Concrete and Mortar Containing Blast-Furnace Slag. *Journal of Advanced Concrete Technology*, *16*(10), 498–511. https://doi.org/10.3151/jact.16.498

Liang, X., Wu, C., Su, Y., Chen, Z., & Li, Z. (2018). Development of ultra-high performance concrete with high fire resistance. *Construction and Building Materials*, *179*, 400–412. https://doi.org/10.1016/j.conbuildmat.2018.05.241

Liang, X., Wu, C., Yang, Y., & Li, Z. (2019). Experimental study on ultra-high performance concrete with high fire resistance under simultaneous effect of elevated temperature and impact loading. *Cement and Concrete Composites*, *98*, 29–38. https://doi.org/10.1016/j.cemconcomp.2019.01.017

Liu, C., Zha, K., & Chen, D. (2011). Possibility of concrete prepared with steel slag as fine and coarse aggregates: A preliminary study. *Procedia Engineering*, *24*, 412–416. https://doi.org/10.1016/j.proeng.2011.11.2667

Liu, H., Chen, X., Che, J., Liu, N., & Zhang, M. (2020). Mechanical Performances of Concrete Produced with Desert Sand After Elevated Temperature. *International Journal of Concrete Structures and Materials*, *14*(1). https://doi.org/10.1186/s40069-020-00402-3

Liu, Y., Wang, W., Chen, Y. F., & Ji, H. (2016). Residual stress-strain relationship for thermal insulation concrete with recycled aggregate after high temperature exposure. *Construction and Building Materials*, *129*, 37–47. https://doi.org/10.1016/j.conbuildmat.2016.11.006

Liu, Y., Li, X., Li, W., & Li, Y. (2019). Study on the Surface Color of Concrete at High Temperature. *Materials*, *12*(7), 1082. https://doi.org/10.3390/ma12071082

Ma, Q., Guo, R., Zhao, Z., Lin, Z., & He, K. (2015). Mechanical properties of concrete at high temperature—A review. *Construction and Building Materials*, *93*, 371–383. https://doi.org/10.1016/j.conbuildmat.2015.05.131

Maghool, F., Arulrajah, A., Horpibulsuk, S., & Du, Y. (2017). Laboratory Evaluation of Ladle Furnace Slag in Unbound Pavement-Base / Subbase Applications. *Journal of Materials in Civil Engineering*, *29*(2), 04016197. https://doi.org/10.1061/(asce)mt.1943-5533.0001724.

Mahasneh, B. Z. (2014). Assessment of replacing wastewater and treated water with tap water in making concrete mix. *Electronic Journal of Geotechnical Engineering*, *19 K*, 2379–2386.

Mahmoud, A. A., Sobhy, E. S., & Elsayed, A. (2019). Predicting Fire Effects on Compressive Strength of Normal-Strength Concrete with Nanoparticles Additives using Artificial Neural Network. *International Research Journal of Engineering and Technology (IRJET)*, *6*(5), 6350–6360.

Malik, M., Bhattacharyya, S. K., & Barai, S. V. (2021). Thermal and mechanical properties of concrete and its constituents at elevated temperatures: A review. *Construction and Building Materials*, *270*, 121398. https://doi.org/10.1016/j.conbuildmat.2020.121398

Manjunath, R., Narasimhan, M. C., & Umesha, K. M. (2019). Studies on high performance alkali activated slag concrete mixes subjected to aggressive environments and sustained elevated temperatures. *Construction and Building Materials*, *229*, 116887. https://doi.org/10.1016/j.conbuildmat.2019.116887

Marchon, D., & Flatt, R. J. (2016). Mechanisms of cement hydration. In *Science and Technology of Concrete Admixtures*. Elsevier Ltd. https://doi.org/10.1016/B978-0-08-100693-1.00008-4

Martins, A. C. P., De Carvalho, J. M. F., Costa, L. C. B., Andrade, H. D., de Melo, T. V., Ribeiro, J. C. L., ... & Peixoto, R. A. F. (2021). Steel slags in cement-based composites: An ultimate review on characterization, applications and performance.

Construction and building materials, 291, 123265. https://doi.org/10.1016/j.conbuildmat.2021.123265

Memon, S. A., Shah, S. F. A., Khushnood, R. A., & Baloch, W. L. (2019). Durability of sustainable concrete subjected to elevated temperature – A review. *Construction and Building Materials*, *199,* 435–455. https://doi.org/10.1016/j.conbuildmat.2018.12.040

Menéndez, E., Vega, L., & Andrade, C. (2012). Use of decomposition of portlandite in concrete fire as indicator of temperature progression into the material: Application to fire-affected builds. *Journal of Thermal Analysis and Calorimetry*, *110*(1), 203–209. https://doi.org/10.1007/s10973-011-2159-4

Miller, S. A., John, V. M., Pacca, S. A., & Horvath, A. (2018). Carbon dioxide reduction potential in the global cement industry by 2050. *Cement and Concrete Research*, *114*, 115–124. https://doi.org/10.1016/j.cemconres.2017.08.026

Mindeguia, J.-C., Pimienta, P., Hager, I., & Hélène, C. (2011). Influence of water content on gas pore pressure in concrete at high temperature. *2nd Int. RILEM Workshop on Concrete Spalling*, *I*(October), 113–121.

Mindeguia, J. C., Pimienta, P., Carré, H., & La Borderie, C. (2012). On the influence of aggregate nature on concrete behaviour at high temperature. *European Journal of Environmental and Civil Engineering*, *16*(2), 236–253. https://doi.org/10.1080/19648189.2012.667682

Mirhosseini, S. R., Fadaee, M., Tabatabaei, R., & Fadaee, M. J. (2017). Mechanical properties of concrete with Sarcheshmeh mineral complex copper slag as a part of cementitious materials. *Construction and Building Materials*, *134*, 44–49. https://doi.org/10.1016/j.conbuildmat.2016.12.024

Mohammed, B. S., Achara, B. E., & Liew, M. S. (2018). The influence of high temperature on microstructural damage and residual properties of nano-silica-modified (NS-modified) self-consolidating engineering cementitious composites (SC-ECC) using response surface methodology (RSM). *Construction and Building Materials*, *192*, 450–466. https://doi.org/10.1016/j.conbuildmat.2018.10.114

Mohammed, G. A., & Al-Mashhadi, S. A. A. (2020). Effect of maximum aggregate size on the strength of normal and high strength concrete. *Civil Engineering Journal (Iran)*, *6*(6), 1155–1165. https://doi.org/10.28991/cej-2020-03091537

Mohammed, M. S., Mohamed, S. A., & Azmi Megat Johari, M. (2016). Influence of Superplasticizer Compatibility on the Setting Time , Strength and Stiffening Characteristics of Concrete. *Advances in Applied Sciences*, *1*(2), 30–36. https://doi.org/10.11648/j.aas.20160102.12

Monosi, S., Ruello, M. L., & Sani, D. (2016). Electric arc furnace slag as natural aggregate replacement in concrete production. *Cement and Concrete Composites, 66*, 66–72. https://doi.org/10.1016/j.cemconcomp.2015.10.004

Mousavi, S. M., Ranjbar, M. M., & Madandoust, R. (2019). Combined effects of steel fibers and water to cementitious materials ratio on the fracture behavior and brittleness of high strength concrete. *Engineering Fracture Mechanics*, *216*, 106517. https://doi.org/10.1016/j.engfracmech.2019.106517

Muhit, I. B. (2013). Dosage Limit Determination of Superplasticizing Admixture and Effect Evaluation on Properties of Concrete. *International Journal of Scientific and Engineering Research, 4*(3).

Murari, K., Siddique, R., & Jain, K. K. (2015). Use of waste copper slag, a sustainable material. *Journal of Material Cycles and Waste Management*, *17*(1), 13–26. https://doi.org/10.1007/s10163-014-0254-x

Myers, R. H., Montgomery, D. C., & Anderson-Cook, C. M. (2016). *Response surface methodology: process and product optimization using designed experiments*. John Wiley & Sons.

Naser, M. Z. (2019). Heuristic machine cognition to predict fire-induced spalling and fire resistance of concrete structures. *Automation in Construction*, *106*, 102916. https://doi.org/10.1016/j.autcon.2019.102916

Nath, P., & Sarker, P. (2011). Effect of Fly Ash on the Durability Properties of High Strength Concrete. *Procedia Engineering*, *14*, 1149–1156. https://doi.org/10.1016/J.PROENG.2011.07.144

Nath, P., & Sarker, P. K. (2014). Effect of GGBFS on setting, workability and early strength properties of fly ash geopolymer concrete cured in ambient condition. *Construction and Building Materials*, *66*, 163–171. https://doi.org/10.1016/j.conbuildmat.2014.05.080

Nazri, F. M., Shahidan, S., Baharuddin, N. K., Beddu, S., & Bakar, B. H. A. (2017). Effects of heating durations on normal concrete residual properties: compressive strength and mass loss. *IOP Conference Series: Materials Science and Engineering*, *271*, 012013. https://doi.org/10.1088/1757-899x/271/1/012013

Nematzadeh, M., Shahmansouri, A. A., & Fakoor, M. (2020). Post-fire compressive strength of recycled PET aggregate concrete reinforced with steel fibers: Optimization and prediction via RSM and GEP. *Construction and Building Materials*, *252*, 119057. https://doi.org/10.1016/j.conbuildmat.2020.119057

Netinger, I., Kesegic, I., & Guljas, I. (2011). The effect of high temperatures on the mechanical properties of concrete made with different types of aggregates. *Fire Safety Journal*, *46*(7), 425–430. https://doi.org/10.1016/j.firesaf.2011.07.002

Netinger, I., Rukavina, M. J., Bjegović, D., & Mladenovič, A. (2012). Concrete containing steel slag aggregate: Performance after high temperature exposure. *Concrete Repair, Rehabilitation and Retrofitting III*, 1347–1352. https://doi.org/10.1201/b12750-225

Netinger, I., Rukavina, M. J., & Mladenovič, A. (2013a). Improvement of post-fire properties of concrete with steel slag aggregate. *Procedia Engineering*, *62*, 745–753. https://doi.org/10.1016/j.proeng.2013.08.121

Netinger, I., Varevac, D., Bjegović, D., & Morić, D. (2013b). Effect of high temperature on properties of steel slag aggregate concrete. *Fire Safety Journal*, *59*, 1–7. https://doi.org/10.1016/j.firesaf.2013.03.008

Nkinamubanzi, P. C., Mantellato, S., & Flatt, R. J. (2016). Superplasticizers in practice. In *Science and Technology of Concrete Admixtures*. Elsevier Ltd. https://doi.org/10.1016/b978-0-08-100693-1.00016-3

Norhasri, M. S. M., Hamidah, M. S., & Fadzil, A. M. (2017). Applications of using nano material in concrete: A review. *Construction and Building Materials*, *133*, 91–97. https://doi.org/10.1016/j.conbuildmat.2016.12.005

Noumowé, A., Siddique, R., & Ranc, G. (2009). Thermo-mechanical characteristics of concrete at elevated temperatures up to 310 °C. *Nuclear Engineering and Design*, *239*(3), 470–476. https://doi.org/10.1016/j.nucengdes.2008.11.020

Omale, S. O., Choong, T. S. Y., Abdullah, L. C., Siajam, S. I., & Yip, M. W. (2019). Utilization of Malaysia EAF slags for effective application in direct aqueous sequestration of carbon dioxide under ambient temperature. *Heliyon*, *5*(10), e02602. https://doi.org/10.1016/j.heliyon.2019.e02602

Omer, S. A., Demirboga, R., & Khushefati, W. H. (2015). Relationship between compressive strength and UPV of GGBFS based geopolymer mortars exposed to elevated temperatures. *Construction and Building Materials*, *94*, 189–195. https://doi.org/10.1016/j.conbuildmat.2015.07.006

Oss, H. g. van. (2020). *2017 Minerals Yearbook: Slag-Iron and Steel*, 69.1-69.8.

Özbay, E., Erdemir, M., & Durmuş, H. I. (2016). Utilization and efficiency of ground granulated blast furnace slag on concrete properties – A review. *Construction and Building Materials*, *105*, 423–434. https://doi.org/10.1016/j.conbuildmat.2015.12.153

Palankar, N., Ravi Shankar, A. U., & Mithun, B. M. (2016). Durability studies on eco-friendly concrete mixes incorporating steel slag as coarse aggregates. *Journal of Cleaner Production*, *129*, 437–448. https://doi.org/10.1016/j.jclepro.2016.04.033

Palod, R., Deo, S. V., & Ramtekkar, G. D. (2020). Effect on mechanical performance, early age shrinkage and electrical resistivity of ternary blended concrete containing blast furnace slag and steel slag. *Materials Today: Proceedings*, *32*, 917–922. https://doi.org/10.1016/j.matpr.2020.04.747

Pan, Z., Zhou, J., Jiang, X., Xu, Y., Jin, R., Ma, J., Zhuang, Y., Diao, Z., Zhang, S., Si, Q., & Chen, W. (2019). Investigating the effects of steel slag powder on the properties of self-compacting concrete with recycled aggregates. *Construction and Building Materials*, *200*, 570–577. https://doi.org/10.1016/j.conbuildmat.2018.12.150

Papachristoforou, M., Anastasiou, E. K., & Papayianni, I. (2020). Durability of steel fiber reinforced concrete with coarse steel slag aggregates including performance at elevated temperatures. *Construction and Building Materials*, *262*, 120569.

https://doi.org/10.1016/j.conbuildmat.2020.120569

Papayianni, I., & Anastasiou, E. (2012). Effect of granulometry on cementitious properties of ladle furnace slag. *Cement and Concrete Composites*, *34*(3), 400–407. https://doi.org/10.1016/j.cemconcomp.2011.11.015

Phiri, T. C., Singh, P., & Nikoloski, A. N. (2021). The potential for copper slag waste as a resource for a circular economy: A review – Part II. *Minerals Engineering*, *172*, 107150. https://doi.org/10.1016/j.mineng.2021.107150

Phul, A. A., Memon, M. J., Shah, S. N. R., & Sandhu, A. R. (2019). GGBS And Fly Ash Effects on Compressive Strength by Partial Replacement of Cement Concrete. *Civil Engineering Journal*, *5*(4), 913–921. https://doi.org/10.28991/cej-2019-03091299

Pulkit, U. (2021). *Effect of micro-structural changes on concrete properties at elevated temperature : Current knowledge and outlook*. *February*, 1–20. https://doi.org/10.1002/suco.202000365

Qiang, W., Mengxiao, S., & Jun, Y. (2016). Influence of classified steel slag with particle sizes smaller than 20 μm on the properties of cement and concrete. *Construction and Building Materials*, *123*, 601–610. https://doi.org/10.1016/j.conbuildmat.2016.07.042

Rahmouni, Z. E. A., & Tebbal, N. (2020). Mechanical Behavior of High-Performance Concrete under Thermal Effect. *Compressive Strength of Concrete*, 105.

Rajawat, D., Siddique, S., Shrivastava, S., Chaudhary, S., & Gupta, T. (2018). Influence of fine ceramic aggregates on the residual properties of concrete subjected to elevated temperature. *Fire and Materials*, *42*(7), 834–842. https://doi.org/10.1002/fam.2639

Raju, M. P., Rao, K. S., & Raju, P. S. N. (2007). Compressive strength of heated high-strength concrete. *Magazine of Concrete Research*, *59*(2), 79–85.

Rashad, A. M. (2015). An investigation on very high volume slag pastes subjected to elevated temperatures. *Construction and Building Materials*, *74*, 249–258. https://doi.org/10.1016/j.conbuildmat.2014.10.019

Rashad, A. M. (2019). A synopsis manual about recycling steel slag as acementitious material. *Journal of Materials Research and Technology*, *8*(5), 4940–4955. https://doi.org/10.1016/j.jmrt.2019.06.038

Rasheed, A., Usman, M., Farooq, H., & Hanif, A. (2018). Effect of Super-plasticizer Dosages on Fresh State Properties and Early-Age Strength of Concrete. *IOP Conference Series: Materials Science and Engineering*, *431*, 062010. https://doi.org/10.1088/1757-899X/431/6/062010

Rashid, M. A., Mansur, M. A., Rashid M. A., & Mansur M. A. (2009). Considerations in producing high strength concrete. *Journal of Civil Engineering (IEB)*, *37*(1), 53–63.

Rosales, J., Cabrera, M., & Agrela, F. (2017). Effect of stainless steel slag waste as a replacement for cement in mortars. Mechanical and statistical study. *Construction and Building Materials*, *142*, 444–458. https://doi.org/10.1016/j.conbuildmat.2017.03.082

Roslan, N. H., Ismail, M., Abdul-Majid, Z., Ghoreishiamiri, S., & Muhammad, B. (2016). Performance of steel slag and steel sludge in concrete. *Construction and Building Materials*, *104*, 16–24. https://doi.org/10.1016/j.conbuildmat.2015.12.008

Roy, S., Miura, T., Nakamura, H., & Yamamoto, Y. (2020). High temperature influence on concrete produced by spherical shaped EAF slag fine aggregate – Physical and mechanical properties. *Construction and Building Materials*, *231*, 117153. https://doi.org/10.1016/j.conbuildmat.2019.117153

Saha, A. K. (2018). Effect of class F fly ash on the durability properties of concrete. *Sustainable Environment Research*, *28*(1), 25–31. https://doi.org/10.1016/J.SERJ.2017.09.001

Sajedi, F., Razak, H. A., Mahmud, H. Bin, & Shafigh, P. (2012). Relationships between compressive strength of cement–slag mortars under air and water curing regimes. *Construction and Building Materials*, *31*, 188–196. https://doi.org/10.1016/j.conbuildmat.2011.12.056

Sakthidoss, D. D., & Senniappan, T. (2020). A Study on High Strength Geopolymer Concrete with Alumina-Silica Materials Using Manufacturing Sand. *Silicon*, *12*(3), 735–746. https://doi.org/10.1007/s12633-019-00263-w

Salem, M., Alsadey, S., & Johari, M. (2016). Effect of Superplasticizer Dosage on Workability and Strength Characteristics of Concrete. *Journal of Mechanical and Civil Engineering*, *13*(4), 153–158. https://doi.org/10.9790/1684-130407153158

San-José, J. T., Vegas, I., Arribas, I., & Marcos, I. (2014). The performance of steel-making slag concretes in the hardened state. *Materials and Design*, *60*, 612–619. https://doi.org/10.1016/j.matdes.2014.04.030

Scrivener, K. L., Juilland, P., & Monteiro, P. J. M. (2015). Advances in understanding hydration of Portland cement. *Cement and Concrete Research*, *78*, 38–56. https://doi.org/10.1016/j.cemconres.2015.05.025

Serrano, R., Cobo, A., Prieto, M. I., & González, M. de las N. (2016). Analysis of fire resistance of concrete with polypropylene or steel fibers. *Construction and Building Materials*, *122*, 302–309. https://doi.org/10.1016/j.conbuildmat.2016.06.055

Shah, S. N. R., Akashah, F. W., & Shafigh, P. (2019). Performance of High Strength Concrete Subjected to Elevated Temperatures: A Review. *Fire Technology*, *55*(5), 1571–1597. https://doi.org/10.1007/s10694-018-0791-2

Shahmansouri, A. A., Akbarzadeh Bengar, H., & Ghanbari, S. (2020). Compressive strength prediction of eco-efficient GGBS-based geopolymer concrete using GEP method. *Journal of Building Engineering*, *31*, 101326.

https://doi.org/10.1016/j.jobe.2020.101326

Shaikh, F. U. A., & Supit, S. W. M. (2015). Compressive strength and durability properties of high volume fly ash (HVFA) concretes containing ultrafine fly ash (UFFA). *Construction and Building Materials*, *82*, 192–205. https://doi.org/10.1016/j.conbuildmat.2015.02.068

Shui, Z., Xuan, D., Chen, W., Yu, R., & Zhang, R. (2009). Cementitious characteristics of hydrated cement paste subjected to various dehydration temperatures. *Construction and Building Materials*, *23*(1), 531–537. https://doi.org/10.1016/j.conbuildmat.2007.10.016

Singh, J., & Singh, S. P. (2019). Development of Alkali-activated Cementitious Material using Copper Slag. *Construction and Building Materials*, *211*, 73–79. https://doi.org/10.1016/j.conbuildmat.2019.03.233

Singh, S. B., Munjal, P., & Thammishetti, N. (2015). Role of water/cement ratio on strength development of cement mortar. *Journal of Building Engineering*, *4*, 94–100. https://doi.org/10.1016/j.jobe.2015.09.003

Smirnova, O. M. (2016). Compatibility of portland cement and polycarboxylate-based superplasticizers in high-strength concrete for precast constructions. *Magazine of Civil Engineering*, *66*(6), 12–22. https://doi.org/10.5862/mce.66.2

Stepkowska, E. T., Blanes, J. M., Franco, F., & Real, C. (2004). *Phase transformation on heating of an aged cement paste*. *420*, 79–87. https://doi.org/10.1016/j.tca.2003.11.057

Su, H., Xu, J., & Ren, W. (2014). Experimental study on the dynamic compressive mechanical properties of concrete at elevated temperature. *Materials and Design*, *56*, 579–588. https://doi.org/10.1016/j.matdes.2013.11.024

Suda, V. B. R., & Rao, P. S. (2020). Experimental investigation on optimum usage of Micro silica and GGBS for the strength characteristics of concrete. *Materials Today: Proceedings*, *27*, 805–811. https://doi.org/10.1016/j.matpr.2019.12.354

Sudarshan, D. K., & Vyas, A. K. (2019). Impact of fire on mechanical properties of concrete containing marble waste. *Journal of King Saud University-Engineering Sciences*, 31(1), 42-51. https://doi.org/10.1016/j.jksues.2017.03.007

Sun, J., Shen, X., Tan, G., Tanner, J. E., & Tanner, J. E. (2019). Compressive strength and hydration characteristics of high-volume fly ash concrete prepared from fly ash. *Journal of Thermal Analysis and Calorimetry*, *136*(2), 565–580. https://doi.org/10.1007/s10973-018-7578-z

Suresh, D., & Nagaraju, K. (2015). Ground granulated blast slag (GGBS) in concrete–a review. *IOSR Journal of Mechanical and Civil Engineering*, *12*(4), 76–82. https://doi.org/10.9790/1684-12467682

Tafesse, M., Lee, H. K., Alemu, A. S., Kim, H. K., & Pyo, S. (2020). On the expansive cracking of a cement matrix containing atomized basic oxygen furnace slag with a metallic iron. *Construction and Building Materials*, *264*, 119806. https://doi.org/10.1016/j.conbuildmat.2020.119806

Tang, W. C., & Lo, T. Y. (2009). Mechanical and fracture properties of normal-and high-strength concretes with fly ash after exposure to high temperatures. *Magazine of Concrete Research*, *61*(5), 323–330. https://doi.org/10.1680/macr.2008.00084

Teo, P. Ter, Zakaria, S. K., Salleh, S. Z., Taib, M. A. A., Sharif, N. M., Seman, A. A., Mohamed, J. J., Yusoff, M., Yusoff, A. H., Mohamad, M., Masri, M. N., & Mamat, S. (2020). Assessment of electric arc furnace (EAF) steel slag waste's recycling options into value added green products: A review. *Metals*, *10*(10), 1–21. https://doi.org/10.3390/met10101347

Tian, H., Guo, Z., Pan, J., Zhu, D., Yang, C., Xue, Y., Li, S., & Wang, D. (2021). Comprehensive review on metallurgical recycling and cleaning of copper slag. *Resources, Conservation and Recycling*, *168*, 105366. https://doi.org/10.1016/j.resconrec.2020.105366

Toumi, B., Resheidat, M., Guemmadi, Z., & Chabil, H. (2009a). Coupled effect of high temperature and heating time on the residual strength of normal and high-strength concretes. *Jordan Journal of Civil Engineering*, *3*(4), 322–330.

Toumi, B., Resheidat, M., Guemmadi, Z., & Chabil, H. (2009b). Coupled Effect of High Temperature and Heating Time on the Residual Strength of Normal and High-Strength Concretes. *Jordan Journal of Civil Engineering*, *3*(4), 322–330.

Ukala, D. (2019). Effect of Heat Intensity and Duration on the Compressive Strength of Concrete. *Journal of Applied Sciences and Environmental Management*, *23*(9), 1637–1642.

Umasabor, R. I., & Okovido, J. O. (2018). Fire resistance evaluation of rice husk ash concrete. *Heliyon*, *4*(12), e01035. https://doi.org/10.1016/j.heliyon.2018.E01035

USGS. (2020). Mineral commodity summaries 2020. In *U.S Departtment OF The Interior, U.S Geological Survey* (Issue 703). https://pubs.usgs.gov/periodicals/mcs2020/mcs2020.pdf

V.K.R. Kodur. (2000). Spalling in High Strength Concrete Exposed to Fire – Concerns, Causes, Critical Parameters and Cures Institute for Research in Construction, National Research Council of Canada. *In Advanced Technology in Structural Engineering*, 1–9.

Varona, F. B., Baeza, F. J., Bru, D., & Ivorra, S. (2018a). Evolution of the bond strength between reinforcing steel and fibre reinforced concrete after high temperature exposure. *Construction and Building Materials*, *176*, 359–370. https://doi.org/10.1016/j.conbuildmat.2018.05.065

Varona, F. B., Baeza, F. J., Bru, D., & Ivorra, S. (2018b). Influence of high temperature on the mechanical properties of hybrid fibre reinforced normal and high strength concrete. *Construction and Building Materials*, *159*, 73–82. https://doi.org/10.1016/j.conbuildmat.2017.10.129

Vishalakshi, K. P., Revathi, V., & Sivamurthy Reddy, S. (2018). Effect of type of coarse aggregate on the strength properties and fracture energy of normal and high strength concrete. *Engineering Fracture Mechanics*, *194*, 52–60. https://doi.org/10.1016/J.ENGFRACMECH.2018.02.029

Wang, Q., Yan, P., Yang, J., & Zhang, B. (2013a). Influence of steel slag on mechanical properties and durability of concrete. *Construction and Building Materials*, *47*, 1414–1420. https://doi.org/10.1016/j.conbuildmat.2013.06.044

Wang, Q., Yang, J., & Yan, P. (2013b). Cementitious properties of super-fine steel slag. *Powder Technology*, *245*, 35–39. https://doi.org/10.1016/j.powtec.2013.04.016

Wang, R., Shi, Q., Li, Y., Cao, Z., & Si, Z. (2021). A critical review on the use of copper slag (CS) as a substitute constituent in concrete. *Construction and Building Materials*, *292*, 123371. https://doi.org/10.1016/j.conbuildmat.2021.123371

Wang, X., Saifullah, H. A., Nishikawa, H., & Nakarai, K. (2020). Effect of water–cement ratio, aggregate type, and curing temperature on the fracture energy of concrete. *Construction and Building Materials*, *259*, 119646. https://doi.org/10.1016/j.conbuildmat.2020.119646

Wang, Y., Liu, F., Xu, L., & Zhao, H. (2019). Effect of elevated temperatures and cooling methods on strength of concrete made with coarse and fine recycled concrete aggregates. *Construction and Building Materials*, *210*, 540–547. https://doi.org/10.1016/j.conbuildmat.2019.03.215

Wang, Y., & Suraneni, P. (2019). Experimental methods to determine the feasibility of steel slags as supplementary cementitious materials. *Construction and Building Materials*, *204*, 458–467. https://doi.org/10.1016/j.conbuildmat.2019.01.196

World Steel Association. (2018). *World Steel Facts*.

World Steel Association. (2020). Major steel-producing countries 2018 and 2019 million. In *2020 World steel in figures* (Issue 30 April).

Xiao, J., Xie, Q., & Xie, W. (2018). Study on high-performance concrete at high temperatures in China (2004–2016) - An updated overview. *Fire Safety Journal*, *95*, 11–24. https://doi.org/10.1016/j.firesaf.2017.10.007

Xing, Z., Beaucour, A., Hebert, R., Noumowe, A., & Ledesert, B. (2011). Influence of the nature of aggregates on the behaviour of concrete subjected to elevated temperature. *Cement and Concrete Research*, *41*(4), 392–402. https://doi.org/10.1016/j.cemconres.2011.01.005

Xu, Z., Li, J., Wu, P., & Wu, C. (2021). Experimental investigation of triaxial strength of ultra-high performance concrete after exposure to elevated temperature. *Construction and Building Materials*, *295*, 123689. https://doi.org/10.1016/j.conbuildmat.2021.123689

Yachandra, S., & Arunakanthi, E. (2020). Evaluating the Effect of Elevated Temparature on Ternary Blended Self Compacting Concrete using Response

Surface Methodology. *International Research Journal of Engineering and Technology (IRJET)*, *7*(10), 1004–1009.

Yap, S., Alengaram, U. J., Jumaat, M. Z., & Foong, K. (2013). Waste Materials in Malaysia for Development of Sustainable Concrete: A Review. *Electronic Journal of Structural Engineering*, *13*(1), 60–64.

Yaqub, M., & Bukhari, I. (2006). Effect Of Size Of Coarse Aggregate on Compressive Strength Of High Strength Concerts. *31st Conference on OUR WORLD IN CONCRETE & STRUCTURES*.

Yi, H., Xu, G., Cheng, H., Wang, J., Wan, Y., & Chen, H. (2012). An Overview of Utilization of Steel Slag. *Procedia Environmental Sciences*, *16*, 791–801. https://doi.org/10.1016/j.proenv.2012.10.108

Yong-Sing, N., Yun-Ming, L., Cheng-Yong, H., Abdullah, M. M. A. B., Chan, L. W. L., Hui-Teng, N., Shee-Ween, O., Wan-En, O., & Yong-Jie, H. (2021). Evaluation of flexural properties and characterisation of v10-mm thin geopolymer based on fly ash and ladle furnace slag. *Journal of Materials Research and Technology*, *15*, 163–176. https://doi.org/10.1016/j.jmrt.2021.08.016

Yu, J., Weng, W., & Yu, K. (2014). Effect of different cooling regimes on the mechanical properties of cementitious composites subjected to high temperatures. *The Scientific World Journal*, *2014*. https://doi.org/10.1155/2014/289213

Zang, J., Li, W., & Shen, X. (2019). The influence of steel slag with variable particle size distribution on the workability and mechanical properties of concrete. *Ceramics - Silikaty*, *63*(1), 67–75. https://doi.org/10.13168/cs.2018.0046

Zhai, Y., Deng, Z., Li, N., & Xu, R. (2014). Study on compressive mechanical capabilities of concrete after high temperature exposure and thermo-damage constitutive model. *Construction and Building Materials*, *68*, 777–782. https://doi.org/10.1016/j.conbuildmat.2014.06.052

Zhai, Y., Li, Y., Li, Y., Wang, S., Liu, Y., & Song, K. (2019). Impact of high-temperature-water cooling damage on the mechanical properties of concrete. *Construction and Building Materials*, *215*, 233–243. https://doi.org/10.1016/j.conbuildmat.2019.04.161

Zhang, B. (2011). Effects of moisture evaporation (weight loss) on fracture properties of high performance concrete subjected to high temperatures. *Fire Safety Journal*, *46*(8), 543–549. https://doi.org/10.1016/j.firesaf.2011.07.010

Zhang, H. (2011). Cement. In *Building materials in civil engineering* (Issue May 9, pp. 46–80). https://doi.org/10.1533/9781845699567.46

Zhang, T., Yu, Q., Wei, J., & Li, J. (2012). Investigation on mechanical properties, durability and micro-structural development of steel slag blended cements. *Journal of Thermal Analysis and Calorimetry*, *110*(2), 633–639. https://doi.org/10.1007/s10973-011-1853-6

Zhao, J., Wang, D., Yan, P., & Li, W. (2016). Comparison of grinding characteristics of converter steel slag with and without pretreatment and grinding aids. *Applied Sciences (Switzerland)*, *6*(11), 1–15. https://doi.org/10.3390/app6110237

Zheng, W., Li, H., & Wang, Y. (2012). Compressive behaviour of hybrid fiber-reinforced reactive powder concrete after high temperature. *Materials & Design*, *41*, 403–409. https://doi.org/10.1016/j.matdes.2012.05.026

Zhou, X., Xie, Y., Long, G., & Li, J. (2021). Effect of surface characteristics of aggregates on the compressive damage of high-strength concrete based on 3D discrete element method. *Construction and Building Materials*, *301*, 124101. https://doi.org/10.1016/j.conbuildmat.2021.124101

Zhu, X., Hou, H., Huang, X., Zhou, M., & Wang, W. (2012). Enhance hydration properties of steel slag using grinding aids by mechanochemical effect. *Construction and Building Materials*, *29*, 476–481. https://doi.org/10.1016/j.conbuildmat.2011.10.064