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Influence of High Volume RHA on Properties of Cement Mortar

Zainab S. Al-Khafaji ¹, Ali Majdi ², Ali A. Shubbar ^{3,*}, Mohammed Salah Nasr ⁴, Shahad F. Al-Mamoori ⁵, Ahmed Alkhayyat ⁶, Ali Al-Rifaie ⁷, Nasser Al-Emadi ³, Rafal Latif Al-Mufti ³, Monower Sadique ³ and Khalid Hashim ³

¹ Al-Furatt Al-Awsat Distribution Foundation \ Ministry of Oil \ Babylon, Iraq.

² Department of Civil Engineering, Al- Mustaqbal University College, Babylon, Iraq

⁴ Department of Civil Engineering, Liverpool John Moores University, UK.

⁴ Babylon Technical Institute, Al-Furat Al-Awsat Technical University, 51015 Babylon, Iraq.

⁵ Department of Civil Engineering, College of Engineering, University of Babylon, Iraq

⁶ Department of Building and Construction Technical Engineering, College of Technical Engineering, the Islamic University, 54001 Najaf, Iraq.

⁷ College of Engineering, Al-Muthanna University, Samawah, 66001, Iraq.

* Corresponding author: alishubbar993@gmail.com , A.A.Shubbar@2014.ljmu.ac.uk

Abstract. This work study the impact of partial cement replacement by high volume Rice Husk Ash (RHA) on some characteristics of cement mortar like compressive strength and flexural strength at different ages. In this research, RHA was used in three different ratios (20, 40, and 60)% as a cement substitution and the findings were compared with control mixture (0% RHA). The findings demonstrated that the replacement of cement by RHA reduced the compressive strength of all selected ratios and the increase in the content of RHA lead to reduce compressive strength comparative to control sample with 100% cement as a binder at all ages. However, the flexural strength results indicated that the RHA in 20% showed approximately same results as control sample at early ages while increasing the curing period lead to improve flexural strength. Increasing RHA higher than 20% lead to decrease Flexural strength at all selected ages.

Keywords: Compressive strength, Cement replacement; Flexural strength; RHA.

1. Introduction

Cement is a heavily used binder material in mortars to act as a bonding layer between construction parts. Conventionally, mortar mainly relies on cement, sand and water for their composition [1]. Cement being one of the essential traditional materials made by humans in construction that plays a part in the growing enormous demand on cement around the world [2]. The energy intensive production process of cement raised concerns due to their cost and environmental effect. Currently, the cement production is considered as the third energy demanding industry and that subsequently raise costs [3-8]. On the other



side, cement production contributes annually in a range of between 7 - 10% of greenhouse gases emissions to the world, especially, Carbon dioxide (CO₂) [9-21]. Therefore, companies and governments have decided to look for other alternatives that would decrease the impact on the environment with a decrease of cost, while attaining similar chemical and physical characteristics of the conventional cement used in construction [22-26]. As a result of that, Mineral additives or Supplementary cementitious materials (SCMs) were encouraged to be used in order to create advanced construction technologies. Materials including fly ash, Ground Granulated Blast Furnace Slag (GGBS), dust of cement kiln, silica fume; bagasse ash, palm oil fuel ash, and RHA from the agriculture industry, which considered as wastes, are always taken under consideration and experiments to act as a cheaper and eco-friendlier supplement to the Portland cement in the making of mortar or concrete structures [27, 28].

An essential source of food on earth is rice. Approximately it covers around 1% of the earth. A residue from the milling process of rice is called Rice husk [29], this waste is extracted from outer crust of rice grain [30], and is calculated to be one fifth of the annual total of rice produced globally [29]. In order to produce the ash from the rice husk, a slow burning process is needed to the husk at a temperature of 500 to 700 °C [31]. It was found that approximately 20% of rice husk can be turned into rice husk ash (RHA) [31]. The content of silica in RHA is the cause of experimenting the material as a SCM, the content could range from 80-95% of silica. This made it to be categorized as a pozzolanic material. Materials which act as siliceous and aluminous substances are considered to be pozzolanic. In the hydration stage of the Portland cement and the exposure of moisture, RHA will chemically react with the calcium hydroxide at an ordinary temperature [30, 32].

The quality of mortar is highly crucial for construction, as the cementitious mixture is used to bind and protect elements of construction or structure. Therefore, strength, durability and protection from acid attacks are the measure of quality for mortars [1]. RHA in mortar was found to improve the compressive strength and also chloride resistivity when compared with regular cementitious or controlled mixes of mortar [32]. Furthermore, many studies were conducted to replace ordinary Portland cement with rice husk ash and observe the influence on its various characteristics. It has been reported by [27] that the previous studies have found that the replacement was only partially and the optimal substitution of OPC with RHA in mortars to be in the range between 10-30%. Additionally, [29] experimented the addition of RHA and nano-silica hydrosols in mortar mixture by adding them separately and together. The samples were tested for their electrical resistivity, capillary absorption, chloride permeability and compressive strength. Results of the samples showed that adding RHA alone didn't attain to higher strength and durability during the early ages but even recorded lower levels of strength unlike adding nano-silica separately, which recorded an improvement to the performance of the mortar. Also, incorporating RHA and nano-silica have demonstrated steep reduce in the compressive strength of the early ages but managed to display the most compelling results for durability and strength at the later ages (28 and 90 days). Another investigation by [30], where authors replaced cement with RHA and investigated the influence of 5, 10, and 15% adding to both the density and compressive strength of mortar samples. The consequences demonstrated that the use of untreated RHA will decrease the density and subsequently will lessen the strength of the mortar as well to almost half of the strength when the 15% is added. This was attributed to the carbon residue and impurity found in RHA. Therefore the authors have advised to acid treat the RHA by adding a more environmentally friendly citric acid to the rice husk before the process of burning it, to partially remove the impurities that could hinder the strength of the mortar. As pointed previously, the studies that investigated RHA incorporation for the replacement of cement didn't exceed 30% of replacement, due to the nature of RHA properties which will require the cement to react chemically with it. Therefore, this research was conducted to explore the influence of using high volume RHA on mechanical performance of cement mortar.

2. Experimental Part

2.1. Materials

2.1.1. Cement

Ordinary Portland cement (CEM-II/A/LL 32.5-N) Factory Warwickshire, UK has been utilized in this work. The physical characteristics and chemical analysing of cement have been demonstrated in Table 1. The BET specific surface area (SSA) of cement is 6.7 m²/g.

2.1.2. Rice Husk Ash (RHA)

Rice Husk Ash (RHA) that utilized in this investigation has been delivered by Company of NK Enterprises, Jharsuguda, Orissa, India Group. The elemental composition of RHA has been analysing by an Energy Dispersive X-ray Florescence Spectrometer (EDXRF) brand Shimadzu EDX-720. Table 1 demonstrates the chemical analysing of the RHA. The BET SSA of RHA is 26.7 m²/g

Table 1. RHA and PC Chemical composition

Oxide composition (% by mass)	PC	RHA
SiO ₂	20.99	88.32
Al ₂ O ₃	6.19	0.46
Fe ₂ O ₃	3.86	0.67
CaO	65.96	0.67
MgO	0.22	0.44
Na ₂ O ₃	0.17	0.12
K ₂ O	0.60	2.91
LOI %	1.73	5.81
Specific Gravity	2.94	2.11

2.1.3. Sand

The natural sand was utilized as a fine aggregate. Figure 1, illustrate the grading of sand used throughout this work.

2.1.4. Water

Tap water has been utilized as mixing water for all mixtures.

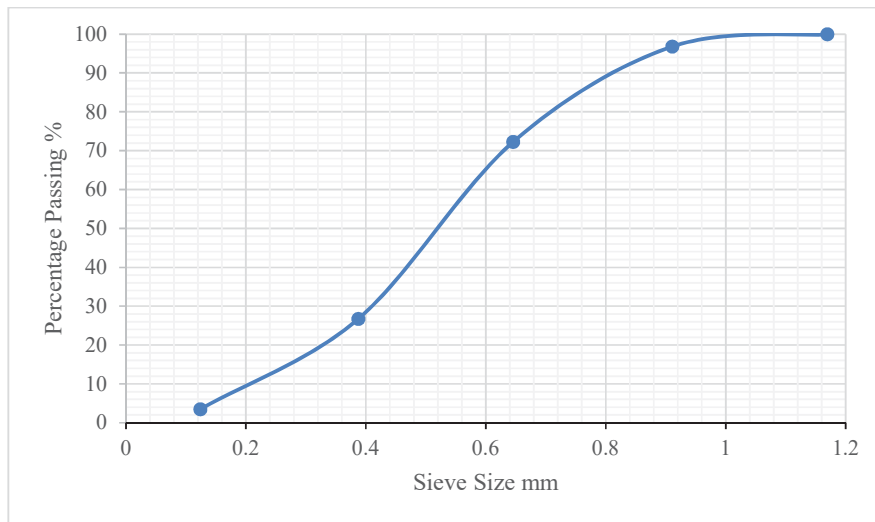


Figure 1. Grading of sand.

2.2. Designing the mixtures

The effect of replacing 0, 20, 40, and 60% of cement by RHA on compressive strength and flexural strength was studied and compared with control mix.

The mix proportion of samples tested for compressive strength flexural strength was 1 cement: 2.5 sand by weight. The compressive strength test has been performed on prisms of (40x40x160) mm size at (7, 14 and 28) days.

Table 2. The proportions of Mixing

Sample ID	OPC %	RHA %	Sand to binder Proportion	Water to binder Proportion
Con	100	0	2.5	0.4
R1	80	20	2.5	0.4
R2	60	40	2.5	0.5
R3	40	60	2.5	0.55

2.3. The Applied Testes

The flexural strength and compressive strength tests of all the mixture has been performed depending on BS EN 196-1 [33]. For each blending proportion at any curing time, two samples with dimensions of 40x40x160 mm have been tested for flexural strength using three points loading of the prism samples to split each sample into two sections and the four sections resulted from this test were utilized to measure the compressive strength. Equation 1 represent the formula followed to calculate the flexural strength.

$$fr = 3PL/2bd^2 \tag{1}$$

Whereas:

- f_r , (MPa) : Strength of flexural;
- P , (N): Max. applied load specified by testing machine;
- L , (mm): Sample's length Span;
- b , (mm) : Sample's average width.
- d , (mm) : Sample's average depth.

3. Results and Discussion

3.1. Compressive Strength Finding

The influence of replacement of cement by (0, 20, 40, and 60%) weight with RHA on compressive strength of mortars can be seen in Figure 2. Figure 2 clearly demonstrate that the compressive strength of all specimens increase with the increase of age of curing as a result of the progress of the hydration reaction. Additionally, it could be detected from Figure 2 that the compressive strength decreases with the increase in the amount of RHA, which may be due to low activity of RHA compared to reference cement mortar and also to the higher water content that caused an increasing in the porosity of the mixtures. The percentage of decrease in compressive strength at 7 curing days reaches 88% when replacing 60% of the cement by RHA, which is considered the worst condition comparison with control samples without any RHA. Figure 2 also shows that for all mixtures, most of the compressive strength were acquired at 7 curing days and after that the enhancement in strength with increasing the age of curing was very small.

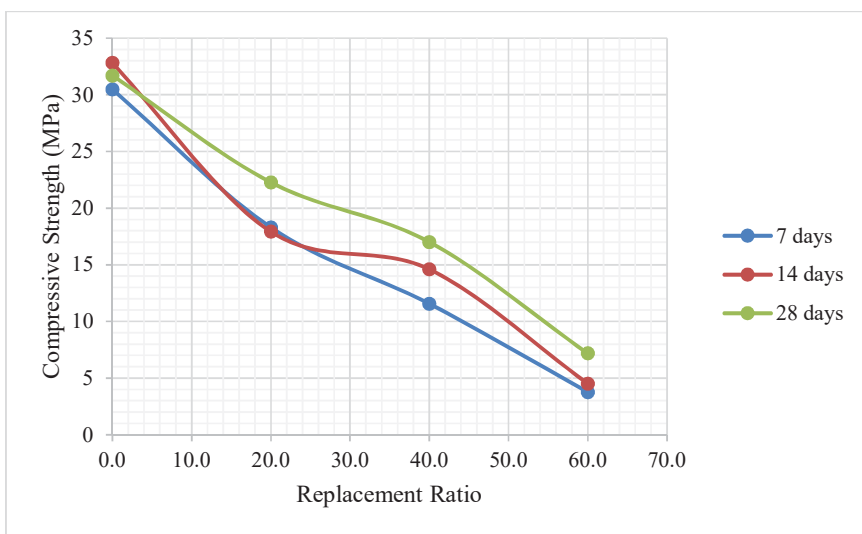


Figure 2. The Effect of Replacing OPC by RHA on compressive strength after 7, 14 and 28 curing days.

3.2. Flexural strength Results

The results of the flexural strength of all mixtures are presented in Figure 3. Figure 3 demonstrates that there is an improvement in the flexural strength of all samples with time due to cement hydration and develop the effect of Pozzolanic. The applying of RHA in the mortar has a varying behavior on the flexural strength, such as using 20% of RHA increased flexural strength at 14 and 28 curing days, but it has been reduced the flexural strength at 7 curing days by about 5% relative to control sample without replacement. Increasing RHA content to 40 and 60 lead to a reduce the flexural strength by 34% and 74%, respectively at 7 days associated to the control sample. At 28 curing age, the decreasing in flexural strength was about 13% and 61% for samples with 40% RHA and 60% RHA, respectively.

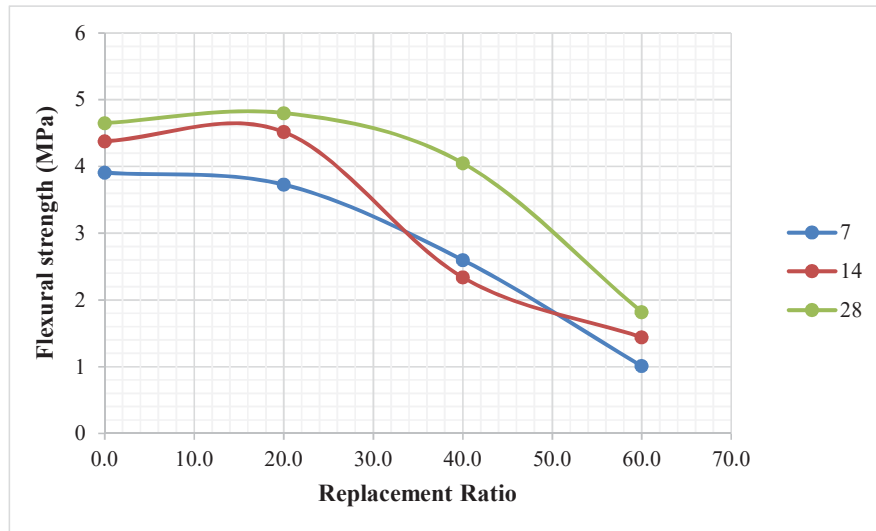


Figure 3. The Effect of Replacing OPC by RHA on Flexural strength after 7, 14 and 28 curing days.

4. Conclusion

Depending on the experimental work and results gained in this exploration, the following facts could be presented:

1. The usage of high volume rice husk ash in mortar mixtures could be used as a cement substitution materials as a result of existence of high amount of SiO_2 approximately 88%.
2. In compressive strength, the applying of RHA in any of the selected ration (20, 40 and 60) % by the weight of cement was lead to reduce the compressive strength comparative with controlling mix without replacement.
3. In flexural strength, the applying of RHA in any of the selected ration (40 and 60)% by the weight of cement was lead to reduce the flexural strength of samples (R2 and R3), while applying 20% RHA improved the flexural strength in comparison with control specimen at after 14 and 28 days of curing.

For future studies investigations, authors highly recommending the use of other waste and by/producted materials in combination with RHA to develop the features of the produced mortars. For example, industrial wastes [34-57] municipal solid wastes [58] and waste from water and wastewater planes [59-62].

References

- [1] Abduh M N, Pertiwi N and Taufieq N A S 2019 The Effect of Rice Husk Ash and Sulfatic Acid Solutions on The Setting Time and Compressive Strength of Mortar. In: *Journal of Physics: Conference Series*: IOP Publishing) p 012046
- [2] Zhang P, Zheng Y, Wang K and Zhang J 2018 A review on properties of fresh and hardened geopolymer mortar *Composites Part B: Engineering* **152** 79-95
- [3] Nasr M S, Hasan Z A and Abed M K 2019 Mechanical Properties of Cement Mortar Made with Black Tea Waste Ash as a Partial Replacement of Cement *Engineering and Technology Journal* **37** 45-8

- [4] Shubbar A A, Al-Shaer A, AlKizwini R S, Hashim K, Al Hawesah H and Sadique M 2019 Investigating the influence of cement replacement by high volume of GGBS and PFA on the mechanical performance of cement mortar. In: *IOP Conference Series: Materials Science and Engineering*: IOP Publishing) p 012022
- [5] Shubbar A A, Jafer H, Dulaimi A, Hashim K, Atherton W and Sadique M 2018 The development of a low carbon binder produced from the ternary blending of cement, ground granulated blast furnace slag and high calcium fly ash: An experimental and statistical approach *Construction and Building Materials* **187** 1051-60
- [6] Shubbar A, Jafer H M, Dulaimi A, Atherton W and Al-Rifaie A 2017 The Development of a Low Carbon Cementitious Material Produced from Cement, Ground Granulated Blast Furnace Slag and High Calcium Fly Ash *International Journal of Civil, Environmental, Structural, Construction and Architectural Engineering* **11** 905-8
- [7] Nasr M S, Shubbar A A, Abed Z A-A R and Ibrahim M S 2020 Properties of eco-friendly cement mortar contained recycled materials from different sources *Journal of Building Engineering* 101444
- [8] Shubbar A A, Al-Jumeily D, Aljaaf A J, Alyafei M, Sadique M and Mustafina J 2019 Investigating the Mechanical and Durability Performance of Cement Mortar Incorporated Modified Fly Ash and Ground Granulated Blast Furnace Slag as Cement Replacement Materials. In: *2019 12th International Conference on Developments in eSystems Engineering (DeSE): IEEE* pp 434-9
- [9] Hasan Z, Nasr M and Abed M 2019 Combined Effect of Silica Fume, and Glass and Ceramic Waste on Properties of High Strength Mortar Reinforced with Hybrid Fibers *Int. Rev. Civ. Eng.(IRECE)* **10**
- [10] Kubba H Z, Nasr M S, Al-Abdaly N M, Dhahir M K and Najim W N 2020 Influence of Incinerated and Non-Incinerated waste paper on Properties of Cement Mortar. In: *IOP Conference Series: Materials Science and Engineering*: IOP Publishing) p 012113
- [11] Shubbar A A, Sadique M, Kot P and Atherton W 2019 Future of clay-based construction materials—A review *Construction and Building Materials* **210** 172-87
- [12] Shubbar A A, Sadique M, Shanbara H K and Hashim K 2020 *Advances in Sustainable Construction Materials and Geotechnical Engineering*: Springer) pp 205-13
- [13] Al-Khafaji Z S, Al Masoodi Z, Jafer H, Dulaimi A and Atherton W 2018 The Effect Of Using Fluid Catalytic Cracking Catalyst Residue (FC3R)" As A Cement Replacement In Soft Soil Stabilisation *International Journal Of Civil Engineering And Technology (IJCIET) Volume* **9** 522-33
- [14] Nasr M S, Hussain T H and Najim W N 2018 Properties of Cement Mortar Containing Biomass Bottom Ash and Sanitary Ceramic Wastes as a Partial Replacement of Cement *International Journal of Civil Engineering and Technology (IJCIET)* **9** 153–65
- [15] Hussain A and Al-Khafaji Z 2020 The fields of applying the recycled and used oils by the internal combustion engines for purposes of protecting the environment against pollutions *J. Adv. Res. Dyn. Control Syst.* **12**
- [16] Hasan Z A, Nasr M S and Abed M K 2021 Properties of reactive powder concrete containing different combinations of fly ash and metakaolin *Materials Today: Proceedings* **34**
- [17] Jafer H, Jawad I, Majeed Z and Shubbar A 2021 The development of an ecofriendly binder containing high volume of cement replacement by incorporating two by-product materials for the use in soil stabilization *Scientific Review Engineering and Environmental Sciences* **30**
- [18] Nasr M S, Ali I M, Hussein A M, Shubbar A A, Kareem Q T and AbdulAmeer A T 2020 Utilization of locally produced waste in the production of sustainable mortar *Case Studies in Construction Materials* **13** e00464

- [19] Nasr M S, Hasan Z A, Abed M K, Dhahir M K, Najim W N, Shubbar A A and Habeeb Z D 2021 Utilization of High Volume Fraction of Binary Combinations of Supplementary Cementitious Materials in the Production of Reactive Powder Concrete *Periodica Polytechnica Civil Engineering* **65** 335-43
- [20] Obaid M K, Nasr M S, Ali I M, Shubbar A A and Hashim K S 2021 Performance of Green Mortar Made from Locally Available Waste Tiles and Silica Fume *Journal of Engineering Science and Technology* **16**
- [21] Shubbar A A, Al-Khafaji Z S, Nasr M S and Falah M W 2020 Using Non-Destructive Tests for Evaluating Flyover Footbridge: Case Study *Knowledge-Based Engineering and Sciences* **1** 23-39
- [22] Nayel I H, Nasr M S and Abdulridha S Q 2020 Impact of elevated temperature on the mechanical properties of cement mortar reinforced with rope waste fibres. In: *IOP Conference Series: Materials Science and Engineering*: IOP Publishing) p 012080
- [23] Nayel I, Burhan S and Nasr M 2018 Characterisation of prepared rice husk ash and its effects on strength development in recycled aggregate concrete. In: *IOP Conference Series: Materials Science and Engineering*, p 012009
- [24] Al-Khafaji Z and Falah M 2020 Applications of high density concrete in preventing the impact of radiation on human health *J Adv Res Dyn Control Syst* **12**
- [25] Al Khafaji Z S and Ruddock F 2018 Study the retardant effect of using different sugar's types on setting time and temperature of cement paste *International Journal of Civil Engineering and Technology* **9**
- [26] Shubbar A A, Sadique M, Nasr M S, Al-Khafaji Z S and Hashim K S 2020 The impact of grinding time on properties of cement mortar incorporated high volume waste paper sludge ash *Karbala International Journal of Modern Science* **6**
- [27] Mohammad N S, Adnan S H, Jamellodin Z and Wan Yusof W Y 2015 Performance of Rice Husk Ash as a Partial Cement Replacement in Fine Grained Mortar. In: *Applied Mechanics and Materials*: Trans Tech Publ) pp 969-73
- [28] Shubbar A A, Jafer H, Abdulredha M, Al-Khafaji Z S, Nasr M S, Al Masoodi Z and Sadique M 2020 Properties of cement mortar incorporated high volume fraction of GGBFS and CKD from 1 day to 550 days *Journal of Building Engineering* 101327
- [29] Zahedi M, Ramezaniangour A A and Ramezaniangour A M 2015 Evaluation of the mechanical properties and durability of cement mortars containing nanosilica and rice husk ash under chloride ion penetration *Construction and Building Materials* **78** 354-61
- [30] Boontawee K, Pansuk W, Tachai L and Kondoh K 2018 Effect of Rice Husk Ash Silica as Cement Replacement for Making Construction Mortar. In: *Key Engineering Materials*: Trans Tech Publ) pp 624-9
- [31] Jamellodin Z, Hamidah M S, Adnan S H, Mohammad N S and Wan Yusof W Y 2015 Strength Development of Fine Grained Mortar Containing Fly Ash and Rice Husk Ash. In: *Applied Mechanics and Materials*: Trans Tech Publ) pp 182-8
- [32] Balapour M, Hajibandeh E and Ramezaniangour A 2018 *High Tech Concrete: Where Technology and Engineering Meet*: Springer) pp 199-206
- [33] BSI 2005 Methods of testing cement—Part 1: Determination of strength. (London: British Standard Institute)
- [34] Majdi H S, Shubbar A A, Nasr M S, Al-Khafaji Z S, Jafer H, Abdulredha M, Al Masoodi Z, Sadique M and Hashim K 2020 Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations *Data in Brief* **31** 105961

- [35] Al Hawesah H, Shubbar A and Al Mufti R L 2018 Non-destructive assessment of early age mortar containing stainless steel powder. In: *The 17th Annual International Conference on Asphalt, Pavement Engineering and Infrastructure 21st-22nd February*,
- [36] Shanbara H K, Shubbar A, Ruddock F and Atherton W 2020 *Advances in Structural Engineering and Rehabilitation*: Springer) pp 221-7
- [37] Shubbar A, Alwan H, Phur E Y, McLoughlin J and Al-khaykan A 2017 Studying the Structural Behaviour of RC Beams with Circular Openings of Different Sizes and Locations Using FE Method
- [38] Shubbar A, Atherton W, Jafer H M, Dulaimi A and Al-Faluji D 2017 The Development of a New Cementitious Material Produced from Cement and GGBS. In: *The 3rd BUiD Doctoral Research Conference-Faculty of engineering and IT: BUiD*) pp 51-63
- [39] Nasr M S, Hussain T, Kubba H and Shubbar A 2020 Influence of Using High Volume Fraction of Silica Fume on Mechanical and Durability Properties of Cement Mortar *Journal of Engineering Science and Technology* **15** 2494-506
- [40] Hussain T H, Nasr M S and Salman H J 2019 Effect of elevated temperature on degradation behavior of reactive powder concrete made with rubber tire wastes as an aggregate replacement *ARPN J. Eng Appl. Sci* **14** 775-80
- [41] Hassan M S, Salih S A and Nasr M S 2016 Pozzolan Activity and Compressive Strength of Concrete Incorporated nano/micro Silica *Engineering and Technology Journal* **34** 483-96
- [42] Hasan Z, Abed M and Nasr M 2019 Studying the Mechanical Properties of Mortar Containing Different Waste Materials as a Partial Replacement for Aggregate *Int. Rev. Civ. Eng.(IRECE)* **10**
- [43] Zhang G, Ali Z H, Aldlemy M S, Mussa M H, Salih S Q, Hameed M M, Al-Khafaji Z S and Yaseen Z M 2020 Reinforced concrete deep beam shear strength capacity modelling using an integrative bio-inspired algorithm with an artificial intelligence model *Engineering with Computers* 1-14
- [44] Tuama W K, Kadhum M M, Alwash N A, Al-Khafaji Z S and Abdulraheem M S 2020 RPC Effect of Crude Oil Products on the Mechanical Characteristics of Reactive-Powder and Normal-Strength Concrete *Periodica Polytechnica Civil Engineering* **64** 422-9
- [45] Al-Rifaie A, Al-Husainy A S and Shanbara H K 2020 Numerical study on the behaviour of end-plate beam-to-column connections under lateral impact loading *International Journal of Structural Engineering* **10** 150-73
- [46] Shanbara H, Ruddock F, Atherton W and Rothwell G 2017 *Bearing Capacity of Roads, Railways and Airfields*: CRC Press) pp 1367-74
- [47] Shanbara H K, Ruddock F and Atherton W 2017 Improving the Mechanical Properties of Cold Mix Asphalt Mixtures Reinforced by Natural and Synthetic Fibers. In: *International Conference on Highway Pavements & airfield Technology*, pp 102-11
- [48] Ali I M, Naje A S and Nasr M S 2020 Eco-Friendly Chopped Tire Rubber as Reinforcements in Fly Ash Based Geopolymer Concrete *Global NEST Journal* **22**
- [49] Al-Salim N H A, Hassan R F and Jaber M H 2018 Compression Zone Rehabilitation of Damaged RC Beams Using Polyester Glue Line *Journal of Engineering and Applied Sciences* **13** 1195-200
- [50] Hassan R F, Jaber M H, Al-Salim N H and Hussein H H 2020 Experimental research on torsional strength of synthetic/steel fiber-reinforced hollow concrete beam *Engineering Structures* **220** 110948
- [51] Jaber M H, Al-Salim N H A and Hassan R F 2018 flexural behavior of hollow rectangular steel (HRS) section beams filled with reactive powder concrete *Technology* **9** 1177-87
- [52] Hassan R F, Al-Salim N H A and Jaber M H 2018 Effect of Polyvinyl Alcohol on flexural behavior of RC Bubble slabs under linear load *Journal of Engineering and Applied Sciences* **13** 3979-84

- [53] Nasr M S, Salih S A and Hassan M S 2016 Some Durability Characteristics of Micro Silica and Nano Silica Contained Concrete *Journal of University of Babylon* **24** 980-90
- [54] Ali I M, Nasr M S and Naje A S 2020 Enhancement of cured cement using environmental waste: particleboards incorporating nano slag *Open Engineering* **10** 273-81
- [55] Abed M, Nasr M and Hasan Z 2018 Effect of silica fume/binder ratio on compressive strength development of reactive powder concrete under two curing systems. In: *MATEC Web of Conferences: EDP Sciences*) p 02022
- [56] Alsalman A, Assi L N, Ghotbi S, Ghahari S and Shubbar A 2021 Users, Planners, and Governments Perspectives: A Public Survey on Autonomous Vehicles Future Advancements *Transportation Engineering* 100044
- [57] Jabbar D N, Al-Rifaie A, Hussein A M, Shubbar A A, Nasr M S and Al-Khafaji Z S 2021 Shear behaviour of reinforced concrete beams with small web openings *Materials Today: Proceedings* **34**
- [58] Abdulredha M, Abdulridha A, Shubbar A, Alkhaddar R, Kot P and Jordan D 2020 Estimating municipal solid waste generation from service processions during the Ashura religious event. In: *IOP Conference Series: Materials Science and Engineering: IOP Publishing*) p 012075
- [59] Abdulraheem F S, Al-Khafaji Z S, Hashim K S, Muradov M, Kot P and Shubbar A A 2020 Natural filtration unit for removal of heavy metals from water. In: *IOP Conference Series: Materials Science and Engineering: IOP Publishing*) p 012034
- [60] Mohammed A-H, Hussein A H, Yeboah D, Al Khaddar R, Abdulhadi B, Shubbar A A and Hashim K S 2020 Electrochemical removal of nitrate from wastewater. In: *IOP Conference Series: Materials Science and Engineering: IOP Publishing*) p 012037
- [61] Alenezi A K, Hasan H A, Hashim K S, Amoako-Attah J, Gkantou M, Muradov M, Kot P and Abdulhadi B 2020 Zeolite-assisted electrocoagulation for remediation of phosphate from calcium-phosphate solution. In: *IOP Conference Series: Materials Science and Engineering: IOP Publishing*) p 012031
- [62] Al-Marri S, AlQuzweeni S S, Hashim K S, AlKhaddar R, Kot P, AlKizwini R S, Zubaidi S L and Al-Khafaji Z S 2020 Ultrasonic-Electrocoagulation method for nitrate removal from water. In: *IOP Conference Series: Materials Science and Engineering: IOP Publishing*) p 012073