Producing cement mortars through implementing cement replacement

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Abstract. Cement mortars have been recognised as one of the most important and effective binding materials. The main materials that can be used in cement mortars are sand and Portland cement. The implementation of natural materials in the production process of cement mortars has many negative environmental effects including energy consumption, production of various pollutants. Scientific research highlighted that the implementation of wasted materials as cementitious materials has large potential environmentally and economically. The present research study aims to assess the compressive strength of cement mortars that contain replacement cementitious materials that are cement kiln dust and silica fume. The compressive strength of the developed mortars was examined after 7 and 28 days of curing. The findings extracted from the specimens that contain cement replacement have been compared to the specimens of cement mortar having only cement. The findings revealed that mixtures that contain cement kiln dust and silica fume have less compressive strength than mixtures of ordinary Portland cement only. Moreover, a lesser compressive strength was obtained with a greater cement kiln dust content. Samples with reduced replacement at various curing times have higher compressive strength values.

Keywords: Cement kiln dust, compressive strength, silica fume, cement mortars.

1. Introduction
In the past, water, cement and sand can be considered as the constituents of concrete. The mortars of cement have wide applications in buildings and the construction sector around the world due to the high working strength and easy application [1, 2]. Cement mortars have been largely implemented as a joining part and even fill the spaces in construction locations, particularly in-residence places and minor projects. Additionally, there are many other applications of the cement mortar like epoxy materials for bridging construction parts [3, 4].

Raw resources like sand and cement formed by grinding limestone are implemented in the production of Portland cement. Many legislation concerning the uses of such raw resources and potentially harmful environmental and economic effects have recently been created [5, 6]. Along with the failure problems of land segments which can occur with increased utilization of raw resources, the environmental damage from raw materials consumption may be described as a significantly higher level of contamination. Moreover, the chemical properties of concrete cause CO₂ to be released, thus increasing power usage and the detrimental effects on the atmosphere[7-11]. Carbon dioxide is accountable for numerous climate impacts, including such potable water scarcities [12-15] and irregular global diversion of water...
resources [16-19]. Furthermore, cement-based industries wastewater is extremely corrosive and retains a high amount of nitrogen material and solid materials [20-22] which damage the environment the watercourses received and thus effective handling procedures are required to reduce this contamination [23-26]. The most common treatment methods used to reduce wastewater contamination in many methods include electrocoagulation [27-36], electrocoagulation [27-36], adsorption [37-40], natural coagulants [41, 42], advanced methods [43] wast even biotic units [44, 45].

In another extreme, increased manufacturing and maintaining prices, with increased demand for raw resources, will contribute the adverse financial effects [46, 47]. The removal of concrete buildings is yet another problem in addition to such results since these refuses should be deposited and treated at protected sites requiring the massive costs involved [48, 49]. Both the above issues with the use of raw resources are contrary to renewable technology principles [50]. A further argument is that more homes have to be constructed, which would also demand further building resources until green substitutes are created [51, 52]. Owing to such significant growth, advanced inventions that maintain low costs and appropriate load-bearing efficiency are used to substitute raw resources. Alternate solution items used are mostly wastes, such as industrial refuse and agricultural wastes, to help improve the atmosphere and reduce costs as low as possible [53, 54]. Agriculture produces thousands of tonnes of various wasted material like seed, weeds and roots root vegetables, oil palm petrol, maize policeman, and tobacco, per year which can be used in the construction sector [48, 55]. Such refuse amounts without adequate monitoring or preparation resulted in different impacts for people and the planet. In several situations, the disposal of refused materials is distributed to vast areas adding to greater concerns as area farmland, construction as well as other social concerns continually is reduced. The gathered waste is typically treated through the combustion of excess smoke and CO2 emissions in the landfill zone. Thus, it is important to analyse the potential to use such wastes for various industries [3, 56, 57].

Various waste forms, like wood ash, base-ash, limestone, fuel ash, etc. have been examined as the substitute for cement, which produced a great value and suitable characteristics. Mortar of cement is known as an adapted blender of cementitious or base metals as a cement substitute. The addition of cementitious substance as a partial substitution for cement may improve mortar’s bearing capacity and longevity [58-60]. Silica fume is produced in the thermal power station as a refused waste product. The silica fume has also been used as a cement substitute for a wide variety of plants to increase the mortars consistency in terms of compression efficiency and longevity. The kiln dust is among the major waste generated by the processing facilities. The texture (finely ground substance) and chemical properties of the product are similar to the Portland cement. One of the negative aspects of kiln dust is the absence of cementitious products, which could be overcome by mixing other pozzolanic with its toughness and resistance property as a limited Portland cement substitute. This analysis explores the characteristics of cement mortar having kiln dust and silica fume used as cement substitutes.

2. Materials and methods

Several mixtures that contain various percentages of Portland cement substitution of kiln dust and silica fume were prepared using several percentages of the replacement materials. The percentages of the replacement materials used in this research project are presented in figures 1. From the figure, it can be seen that five mixtures were developed each mixture contains various percentages of replacement materials. In mixture 0, Portland cement only was used as cementitious materials for comparison purposes. Then, various percentages of the kiln dust and silica fume were used to replace the cement in the other 4 mixtures. These percentages were used to examine the effects of waste materials on the compressive strength of the developed mortars.
2.1. Compressive strength test

The British Standard (BS EN 196-1) was followed to conduct the sample preparation and testing to evaluate the compressive strength of the developed mortars using various percentages of waste materials namely silica fume and kiln dust. Initially, dry materials were correctly blended by implementing an electronic blender to ensure homogenisation [61]. The obtained mixture is then combined with the right water proportion. Several prisms that have dimensions of 40mm * 40mm * 160mm were filled with the samples. In order to facilitate the removal after hardening, each prism was greased until the mortar was placed. The specimens were packaged in plastic bags to reduce water loss during ageing. Three samples were prepared and tested of each mixture are to ensure the trustworthiness of the information. Then, the developed samples were tested at age 7 days and 28 days to understand the development of the compressive strength of the mortars that implement silica fume and kiln dust.

3. Results and discussion

The test of the compressive strength of the mortar’s findings indicates that perhaps the compressive strength of Portland cement was only the best among all of 28 treatment days based on the results presented in figure 2. The compressive strength of the mortars developed from cement only without any waste materials was 9.5 MPa after 7 days of curing. Then, after 14 days of curing the compressive strength increased from 9.5 MPa to about 10.2 MPa. The compressive strength of the developed mortars using cement only reached 11.1 after 28 days of curing. These samples were produced and tested to compare the mortars that developed using percentages of waste materials with the compressive strength using cement only.

The second group of mortars was developed using only 10% of waste materials (5% kiln dust and 5% silica fume). From figure 2, it can be said that the compressive strength of the mortars containing only 10 waste materials dropped by about 8% among all curing ages. When cement replacement increased from 10% to 20%, the compressive strength of the developed mortars with cement replacement, even more, dropped to only about 85% of the compressive strength of mortars without cement replacements. From the figure, it can be seen that the compressive strength reaches only 9.3 MPa after 28 days of curing. The compressive strength continues to drop with the increase in the percentage of the replacement materials to reach only 60% after adding 20% of Klin dust and 20% of the silica fume. The
findings of this research are in agreement with the conclusions of Shoaib and Balaha [62]. Shoaib and Balaha [62] reported that the compressive strength is reduced with the increase in the fraction of kiln dust replacement.

![Figure 2: The compressive strength of the developed mixtures using various percentages of kiln dust and silica fume.](image)

4. Conclusions
The usage of wasted materials as cement replacement has been wildly investigated. This research analyses the application of kiln dust and silica fume to replace Portland cement in the production of cement mortars. Various percentages were used to assess analyses the impact of waste materials on the development of the compressive strength. Based on the results, it can be concluded that mortars compressive strength has a negative relationship with the percentage of the replaced cementitious materials.

References
[1] Abdulredha M, al-Khaddar R, Kot P, Jordan D and Abdulridha A 2018 Benchmarking of the Current Solid Waste Management System in Karbala, Iraq, Using Wasteware Benchmark Indicators. In: World Environmental and Water Resources Congress 2018: Groundwater, Sustainability, and Hydro-Climate/Climate Change: American Society of Civil Engineers Reston, VA) pp 40-8
[2] Abdulredha M, Kadhim N, Hussein A, Almutairi M, Alkhaddar R, Yeboah D and Hashim K 2021 Zeolite as a natural adsorbent for nitrogenous compounds being removed from water. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012082
[3] Shubbar A A, Sadique M, Shanbara H K and Hashim K 2020 The Development of a New Low Carbon Binder for Construction as an Alternative to Cement. In Advances in Sustainable Construction Materials and Geotechnical Engineering (Berlin: Springer)
[4] Shubbar A A, Jafer H, Dulaimei 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

[5] Naqi A and Jang J G 2019 Recent progress in green cement technology utilizing low-carbon emission fuels and raw materials: A review Sustainability 11 537

[6] Shubbar A A, Al-Saer A, AlKizwini R S, Hashim K, Hawesah H A 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: First International Conference on Civil and Environmental Engineering Technologies (ICCEET), (University of Kufa, Iraq pp 31-8

[7] Aayef A N, Al Masoodi W T M, Kamel R J, Abdulredha M, Almansoori N A, Kot P and Muradov M 2021 An experimental study for adapting electrocoagulation as a technique for fluoride removal from water. In: IOP Conference Series: Materials Science and Engineering; IOP Publishing) p 012012

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

Abdulredha M, Al Khaddar R and Jordan D 2017 Hoteliers’ attitude towards solid waste source separation through mega festivals: A pilot study in Karbala. In: International Conference for Doctoral Research: BUID)

Abdulredha M, Al Khaddar R, Jordan D, Al-Attabi A and Alzeyadi A 2017 Public participation in solid waste management during mega festivals: A pilot study. In: WCST World Congress on Sustainable Technologies Proceedings 2017: Infonomics Society) pp 38-41

Abdulredha M, Al Khaddar R, Jordan D, Kot P, Abdulridha A and Hashim K J W M 2018 Estimating solid waste generation by hospitality industry during major festivals: A quantification model based on multiple regression 77 388-400

Abdulredha M, Kot P, Al Khaddar R, Jordan D, Abdulridha A J E, Development and Sustainability 2020 Investigating municipal solid waste management system performance during the Arba’een event in the city of Kerbala, Iraq 22 1431-54

Abdulredha M, Muhsin A A, Al-Janabi A, Alajmi B N, Gkantou M, Amoako-Atta J, Al-Jumeily D, Mustafina J and AlKhayyat A 2021 Using SF and CKD as cement replacement materials for producing cement mortar. In: IOP Conference Series: Materials Science and Engineering; IOP Publishing) p 012007

Abdulredha M, Rafid A, Jordan D and Alattabi A J P e 2017 Facing up to waste: how can hotel managers in Kerbala, Iraq, help the city deal with its waste problem? 196 771-8

Abdulredha M, Rafid A, Jordan D and Hashim K J P E 2017 The development of a waste management system in Kerbala during major pilgrimage events: determination of solid waste composition 196 779-84

Al-Anbari R, Alnakeeb A, Abdulredha M J E and Journal T 2013 Landfill site selection for Kerbala municipal solid wastes by using geographical information system techniques 32 13

Alattabi A W, Harris C, Alkhaddar R, Alzeyadi A and Abdulredha M J P e 2017 Online monitoring of a sequencing batch reactor treating domestic wastewater 196 800-7

Al-Sareji O J, Abdulredha M, Mubarak H A, Grmasha R A, Alnowaishry A, Kot P, Al-Kh addar R and AlKhayyat A 2021 Copper removal from water using carbonized sawdust. In: IOP Conference Series: Materials Science and Engineering; IOP Publishing) p 012015

ALWAN H H, SALEH L A, AL-MOHAMMED F M, ABUDREDHA M A J o E S and Technology 2020 EXPERIMENTAL PREDICTION OF THE DISCHARGE COEFFICIENTS FOR RECTANGULAR WEIR WITH BOTTOM ORIFICES 15 3265-80

Alyafei A, AlKizwini R S, Hashim K S, Yeboah D, Gkantou M, Al Khaddar R, Al-Faluji D and Zubaidi S L 2020 Treatment of effluents of construction industry using a combined filtration-electrocoagulation method. In: IOP Conference Series: Materials Science and Engineering; IOP Publishing) p 012032
[21] Hassan Alnaimi I J I, Abdujlajee Al-Janabi, Khalid Hashim, Michaela Gkantou, Salah L. Zubaidi, Patryk Kot, Magomed Muradov 2020 Ultrasonic-electrochemical treatment for effluents of concrete plants. In: IOP Conference Series Materials Science and Engineering (University of Kufa, Najaf, Iraq pp 1-9

[22] Zanki A K, Mohammad F H, Hashim K S, Muradov M, Kot P, Kareem M M and Abdulhadi B 2020 Removal of organic matter from water using ultrasonic-assisted electrocoagulation method. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012033

[23] Hashim K S, Al-Saati N H, Alquzweeni S S, Zubaidi S L, Kot P, Kraidy L, Hussein A H, Alkhaddar R, Shaw A and Alwash R 2019 Decolourization of dye solutions by electrocoagulation: an investigation of the effect of operational parameters. In: First International Conference on Civil and Environmental Engineering Technologies (ICCEET), (University of Kufa, Iraq pp 25-32

[24] Hashim K S, Hussein A H, Zubaidi S L, Kot P, Kraidy L, Alkhaddar R, Shaw A and Alwash R 2019 Effect of initial pH value on the removal of reactive black dye from water by electrocoagulation (EC) method. In: 2nd International Scientific Conference, (Al-Qadisiyah University, Iraq pp 12-22

[25] Omran I I, Al-Saati N H, Hashim K S, Al-Saati Z N, Patryk K, Khaddar R A, Al-Jumeily D, Shaw A, Ruddock F and Aljeferi M 2019 Assessment of heavy metal pollution in the Great Al-Mussaib irrigation channel Desalination and Water Treatment 168 165-74

[26] Hashim K S, Al-Saati N H, Hussein A H and Al-Saati Z N 2018 An investigation into the level of heavy metals leaching from canal-dreged sediment: a case study metals leaching from dreged sediment. In: First International Conference on Materials Engineering & Science, (Istanbul Aydin University (IAU), Turkey pp 12-22

[27] Aqeel K, Mubarak H A, Amoako-Attah J, Abdul-Rahaim L A, Al Khaddar R, Abdellatif M, Al-Janabi A and Hashim K S 2020 Electrochemical removal of brilliant green dye from wastewater. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012036

[28] Hashim K, Kot P, Zubaidy S, Alwash R, Al Khaddar R, Shaw A, Al-Jumeily D and Aljeferi M 2020 Energy efficient electrocoagulation using baffle-plates electrodes for efficient Escherichia Coli removal from Wastewater Journal of Water Process Engineering 33 101079-86

[29] Hashim K S, Ali S S M, AlRifaie J K, Kot P, Shaw A, Al Khaddar R, Iidowu I and Gkantou M 2020 Escherichia coli inactivation using a hybrid ultrasonic–electrocoagulation reactor Chemosphere 247 125868-75

[30] 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

[31] Hashim K S, Shaw A, AlKhaddar R, Kot P and Al-Shamma’a A 2021 Water purification from metal ions in the presence of organic matter using electromagnetic radiation-assisted treatment Journal of Cleaner Production 280 2021

[32] Hashim K S, Shaw A, Al Khaddar R, Ortoneda Pedrola M and Phipps D 2017 Defluoridation of drinking water using a new flow column-electrocoagulation reactor (FCER) - Experimental, statistical, and economic approach Journal of Environmental Management 197 80-8

[33] Hashim K S, Shaw A, Al Khaddar R, Pedrola M O and Phipps D 2017 Iron removal, energy consumption and operating cost of electrocoagulation of drinking water using a new flow column reactor Journal of Environmental Management 189 98-108

[34] Hashim K S, Shaw A, Al Khaddar R, Pedrola M O and Phipps D 2017 Energy efficient electrocoagulation using a new flow column reactor to remove nitrate from drinking water - Experimental, statistical, and economic approach Journal of Environmental Management 196 224-33
Abdulhadi B A, Kot P, Hashim K S, Shaw A and Khaddar R A 2019 Influence of current density and electrodes spacing on reactive red 120 dye removal from dyed water using electrocoagulation/electroflotation (EC/EF) process. In: First International Conference on Civil and Environmental Engineering Technologies (ICCEET), (University of Kufa, Iraq pp 12-22.

Hashim K S, Khaddar R A, Jasim N, Shaw A, Phipps D, Kot P, Pedrola M O, Alattabi A W, Abdulredha M and Alawsh R 2019 Electrocoagulation as a green technology for phosphate removal from River water Separation and Purification Technology 210 135-44

Abdulla G, Kareem M M, Hashim K S, Muradov M, Kot P, Mubarak H A, Abdellatif M and Abdulhadi B 2020 Removal of iron from wastewater using a hybrid filter. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012035

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

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

Hashim K S, Ewadh H M, Muhsin A A, Zubaidi S L, Kot P, Muradov M, Aljeferiy M and Al-Khaddar R 2020 Phosphate removal from water using bottom ash: Adsorption performance, coexisting anions and modelling studies Water Science and Technology 83 1-17

Al-Jumeily D, Hashim K, AlKaddar R, Al-Tufaily M and Lunn J 2019 Sustainable and Environmental Friendly Ancient Reed Houses (Inspired by the Past to Motivate the Future). In: 11th International Conference on Developments in eSystems Engineering (DeSE), (Cambridge, UK pp 214-9

Al-Saati N H, Hussein T K, Abbas M H, Hashim K, Al-Saati Z N, Kot P, Sadique M, Aljeferiy M H and Carnacina I 2019 Statistical modelling of turbidity removal applied to non-toxic natural coagulants in water treatment: a case study Desalination and Water Treatment 150 406-12

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

Alattabi A W, Harris C, Alkhaddar R, Alzeyadi A and Hashim K 2017 Treatment of Residential Complexes’ Wastewater using Environmentally Friendly Technology Procedia Engineering 196 792-9

Alattabi A W, Harris C B, Alkhaddar R M, Hashim K S, Ortoneda-Pedrola M and Phipps D 2017 Improving sludge settleability by introducing an innovative, two-stage settling sequencing batch reactor Journal of Water Process Engineering 20 207-16

Shubbar A A, Sadique M, Nasr M S, Al-Khafaji Z S and Hashim K S 2020 The impact of gridding time on properties of cement mortar incorporated high volume waste paper sludge ash Karbala International Journal of Modern Science 6 1-23

Kadhim A, Sadique M, Al-Mufti R and Hashim K 2020 Long-term performance of novel high-calcium one-part alkali-activated cement developed from thermally activated lime kiln dust Journal of Building Engineering 32 1-17

Abdulredha M, Rafid A, Jordan D and Hashim K 2017 The development of a waste management system in Kerbala during major pilgrimage events: determination of solid waste composition Procedia Engineering 196 779-84

Idowu I A, Atherton W, Hashim K, Kot P, Alkhaddar R, Alo B I and Shaw A 2019 An analyses of the status of landfill classification systems in developing countries: Sub Saharan Africa landfill experiences Waste Management 87 761-71

Kadhim A, Sadique M, Al-Mufti R and Hashim K 2020 Developing One-Part Alkali-Activated metakaolin/natural pozzolan Binders using Lime Waste as activation Agent Advances in Cement Research 32 1-38
[51] 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
[52] Majdi H S, Shubbar A, Nasr M S, Al-Khafaji Z S, Jafer H, Abdulredha M, Masoodi Z A, 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 105961-72
[53] Majdi H S, Shubbar A, Nasr M S, Al-Khafaji Z S, Jafer H, Abdulredha M, Al Masoodi Z, Sadique M and Hashim K J D i B 2020 Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations
[54] Shubbar A A, Jafer H, Abdulredha M, Al-Khafaji Z S, Nasr M S, Al Masoodi Z and Sadique M J J o B E 2020 Properties of cement mortar incorporated high volume fraction of GGBFS and CKD from 1 day to 550 days 30 101327
[55] Abdulredha M, Al Khaddar R, Jordan D, Kot P, Abdulridha A and Hashim K 2018 Estimating solid waste generation by hospitality industry during major festivals: A quantification model based on multiple regression Waste Management 77 388-400
[56] Farhan S L, Jasim I A and Al-Mamoori S K 2019 The transformation of the city of Najaf, Iraq: Analysis, reality and future prospects Journal of Urban Regeneration & Renewal 13 160-71
[57] Hashim K S, Al Khaddar R, Jasim N, Shaw A, Phipps D, Kot P, Pedrola M O, Alattabi A W, Abdulredha M, Alawsh R J S and Technology P 2019 Electrocoagulation as a green technology for phosphate removal from River water 210 135-44
[58] Hashim K S, Idowu I A, Jasim N, Al Khaddar R, Shaw A, Phipps D, Kot P, Pedrola M O, Alattabi A W and Abdulredha M J M 2018 Removal of phosphate from River water using a new baffle plates electrochemical reactor 5 1413-8
[59] Isra’ a S S, Al-Janabi A, Abdulredha M, Alkandari A, Abdellatif M and Yeboah D 2021 Reusing of furnace bottom ash as an adsorbent for phosphate removal from water. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012006
[60] Jawad S F, Saddam N S, Adaami Q J, Kareem M M, Abdulredha M, Mubarak H A, Kot P, Gkantou M and AlKhayyat A 2021 Dye removal from textile wastewater using solar-powered electrocoagulation reactor. In: IOP Conference Series: Materials Science and Engineering: IOP Publishing) p 012016
[61] 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
[62] Shoab M and Balaha M 2004 THERMO-CHEMICAL STABILITY AND MECHANICAL PROPERTIES OF MORTAR MADE WITH CEMENT KILN DUST-BLENDED CEMENT ERJ. Engineering Research Journal 27 49-58