Engineering and Technology Journal
Journal homepage: engtechjournal.org

Incorporation of Iraqi Rocks in the Production of Eco-Friendly Cement Mortar

Rawnaq S. Mahdi[a*], Aseel B.AL-Zubaidi[b], Hassan N. Hashim[c]

[a] Department of Materials Engineering, University of Technology, Baghdad, Iraq, 130073@uotechnology.edu.iq

[b] Department of Materials Engineering, University of Technology, Baghdad, Iraq, 130030@uotechnology.edu.iq

[c] Department of Physics, College of Science, Al-Nahrain University, Baghdad, Iraq, Hassan.hashim@ced.nahrainuniv.edu.iq

*Corresponding author.

Submitted: 09/12/2019 Accepted: 24/01/2020 Published: 25/10/2020

KEYWORDS

Cement Mortar, Kaolin, Flint, eco-friendly mortars.

ABSTRACT

This work reports on the incorporation of Flint and Kaolin rocks powders in the cement mortar in an attempt to improve its mechanical properties and produce an eco-friendly mortar. Flint and Kaolin powders are prepared by dry mechanical milling. The two powders are added separately to the mortars substituting cement partially. The two powders are found to improve the mechanical properties of the mortars. Hardness and compressive strength are found to increase with the increase of powders constituents in the cement mortars. In addition, the two powders affect water absorption and thermal conductivity of the mortar specimens which are desirable for construction applications. Kaolin is found to have a greater effect on the mechanical properties, water absorption, and thermal conductivity of the mortars than Flint. This behavior is discussed and analyzed based on the compositional and structural properties of the rocks powders.

How to cite this article: R. S. Mahdi, A. B. AL-Zubaidi, and H. N. Hashim, "Incorporation of Iraqi Rocks in the Production of Eco-Friendly Cement Mortar," Engineering and Technology Journal, Vol. 38, Part A, No. 10, pp. 1522-1530, 2020.
DOI: https://doi.org/10.30684/etj.v38i10A.1479

1. Introduction

Rocks are classified generally based on their chemical and compositional properties, their permeability, and texture of the constituting particles and their particle sizes [1-3]. Rocks can also transform from one type to another based on environmental effects and time. Accordingly, three types of rocks are generated igneous, sedimentary, and metamorphic [4]. Flint and Kaolin are two important forms of rocks. They are deposits of microcrystalline silica. Flint is easy to spot, covered by a thin white layer in contrast to the other pebbles. It is quite hard material but not as brittle as quartz. Flint has a homogeneous, non-crystalline structure, and stress dissipates in its rocks. This is unlike crystal structure where stress-induced small cracks often propagate through the entire crystal [5]. Kaolin is a relatively soft, lightweight, and chalk-like material. It is commonly used in the paper-coating industry and as filler in plastic and rubber components. It is also used as a pigment additive in paints, ceramics, and pharmaceuticals. Kaolin coexists with other rocks such as quartz, iron oxide, and minerals. Therefore, it is typically processed to remove these coexisting materials. Kaolin is often further modified from its natural state by chemical treatments, physical delamination, and high-temperature heating processes [6, 7]. The pozzolanic reactivity of Flint and Kaolin, investigated by other researchers, has shown direct dependence on their compositional and mineral structures [8]. Also, the processing parameters of these materials before or during their incorporation in cement manufacturing play an important role in the final properties of the cement mortars [9-13]. In the present work, Flint and Kaolin powders are incorporated in the cement mortars after being subjected to mechanical grinding at room temperature. Unlike precedent work by other researchers, no thermal processing is applied to the processed powders. This is to reduce the amount of energy required which becomes a critical issue when mortars are being prepared in large quantities.

Figure 1: Production of Flint and Kaolin powders from their respective rocks. (a, b) Flint (c, d) Kaolin.

TABLE I: The mixing ratios of the Flint and Kaolin powders in the cement mortars.

Specimens	Cement (g)	Sand (g)	Flint or Kaolin powder (g)	Flint or kaolin powder (%)	Water (ml)
1	75	225	0	0	50
2	74.625	225	0.375	0.5	50
3	74.25	225	0.75	1	50
4	73.875	225	1.125	1.5	50
5	73.5	225	1.5	2	50
6	73.125	225	1.875	2.5	50

Cubic molds of 5×5×5 cm were used for the preparation of the cement mortars specimens. These specimens were prepared for the compressive strength test. All the specimens were left for setting for 28 days. Figure 2 shows the mortar specimens after being removed from the molds. Figure 3 shows the cement mortar specimen for the hardness and thermal conductivity tests. These specimens have dimensions of 5 cm radii 1 cm thickness.

Figure 2: The cement mortars prepared with the incorporation of Flint and Kaolin rocks powders.

Figure 3:. The cement mortars for the hardness and thermal conductivity tests.

After 28 days the following properties were investigated; water absorption, thermal conductivity, hardness, and compressive strength. For water absorption, the specimens were initially dried and weighed. They were then submerged in water for 24 h. Their weight was measured immediately after being removed from the water. The weight difference was then calculated to determine the amount of water absorption. The thermal conductivity measurements of the mortar specimens were achieved using Lee's disk setup. The thermal conductivity factor was determined by Fourier law [14].

$$I \times V = \pi r^2 e^{(T_1+T_2)} + 2\pi r e^{(d_1 T_1 + 0.5 d_s (T_1+T_2) + d_2 T_2 + d_3 T_3)} \qquad \text{--- (1)}$$

$$K\left(\frac{T_2-T_1}{d_s}\right) = e^{\left(T_1 + \left(\frac{2}{r}\right)(d_1 + 0.5 d_s)T_1\right)} + \frac{1}{r} d_s T_2 \qquad \text{--- (2)}$$

Where: K is the thermal conductivity measured in (W/m.K), I is the electric current measured in Ampere, V is the applied voltage in (volt), r is the radius of lee disk meter and d_s is the specimen diameter. T_1, T_2 initial and final temperature.

The hardness test was accomplished according to the ASTM D2240-05 (2010) standard. Each specimen was subjected to three measurements and an average value of hardness was determined. The compressive strength, which is used to determine the elastic limit of the material under compression, is measured according to ASTM C109 / C109M - 16a standard.

2. Results and discussion

Figure 4 (a, b) shows the XRD patterns of the Flint and Kaolin powders respectively. In the case of the XRD pattern for Flint powder, the peaks could be indexed to two major phases. The first phase identified, indicated by the 010, 111, 020, and 022 peaks in Figure 4 (a)It was possible to obtain diffraction patterns with high-intensity peaks at a relatively small scan rate indicating the presence of a high crystalline structure. Figure 4(a) has a structure similar to that of Kaolinite [15]. The second peak is quartz which is identified by the 001 and 101 peaks [16, 17]. The intensity peaks of the two phases indicate that Kaolinite is a major phase constituting the crystalline powder.

Figure 4: The XRD patterns of (a) Flint and (b) Kaolin powder.

Figure 4 (b), the XRD pattern of the Kaolin powder, show intensity peaks that could be indexed to multiple phase structures. Three-phases were identified; anorthic crystal system [18], boehmite crystal system (identified with the presence of (020), (120), (140) peaks) [19] and quartz crystal system (identified with the presence of (101), (210), (211) peaks [20].it was possible to obtain diffraction patterns with high-intensity peaks at a relatively small scan rate indicating the presence of a high crystalline structure

Figure 5 (a and b) shows the EDS spectra of the Flint and Kaolin powders respectively. The elemental composition of the two powders, obtained from the EDS analysis are summarized in Tables 2 and 3.Table 4 and 5 show the elemental composition of cement mortar with Flint powder and with Kaolin powder.

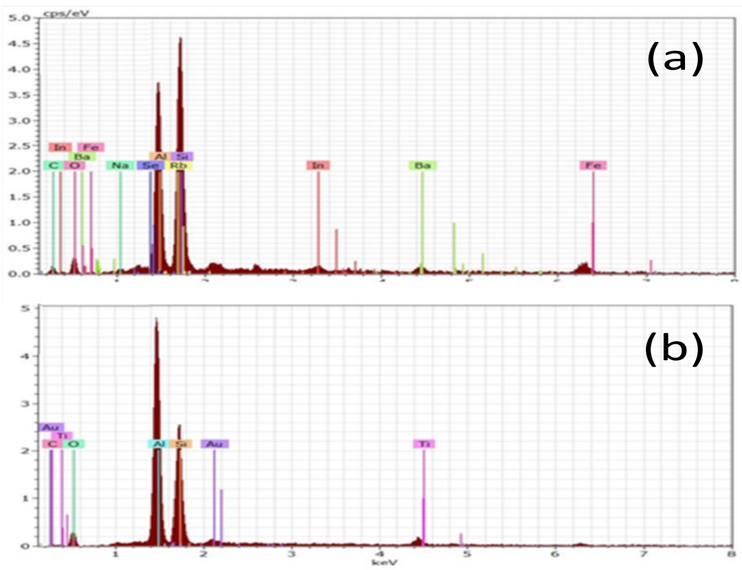

Figure 5: The energy dispersive X-ray spectra of the (a) Flint (b) Kaolin powders.

TABLE II: Elemental composition of Flint powder by EDS analysis.

Element	AN	series	[wt.%]	[norm. wt.%]	[norm. at.%]	Error in wt.% (1 Sigma)
Aluminium	13	K-series	48.99	35.37	44.66	2.383
Rubidium	37	L-series	43.70	31.55	12.57	2.024
Selenium	34	L-series	12.35	8.92	3.84	0.746
Silicon	14	K-series	11.35	8.19	9.94	0.576
Oxygen	8	K-series	10.86	7.84	16.70	2.794
Barium	56	L-series	5.74	4.14	1.028	0.309
Carbon	6	K-series	5.48	3.96	11.238	2.842
		Sum:	138.50	100	100	

TABLE III: Elemental composition of Kaolin powder by EDS analysis.

Element	AN	series	[wt.%]	[norm. wt.%]	[norm. at.%]	Error in wt.% (1 Sigma)
Rubidium	37	L-series	62.26	40.41	15.63	2.857
Aluminium	13	K-series	30.90	20.06	24.59	1.580
Silicon	14	K-series	15.61	10.13	11.93	0.780
Carbon	6	K-series	14.97	9.72	26.76	5.945
Oxygen	8	K-series	11.40	7.40	15.30	3.409
Selenium	34	L-series	9.25	6.00	2.51	0.628
Iron	26	K-series	3.16	2.05	1.21	0.259
Barium	56	L-series	2.88	1.86	0.45	0.226
Indium	49	L-series	2.34	1.52	0.43	0.185
Sodium	11	K-series	1.22	0.79	1.14	0.200
		Sum:	154.04	100	100	

TABLE IV: Elemental composition of cement mortar with Flint powder.

Element	AN	series	[wt.%]	[norm. wt.%]	[norm. at.%]	Compound	[wt.%]	[norm. wt.%]	Error in wt.% (1 Sigma)
Calcium	20	K-series	41.67	31.99	41.05	CaO	58.31	44.77	3.26
Tantalum	73	M-series	52.66	40.43	11.48		52.66	40.43	4.45
Tin	50	L-series	19.26	14.79	6.40		19.26	14.79	2.32
Oxygen	8	K-series	16.63	12.77	41.05		-2.5E-09	-1.9E-09	31.80
		Sum:	130.24	100	100	Tsl			

TABLE V: Elemental composition of cement mortar with Kaolin powder.

Element	AN	Series	[wt.%]	[norm. t.%]	[norm at.%]	Error in wt %(1 sigma)
Sb	51	L-series	123.30	55.41	42.25	11.23
Ta	73	M-eries	56.20	25.26	12.96	6.63
Ca	20	k-series	43.02	19.33	44.79	5.22
		sum :	222.52	100.00	100.00	

Figure 6 (a and b) shows the scanning electron micrographs of the Flint and Kaolin powders respectively. The typical Flint and Kaolin morphology in the form of heterogeneous layered sheets with heterogeneous sizes can be identified in (a) and (b). Figure 6 (c and d) are the SEMs of the cement mortars incorporating Flint and kaolin powders respectively. These images indicate the difficulty in recognizing the rocks powders incorporated in the cement mortar. This is because of the small amount of these powders and the presence of other constituents (sand and impurities in water) in the specimen matrix. Nevertheless, a careful investigation of the SEMs provides strong evidence about the homogeneous distribution of the rocks powders in the cement matrix. Furthermore, the comparison of Figures (c and d) with (a) and (b) shows the effect of forming hydrated phases during the pozzolanic reaction. In (c) and (d), C–S–H gels are identifiable leading to the reduction of pores in the specimen area.

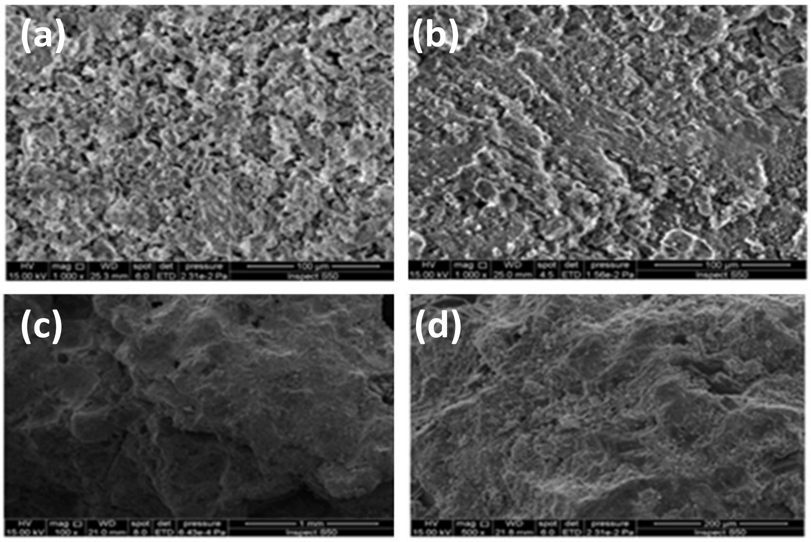

Figure 6: Scanning electron micrographs of (a) Flint (b) Kaolin powders. (c) and (d) are SEMs of the cement mortars containing Flint and Kaolin respectively.

Figure 7 shows the water absorption results. Both mortars exhibited a reduction in the water absorption value with the increase in powder ratio (Flint or Kaolin). This reduction was found reproducible in all the mortars examined regardless of the time interval after which measurements were taken. This behavior is attributed to the fact that the rocks powders fill the micro-cracks and the pores in the mortar leading to a decrease of voids being otherwise occupied with water [21].

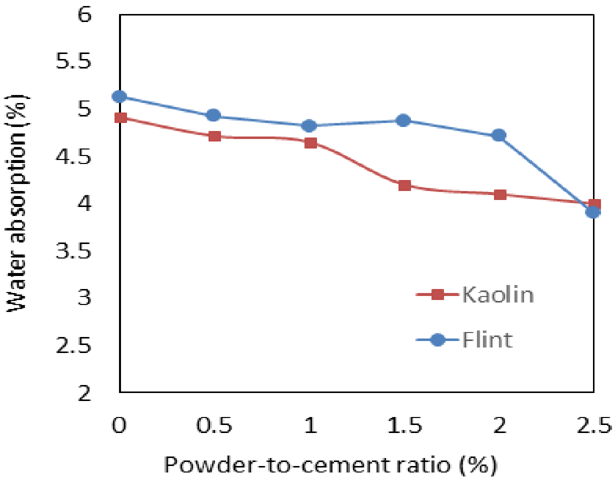

Figure 7: Water absorption of cement mortars with Flint and Kaolin powders.

Figure 8 shows the thermal conductivity test of the cement mortars before and after the incorporation of the rocks powders. Results show that the thermal conductivity decreases in general with the increase of Flint and Kaolin in the cement mortars. However, there is a slight deviation from this behavior at certain powder-to-cement ratios where the thermal absorption value is more or less than its preceding one. This might be attributed to the fact that the thermal conductivity test is sensitive to the specimen condition, particularly its internal humidity [22].

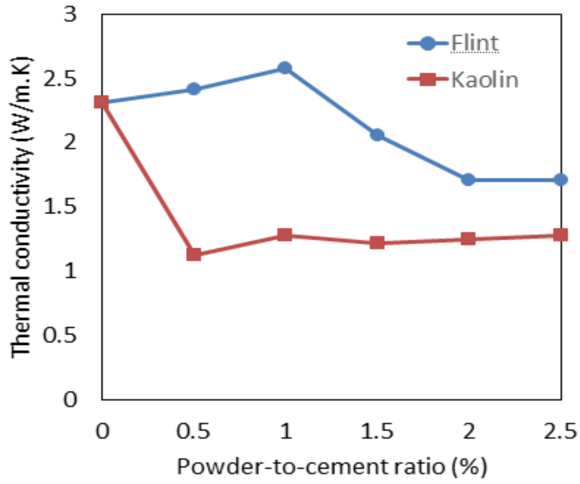

Figure 8: Thermal conductivity of cement mortars with Flint and Kaolin powders.

Figure 9 shows the behavior hardness of the cement mortars with the increase of rocks powders. Results show that the hardness increases with the increase of the Flint and Kaolin ratio in the mortar specimen. The rate of increase of hardness at low additions is higher than that at high powders addition indicating that there is a limited hardness achievable with these substituents. Furthermore, Kaolin resulted into higher hardness values than Flint which might be attributed to the inherited hardness of the Kaolin rock powder [23].

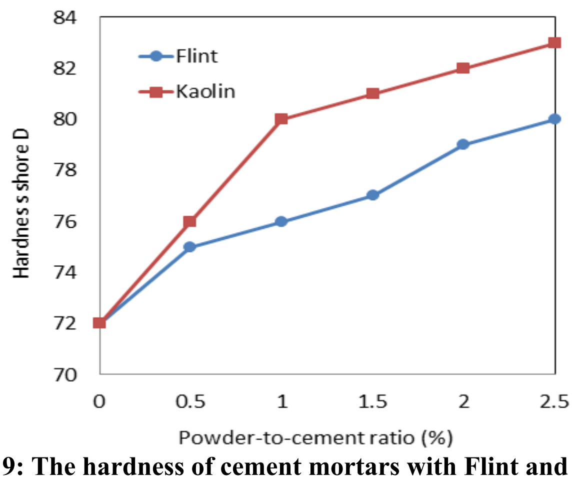

Figure 9: The hardness of cement mortars with Flint and Kaolin addition.

Figure 10 shows the results of the compressive strength measurements of the cement mortars before and after the addition of the Flint and Kaolin powders. Both powders exhibited an increase of compression resistance with the increase of powders constituents in the cement mortars. In addition, the effect of Kaolin on compression resistance values is higher than that of Flint. This behavior is directly related to the hardness behavior (Figure 9). The increase of hardness and compression strength with the increase of Flint and Kaolin is due to the inherent properties of these two additives.

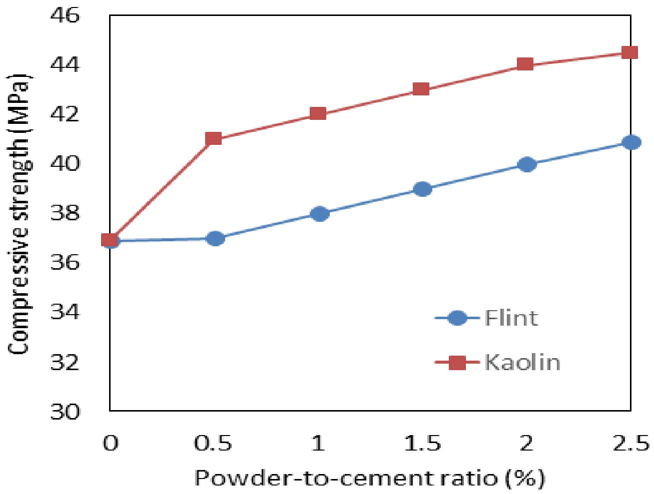

Figure 10: Compressive strength of cement mortars before and after the incorporation of Flint and Kaolin powders.

CONCLUSIONS

1) Utilization of Iraqi rocks powders, namely Flint and Kaolin powders, in cement mortars was achieved in an attempt to improve the mechanical properties of the mortars.
2) The two rocks powders were produced by ball milling and incorporated in the cement mortars at certain ratios substituting cement partially.
3) The effect of Flint and Kaolin powders on cement mortars included water absorption, thermal conductivity, this investigation showed that Flint and kaolin led to a decrease of water absorption and thermal conductivity of the cement mortar specimens.
4) The hardness and compressive strength Furthermore, increase with the increase of the powders in the mortars. This behavior was discussed and analyzed based on the inherited properties of the Flint and Kaolin powders.

REFERENCES

[1] D. Jevtić, D. Zakić, A. Savić, ″Achieving sustainability of concrete by recycling of solid waste materials‶, Mechanical Testing and Diagnosis, 1(II), pp.22-39, 2012.

[2] G. Battiato, C. Verga,″ The AGIP viscoelastic method for asphalt pavement design, proceedings of the fifth international conference on the structural design of asphalt pavements‶, Internat Exe Comm. Study Centre for Road Constr., Vol.1, pp. 59-66, 1982.

[3] J. Aguiar, A. Camões, R. Fangueiro, R. Eires, S. Cunha, M. Kheradmand, ″Materiais de construção sustentáveis‶, Congresso Luso-Brasileiro de Materiais de Construção Sustentáveis, Vol. 1-2, pp.2183-1866, 2014.

[4] P. Victor, "The Green Imperative: Ecology and Ethics in Design and Architecture", Lisboa, published by Thames and Hudson, London. Paperback. 1995.

[5] E. Arit, ″Non plastic ceramics material‶, International Journal of Advanced Engineering Research and Technology, Vol.4, Issue 9, pp. 296-298, September, 2016.

[6] E. Lane, ″Florida's geological history and geological resources", Florida Geological Survey Special Publication, No. 35, p. 64, 1994.

[7] L. P. Knauth , ″Petrogenesis of chert: physical behavior, geochemistry and materials applications, silica‶, Mineralogical Society of America, Vol.29, pp. 233-258, 1994.

[8] M. Aleksandra, M. Zdujić, ″Preparation of pozzolanic addition by mechanical treatment of kaolin clay", International Journal of Mineral Processing, Vol.132, pp.59–66, 2014.

[9] T. Kovářík, P. Bělský, P. Novotný, J. Říha, J. Savková, R. Medlín, D. Rieger, P. Holba, ″Structural and physical changes of re-calcined metakaolin regarding its reactivity‶, Construction and Building Materials , Vol.80, pp. 98–104, 2015.

[10] M.Aleksandra, M. Zdujic, ″Mechanochemical treatment of serbian kaolin clay to obtain high reactive pozzolana‶, Journal of the Serbian Chemical Society, Vol.78, No.4, pp.579–90, 2013.

[11] M. S. Labied, T. El ghailassi, A. Bouih, L. Moutei, Y. Benbrahim, T. Guedira, O. Benali, ″Study of the effect of kaolin in the mortar of cement matrices by confinement of ion exchange resins‶, MATEC Web of Conferences , Vol.149, pp.01056, 2018.

[12] L. Osterhus, F. Ditz, F. Schmidt-Döhl, ″Pozzolanic activity of flint powder", Fifth International Conference on Sustainable Construction Materials and Technologies, 2019.

[13] P. C. Hewlett, ″Lea's chemistry of cement and concrete book‶, Hardcover, Butterworth-Heinemann, Page Count: 1092, 4th Edition, 2003.

[14] A. L. Moore, M. T. Pettes, F. Zhou and L. Shi, ″Thermal conductivity suppression in bismuth nanowires", J. Appl. Phys., Vol.106, pp. 034310, 2009.

[15] A. W. Hewat, R. A. Young, ″Verification of the triclinic crystal structure of kaolinite", Clays and Clay Minerals, Vol. 36, pp.225-232, 1988.

[16] M. C. Morris, H. F. McMurdie, Eloise. H. Evans, B. Paretzkin, H. S. Parker, and N. C. Panagiotopoulos, ″Standard X-Ray diffraction powder pattern‶, Natl. Bur. Stand., NBS Monographs 25, section 18, 1981.

[17] H.E. Swanson,R.K Fuyat and G.M. Ugrinic, ″Standard X-ray diffraction powder patterns‶, Natl. Bur. of Stand. (U.S.), Circ. 539, Vol.3, pp.24, 1954.

[18] S. Grangeon, B. Lanson, N. Miyata, Y. Tani, and A. Manceau1, ″Structure of nanocrystalline phyllomanganates produced by freshwater fungi‶, American Mineralogist, Vol. 95, pp.1608-1616, 2010.

[19] H. J. Werner, P.J. Knowles,G.Knizia,F.R. Manby, and M.Shutz, ″Eco. cement to reduce Co_2 emission‶, Wiley Interdiscip. Rev. : Comput. Mol. Sci.2, pp.242, 2012.

[20] R. A. Young, P. E. Mackie and R. B. Von, ″Application of the pattern-fitting structure-refinement method to X-ray powder diffractometer patterns", Journal of Applied Crystallography , vol 10, pp. 262-269, 1977.

[21] A. Al Ghabban, A. B. Al Zubaidi ,M. Jafar and Z. Fakhri, "Effect of nano SiO_2 and nano $CaCO_3$ on the mechanical properties, durability and flowability of concrete", IOP Conference Series: Materials Science and Engineering PAPER, Mater. Sci. Eng. 454 012016, 2018.

[22] A. B. AL-Zubaidi "Effect of natural fibers on mechanical properties of green cement mortar" AIP Conference Proceedings 1968, 020003, 2018.

[23] B. A. Abdul Majeed and D. A. Sabar, "Effect of kaolinite on the mechanical properties, thermal properties, flammability and water absorption percentage of poly (Vinyl Chloride) composite" Iraqi Journal of Chemical and Petroleum, Vol.18, No.2, pp. 27 – 39, June, 2017.