Egypt. J. Chem. **Vol. 64,** No. 7 pp. 3255 - 3264 (2021)

Egyptian Journal of Chemistry

http://ejchem.journals.ekb.eg/

Effect of Refuse Derived Fuel Ash on the Hydration Characteristics of Portland Cement

E. E. Hekal [1]; W. H. Hegazy [2]; R. M. Kamel[3], and K. A.Moustafa[4]

[1] Physical Chemistry, Faculty of Science, Ain-Shams University-Cairo - Egypt
[2] inorganic chemistry, Faculty of Science, Suez University-Suez - Egypt
[3] Analytical Chemistry, Faculty of Science, Suez University-Suez - Egypt
[4] QC Manager in National Company for Cement (Khaled Abdelrehim), Suez - Egypt

Abstract

The use of alternative fuels in Portland cement manufacturing reduces the amount of emissions such as CO_2 and NO_X gases. Also, it causes a considerable energy cost reduction. In addition, the use of alternative fuel has a positive impact on environment as a result of reduction of solid waste disposal. Therefore, the aim of this work is to investigate the effect of residual ashes produced from using RDF solid waste as biofuel in Portland cement manufacture on its properties. The solid waste used in this study is refuse derived fuel (RDF) mainly from municipal waste. The effect of adding different ratios of the ash, produced after burning such solid waste, to Portland cement on its hydration characteristics was investigated. This is done through the determination of standard water of consistency, initial and final setting times, compressive strength, chemically combined water content as well as the phase composition of the hydration products via the XRD examination. The ratios of ash used were: 0.0, 0.5, 1.0, 1.5 and 2.0% by weight of Portland cement. The samples with RDF ash showed relatively high values of compressive strength compared to blank sample at early ages of hydration up to 7 days.
Keywords: Alternative; fuel; ash; hydration; cement; compressive; strength.

1. Introduction

Cement is considered one of the most important building materials around the world. Cement production is an energy- intensive process consuming coal around 120 kg/ton.CK (every 1 gm from coal contains 6000 Cal/g) and we have used instead of coal as every two tons from AFR is equal one ton from coal where (every 1 gm from RDF contain 3200 Cal/g). (Giddings et al, 2000 and Madlool el al, 2011).

The cement industry contributes 5 percent of the global CO2 emissions (Madlool et al, 2011). In modern cement plant, 60 percent of CO2 emitted by cement plant results from the calcinations of limestone, 30 percent from combustion of fuels in the kiln and 10 percent from other downstream plant operations (Bosoaga et al, 2009).

Cement kilns use different sources of energy to produce the high temperatures necessary for the formation of clinker. The most common sources of fuel for cement industry are coal, fuel oil, petroleum coke and natural gas (Singhi and Bhargava, 2010). Alternative fuel (AF) is another source of energy used by cement producers around the world. These fuels are usually derived from the mixtures of industrial, municipal and other wastes (Mokrzycki and Uliasz-Bochenczyk, 2003).

The product of municipal solid waste (MSW) processing is typically referred to as "refuse derived fuel" (RDF) and is a common fuel alternative in many European countries. The RDFs from MSW have different physical and chemical properties depending on their sources, especially with respect to their ash, chlorine, sulfur and water contents. Using RDF as a supplemental fuel in cement production is an economically viable option to minimize fuel costs and landfill disposals (Gendebien et al, 2003; Junior 2003; Wirthwein and Emberger, 2010).

Energy costs and environmental concerns have encouraged cement companies worldwide to evaluate to what extent conventional fuels can be replaced by

*Corresponding author e-mail: k.rahim@nccegypt.com.; (K. A.Moustafa).
Receive Date: 16 December 2020, Revise Date: 16 January 2021, Accept Date: 14 March 2021
DOI: 10.21608/EJCHEM.2021.53751.3117

waste materials, such as waste oils, mixtures of non-recycled plastics and papers, used tires, biomass wastes and waste water sludge (Chatziaras et al, 2016). The possibilities of utilization of the highly calorific refused derived fuel (RDF) to reduce the use of fossil energy resources in cement production and to reach environmental protection have been discussed (Chamurova et al, 2017).
Biomass as alternative refused derived fuel (RDF) can substitute for approximately 20% by weight of fossil fuel (Halimehjani et al, 2016). The use of RDF in the cement production can be environmentally and economically has positive impact (Reza et al, 2013). Efforts were made to characterize municipal solid waste bottom ash and to evaluate the effects of the ash as a partial replacement of cement and fine aggregate in cement paste and concrete respectively (An et al, 2017). Alternative fuels should be considered in energy intensive industries such as cement industry becomes more challenging for the following main factors: the lowest production cost and the lean environmental impact (Zieri and Ismail 2018).
In recent study, four solid refused derived fuels namely; ruber waste, tree trimmings, rice straw and municipal solid wastes (MSW) are characterized and tested as RDF. Also, the effect of their ashes on hydration characteristics of Portland cement pastes was investigated (Hashem et al, 2018). In addition, Hashem et al, (2019) studied the efficiency of rubber waste (RW) and plastic waste (PW) as fuel sources as well as the effect of their ashes residue on the properties and hydration characteristics of Portland cement. The aim of this study is to investigate the presence of RDF ash on the hydration characteristics of Portland cement.

The benefits of using alternative fuels like RDF in cement production for cement producers are lower their production costs by use of low-grade alternative fuels such as paper, wood, plastic and rubbish etc. in pre-calciner is a viable option because combustion in pre-calciner vessel takes place at a lower temperature (850 oC to 950 oC). In pre-calciner where kiln exhaust gases pass through. The use of alternative fuels in cement manufacture is also ecologically beneficial, for three reasons:
a-NOx emissions are much reduced due to re-burn reactions, there is an increased net global reduction in CO2 emissions when waste is combusted in the cement kiln systems as opposed to dedicated incinerators, resulting in reduction in the CO2 penalties.
b- The conservation of non-renewable resources (Coal, natural gas, petroleum) Since alternative fuels are often deemed cheaper than conventional fossil fuels, the possibility of a competitive edge is generated. The use of alternative fuels in European cement kilns saves fossil fuels equivalent to 2.5 million tons of coal per year. The proportion of alternative fuels used in cement kiln systems between 1990 and 1998 in some European countries are as follows in order of importance: France 52.4 percent; Switzerland 25 percent; Great Britain 20 percent; Belgium 18 percent; Germany 15 percent; Czech Republic 9.7 percent, Italy 4.1 percent; Sweden 2 percent; Poland 1.4 percent; Portugal 1.3 percent and Spain 1 percent [Mokrzycki et.al 2003].
C- Reduction of waste disposal requirements.
Challenges of using alternative fuels in cement production Alternative fuels used in cement manufacturing have different characteristics compared to the conventional fuels. Switching from conventional fuels to alternatives fuels presents several challenges that must be addressed in order to achieve successful application. Poor heat distribution, unstable pre-calciner operation, blockages in the preheater cyclones, build-ups in the kiln riser ducts, higher SO2, NOx, and CO emissions, and dusty kilns are some of the major challenges [Roy 2002].

The aim of this study is to examine the effects of the retained ash from the burning of RDF in the produced cement clinker on the hydration characteristics of Portland cement. In this study we use small ratios of the RDF ash because the amount used of the refused derived fuel produces small ratio of the ash.

2. Materials and Experimental Techniques

The materials used in this study were:
Ordinary Portland cement Type I conforming with ASTM C150 was used in this study from Misr Beni Suef (manufacturing without using RDF as biofuel). and Standard sand according to ASTM C778 and RDF ash which was prepared by burning RDF (The RDF technology can effectively by separate of glassy materials and ferrous and any metals from RDF then reduce both volume and weight of municipal wastes, the maximum particle size of RDF is generally less than 50 mm (1.97 in.), then take around 50kg from homogeny RDF and transfer to lab to dry it at 45 ^{o}C for 24hr, and then shredded it to small fine parts and take small quantity around 10 gm and put in porcelain crucible to ignite in oven (high temperature) at 950 ^{o}C for 25 min, then collect ash from porcelain crucible after cool to room temperature).where this preparation technique in time and temperature are the same technique in cement rotary kiln process (the same time which remaining inside rotary kiln). The ratio of ash retained after

burning RDF waste was 20% (we cannot increase RDF quantity in the rotary kiln system in cement industry because ash produce after RDF burnet have a bad effect on compressive strength in cement when used more than 25% from alternative fuel instead of traditional fuel , like gas or coal where we used around 750 tons/day from coal and we can substituted it by used 250 tons/day from RDF and used 625 tons/days from coal until give the same calorific value according to this equation:

Thermal substitution rate (TSR%) =

Total heat input (AFR) / Total heat input

Where; Total heat input (K. Cal) =

[quantity(ton)×Calorific value] Coal

+[quantity(ton)×Calorific value] AFR

and the RDF kiln system in any factory cannot used more because this is related with combustion system and main ID fan kiln system.

The XRD analysis as well as the sieve analysis of RDF, are given in the following figures (1) and (2)

The chemical composition of starting materials is given in table (1) as examined by XRF.

Table 1. Chemical oxide compositions of the starting materials, Wt.%

Oxide materials (%)	Cement Type I – ASTM-C150	RDF
SiO_2	20.20	45.51
Al_2O_3	5.34	7.98
Fe_2O_3	3.69	21.03
CaO	61.76	21.85
MgO	1.53	1.83
SO_3	3.30	1.92
K_2O	0.24	0.52
Na_2O	0.39	0.83
Cl	0.06	0.88
LOI	2.70	80.00
Free CaO	1.43	

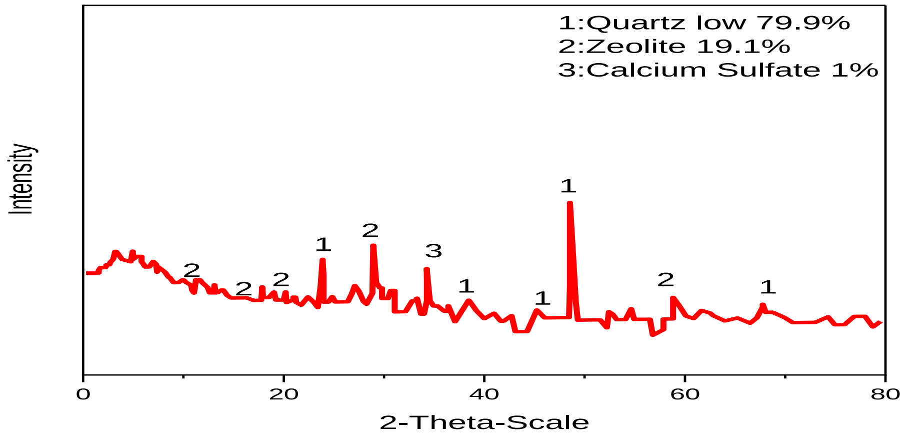


Fig. (1) XRD pattern of RDF (Refuse derived fuel) ash.

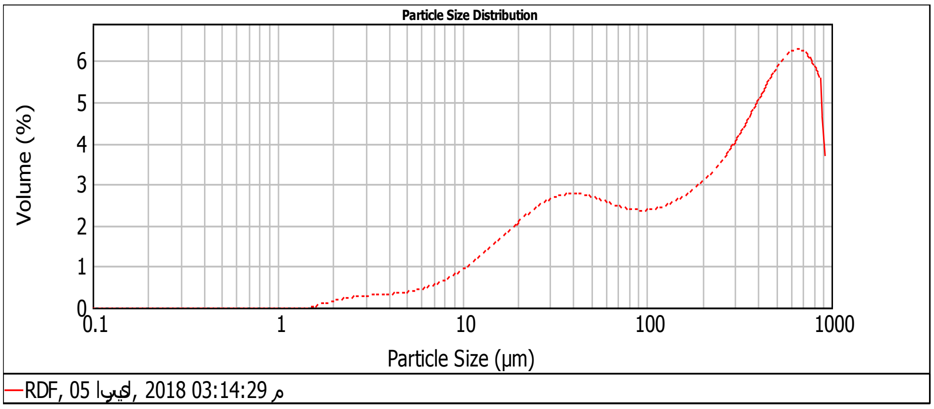


Fig. (2) Sieve analysis pattern of RDF (Refuse derived fuel) ash.

2.1. Preparation of dry mixes

The composition of the dry mixes as well as their designations are given in Table (2).

Table (2): The composition and designation of the different mixes with RDF

Mixes	Type I	RDF ash%
RDF (0)	100	0
RDF (0.5)	99.5	0.5
RDF (1.0)	99.0	1.0
RDF (1.5)	98.5	1.5
RDF (2.0)	98.0	2.0

2.2. Preparation of mortars samples for compressive strength

The proportions of materials for the standard mortars are one part of cement to 2.75 parts of graded standard sand by weight (500gm cement: 1375gm sand), according to ASTM – C109. Use a water-cement ratio of 0.485 for Portland cement (242ml: 500gm cement). The process of mixing mortar was prepared according to ASTM C109 procedure and compressive strength was measured according to ASTM C109 and this by three cubic shaped specimens (50 mm [1.97 inch] in length, width and height). Different mixes of dry mortar were admixed with various ratios of RDF ash. These ratios were 0.5, 1.0, 1.5 and 2.0% by weight of cement. Moulds were cured in cabinet room for 24 hrs. ± 1 hr at about 90~100 RH and 23^{O}C ±2 after record date and time on samples. Samples were removed from moulds after 24 hrs. ± 1 hr and were kept under water till the time of testing (3days,7days,28days and 90days).

2.3. Procedure for Mixing cement pastes

First; determination normal consistency of hydraulic cement according to ASTM C187.

Place all the mixing water in the bowl of mixer machine (the water to Portland cement ratio used was 27~28% according mix quantity and type). Add the cement to the water and allow 30 s for the absorption of the water. Start the mixer and mix at slow speed (140r/min) for 30 s. Stop the mixer for 15 s and during this time scrape down into the batch any paste that may have collected on sides of the bowl. Start the mixer at medium speed (285r/min) and mix for 1 min. After stop mixer machine and finished mixed paste, take paste from mixer bowel and start measure water consistency as the following technique:

Water consistency technique:

Molding Test Specimen—Quickly form the cement paste, prepared as described in above section, into the approximate shape of a ball with gloved hands. Then toss six times through a free path of about 150 mm (6 in.) from one hand to another so as to produce a nearly spherical mass that may be easily inserted into the Vicat ring with a minimum amount of additional manipulation. Press the ball, resting in the palm of one hand, into the larger end of the conical ring G, Fig. (3), held in the other hand, completely filling the ring with paste. Remove the excess at the larger end by a single movement of the palm of the hand. Place the ring on its larger end on the base plate H, and slice off the excess paste at the smaller end at the top of the ring by a single oblique stroke of a sharp-edged trowel held at a slight angle with the top of the ring, and smooth the top, if necessary, with a few light touches of the pointed end of the trowel. During these operations of cutting and smoothing, take care not to compress the paste.

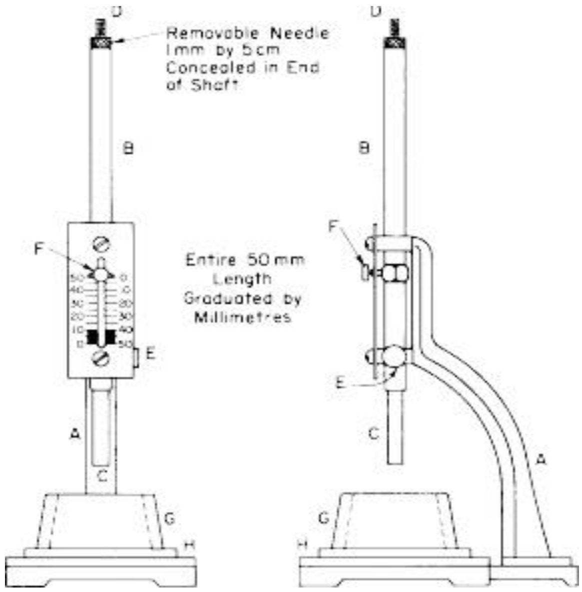


Fig. (3) Vicat Apparatus

Consistency Determination—Centre the paste confined in the ring, resting on the plate, under the rod B, Fig. (3), the plunger end C of which shall be brought in contact with the surface of the paste, and tighten the set-screw E. Then set the movable indicator F to the upper zero mark of the scale, or take an initial reading, and release the rod immediately. This must not exceed 30 s after completion of mixing. The apparatus shall be free of all vibrations during the test. The paste shall be of normal consistency when the rod settles to a point 10 ± 1 mm below the original surface in 30 s after being released. Make trial pastes with varying percentages of water until the normal consistency is obtained. Make each trial with fresh cement.

Second; determine setting times according to ASTM C191.

Time of Setting Determination— Allow the time of setting specimen to remain in the moist cabinet for 30 min after molding without being disturbed. Determine the penetration of the 1-mm needle at this time and every 15 min thereafter until a penetration of 25 mm or less is obtained. For the penetration test, lower the needle D of the rod B until it rests on the surface of the cement paste. Tighten the set screw, E, and set the indicator, F, at the upper end of the scale, or take an initial reading. Release the rod quickly by releasing the set screw, E, and allow the needle to settle for 30 s; then take the reading to determine the penetration. (If the paste is obviously quite soft on the early readings, the fall of the rod may be retarded to avoid bending, the 1-mm needle, but the rod shall be released only by the set screw when actual determinations for the setting time are made.) Make each penetration test at least 5 mm away from any previous penetration and at least 10 mm away from the inner side of the mold. Record the results of all penetration tests and, by interpolation, determine the time when a penetration of 25 mm is obtained. This is the initial setting time. The final setting time is when the needle does not sink visibly into the paste.

Note: Different cement pastes in presence and absence of RDF ash were cured at RH ~ 95 % for 24 hrs. Then under water for 1,3,7,28 and 90 days.

Stopping of hydration for cement pastes

the stopping of hydration was carried out as follows: for each sample, about 10~15 grams of the crushed pastes, after doing initial and final setting time test, were ground and poured into a beaker containing about 100 ml of acetone / methanol mixture (1:1 by volume). The mixture was mechanically stirred for 20 min. The residue was filtered off, washed with about 30 ml methanol and dried at 70 ^{0}C for 24 hours to remove the free water completely. Keep dry sample in a tide package and desiccator, for the determination of chemically combined water content and phase composition by using XRD.

Chemically combined water content (Wn%)

Three representative samples of each dried hardened Portland cement paste, exactly about three grams of each, were weighed in silica crucibles and ignited for one hour at 950 ^{0}C in an adjusted muffle furnace, cooled in a desiccator the weighed (El-Didamony et al, 2011). The chemically combined water (i.e., the amount of water retained after drying) was calculated as Wn% using the following equation: -

Wn%= [(W2-W3)/(W3-W1)] ×100

Where, W1: the weight of the empty crucible,

W2: the weight of the crucible + sample before ignition,

And W3: the weight of the crucible + sample after ignition.

X-Ray Diffraction Analysis(XRD)

The formed hydration products of each sample were identified by means of X-ray diffractometer using (ARL 9900) using Cu target and Cu kα radiation under working conditions of 30 kilo volts and 80 milliamps.

Compressive Strength

A set of three mortar cubes, representing the same mix and same age, was used for the determination of the compressive strength of the hardened cement mortars. The average of the three results expressed was considered, in N/mm2. The strength test machine used in this work was of Toni Technik industry type, West Germany, and having a maximum load of 60 tons.

3.Results and Discussion

- Effect of refuse derived fuel (RDF) ash on cement hydration.

The effect of refuse derived fuel (RDF) ash admixture on the hydration characteristics of Portland cement was studied. This was carried out via the investigation of water of standard consistence, initial and final setting times, compressive strength, chemically combined water as well as XRD analysis of the hydration products. The ratios of RDF ash used were 0, 0.5, 1.0, 1.5, and 2.0% by weight of Portland cement and the mixes were designated as RDF (0), RDF (0.5), RDF (1.0), RDF (1.5), and RDF (2.0) respectively.

Water of standard consistency, initial and final setting times

Water of standard consistency as well as initial and final setting times were investigated for the different cement mixes containing RDF ashes. The results are given in table (3).

Table (3): The results of water of standard consistency and initial and final setting times.

Mixes	Water consistence (%)	Initial setting time (min)	final setting time (min)
RDF (0)	**27.50**	**190**	**245**
RDF (0.5)	**27.01**	**190**	**245**
RDF (1.0)	**27.82**	**180**	**245**
RDF (1.5)	**27.38**	**160**	**220**
RDF(2.0)	**27.25**	**155**	**215**

Obviously, there is no significant change in the values of water of standard consistency with increasing the ratio of RDF ash. Setting was used as an indicator of hardening due to cement hydration or other possible chemical reactions. The samples RDF (0.5) and RDF (1.0) show no significant change in agreement with the results of compressive strength and combined water contents. We observe when we increase RDF ash the times of initial setting times decrease. These can be explained by several reasons. The amount of calcium silicate hydrate (C-S-H) from un-hydrate cement will be reduced by the replaced amount of RDF ash. In addition, it is interesting to note that the initial setting time of the RDF ash (2%) mixture is even faster than initial setting time of control cement paste RDF ash (0%) refer to Table 3.

initial and final setting times compared to blank sample (RDF (0)). While as the sample's RDF (1.5) and RDF (2.0) show a slight decrease in initial and final setting times. This could be attributed to increasing rate of hydration as a result of nucleation effect of ash particles such explanation is in a good This faster initial setting can be explained by two possible mechanisms. First, the reaction of C_3A with water can cause flash set. Moreover, the generated heat due to the flash set may accelerate other chemical reaction in RDF ash (2%) mixture. The other mechanism is that the chemical compound of plaster ($CaSO_4·1/2H_2O$) in RDF ash produces gypsum with water (refer to Eq. (5)). Equation (4) shows the reaction from gypsum to plaster of Paris which may occur in the combustion process.

$CaSO_4.\ 2H_2O\ (s) \longrightarrow CaSO_4\ .1/2H_2O(s) + 1.5H_2O\ (g)$ ………………………………….. (4)

(gypsum) 100 to 130 deg (plaster of Paris) (released as steam)

$CaSO_4.1/2H_2O(s)+1.5H_2O(g) \longrightarrow CaSO_4.\ 2H_2O\ (s)$ ……….. (5)

(Plaster of Paris) (gypsum)

The nature of plaster of Paris includes quick initial setting and easy mixing with water. The XRD analysis shows the gypsum as a by-product on the hydrated RDF ash and the plaster on the RDF ash (refer to Fig. 8).

Compressive strength for mortar samples Compressive strength of the mortar samples made from Portland cement admixed with ashes of RDF and standard sand was investigated, the results of compressive strength are represented graphically in Fig. (4).

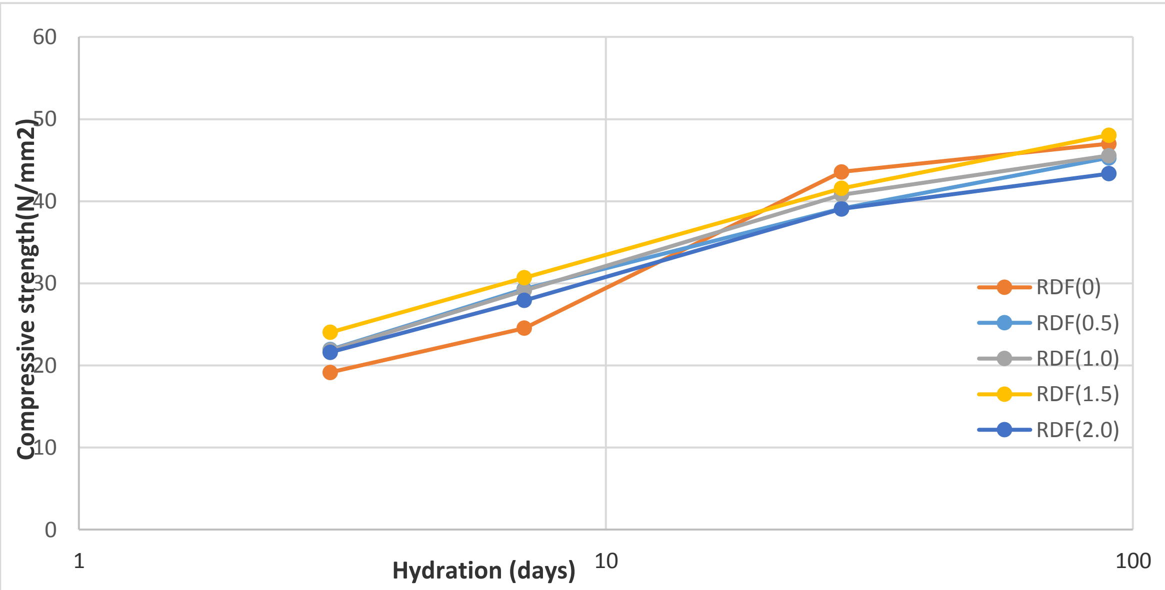


Fig. (4) Compressive strength for cement mortar admixed with different ratios of RDF ashes against hydration ages.

All mortar mixes showed a continues increase in the values of compressive strength with increasing hydration ages. This increase is due to the progress of the hydration of the Portland cement constituents; C3S, β-C2S, C3A and C4AF. The main hydration products are ill-crystallized calcium silicate hydrates

(CSH) which are considered the main binding agent and the well crystallized calcium hydroxide (CH), in addition to the hydration products of the aluminate phases. It is obvious that the presence of RDF ash increases the values of compressive strength at early ages up to 7 days. While as, at later ages up to 90 days the mortar sample without RDF ash show slightly higher values of compressive strength compared to the other samples. The high values of compressive strength of mortar samples with RDF ashes at early ages can be attributed to the nucleation effect of the fine particles of ashes. On the other side, the slightly low values of such samples at later ages can be attributed to the less activity of RDF ashes compared to Portland cement constituents.

Chemically combined water content

The results of chemically combined water content of Portland cement pastes containing 0.0, 0.5, 1.0, 1.5, and 2.0 Wt. % of RDF ashes are shown in Fig. (5).

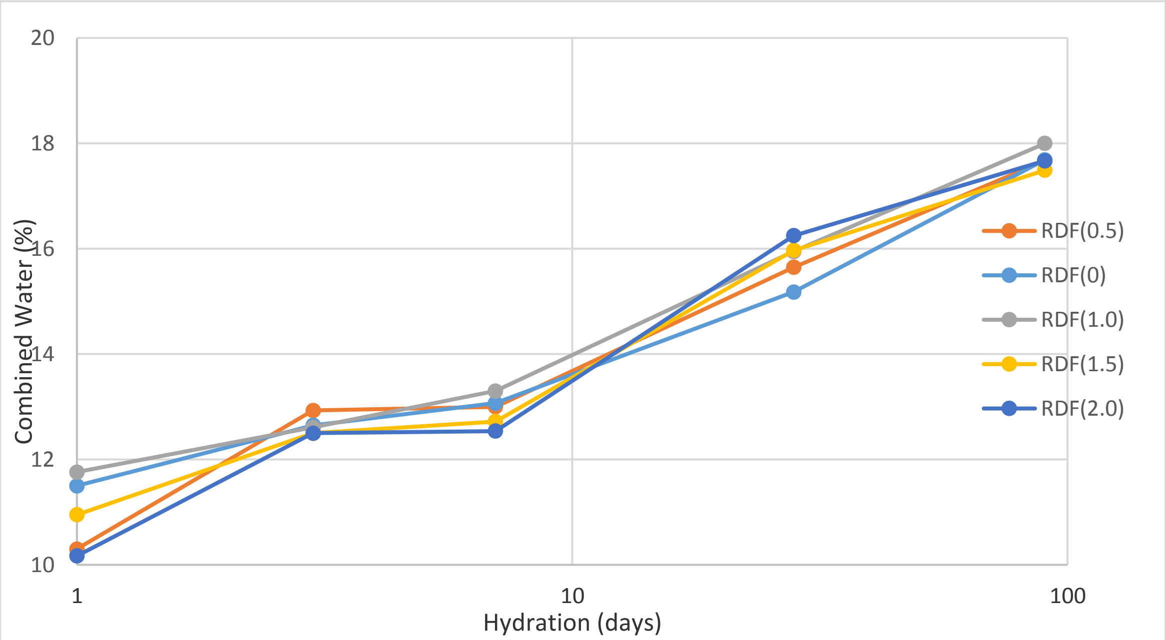


Fig. (5) Combined water for cement pastes admixed with different ratios of RDF ash against hydration ages.

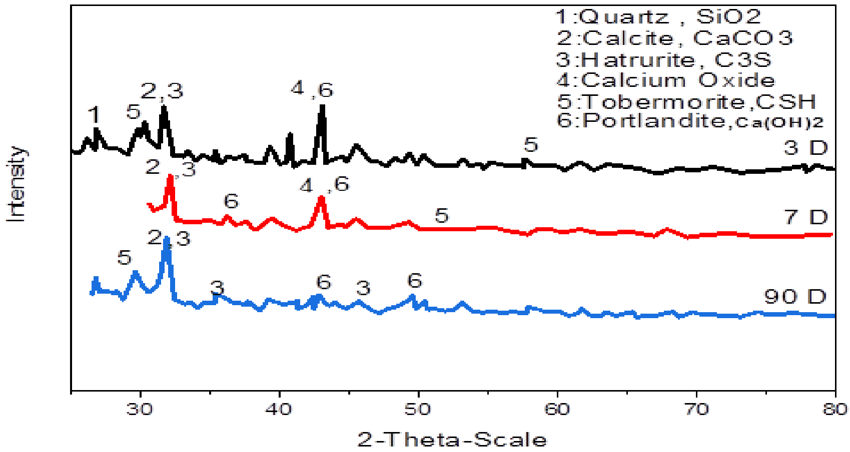
It can be noticed that there are four stages of increasing combined water with time of hydration. The first stage is the fastest step during the early age from mixing of water up to 24 hours of hydration. The second step is from 1 to 3 days of hydration. This step shows a gradual increasing in chemically combined water. The third step is from 3 to 7 days of hydration. This step can be considered a dormant stage because there are no great changes in combined water. The last step from 7 days up to 90 days, this step shows a continuous and gradual increase in combined water contents. The first fastest step can be attributed to the high reactivity of cement components as well as the high concentration at the start of the reaction. The dormant stage (3rd) is due to the formation of a layer of hydration products around the cement grains. This prevents the passage of water to cement grains. The gradual increase in combined water contents during the second and the fourth stages can be attributed to the progress of hydration of OPC constituents to form the corresponding hydration products. The main hydration products for all mixes are calcium silicate hydrate (CSH) and calcium hydroxide (CH) in addition to the hydrates of the aluminate phases. It is obvious that there is no significant effect of the presence of RDF ash on the sequence of the hydration kinetics the values of combined water of the samples with RDF ash are slightly higher than the blank sample RDF (0) at early ages of hydration up to 3 days. This could be attributed again to the nucleation effect of RDF ash which increases the rate of hydration. There is no great change in the values of combined water content at the later ages of hydration.

XRD examination for the samples with RDF ash

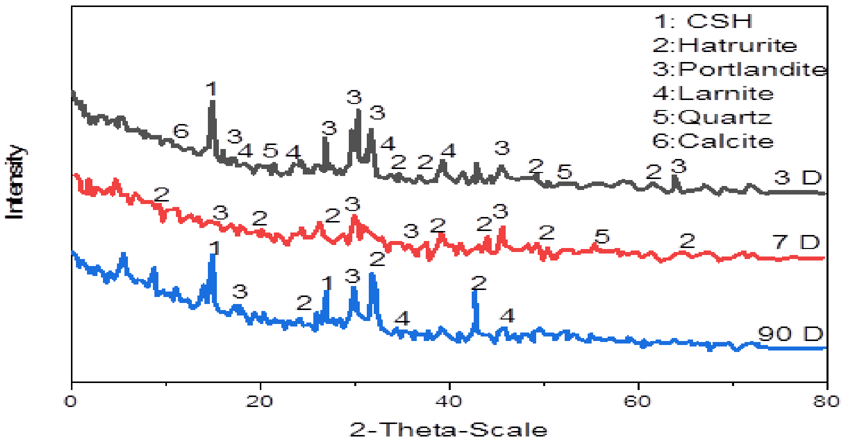
The phase composition of the various hardened cement mixes without and with various ratios of RDF ash at 3, 7 and 90 days of hydration is examined by using the X-Ray diffraction technique. Fig. (6) show the XRD patterns of the hardened neat Portland cement paste (without RDF ash, blank sample) at 3, 7 and 90 days of hydration. The hydration of Portland cement components results in a gradual conversion of the well crystallized C3S (alite) and β-C2S (belite phase) into their hydration products; ill crystallized calcium silicate hydrate (CSH) and the well crystallized calcium hydroxide (CH).

Accordingly, the intensity of the characteristic's peaks of CH at d-spacing 4.91 and 2.62 A0 gradually increase with increasing hydration age due to the progress of hydration of Portland cement. On the other hand, the intensity of the peaks Characterise of reactants such as alite and belite phases decreases with increasing hydration time.

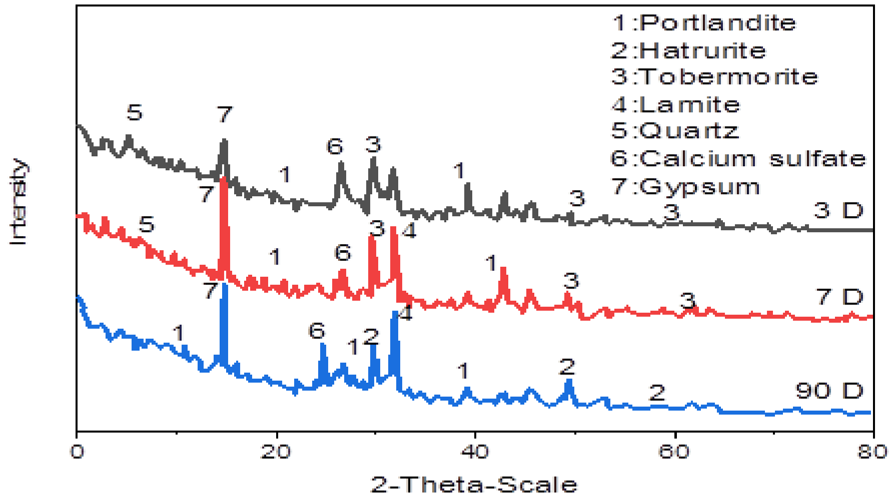
Fig. (7) show the x-ray diffraction patterns of Portland cement paste containing 0.5 % of RDF ash hydrated at 3, 7 and 90 days. The intensity of the peaks characteristics of calcium hydroxide (CH), as one of the well crystallized hydration products, increases with increasing hydration age up to 90 days. On the other hand, the intensity of the reactant peaks (C3S and β-C2S) decreases with hydration age. It can be noticed that the intensity of the portlandite (CH) peaks at all hydration ages is nearly similar to that of the blank mix [RDF (0)] without RDF ash. Therefore, it can be considered that the presence of 0.5% of RDF ash has no significant effect on the hydration characteristics of Portland cement.



[Fig. (6) XRD patterns of cement paste without RDF after 3,7 and 90 days of hydration]



[Fig. (7) XRD patterns of mix RDF (0.50) after 3,7 and 90 days of hydration]



[Fig. (8) XRD patterns of mix RDF (1.5) after 3,7 and 90 days of hydration]

4.Conclusions

The use of RDF as partial substitute of conventional fuels has positive impacts economically and environmentally. In addition, the following conclusions could be derived from this study can be summarized as follow:

1-All the used ratios of RDF ash (0.5-2.0%) have no significant effect on the amount of water required for standard consistency.

2-The ratios 0.5 and 1.0% of RDF ash have no effect on the initial and final setting times. While as, the ratios 1.5 and 2.0% of the ash decrease the initial and final setting times.

3-All the used ratios of RDF ash increase the compressive strength at early ages up to 7 days.

4-Chemically combined water contents of the mixes contain 0.5, 1.0 and 1.5% RDF ash are higher compared to blank mix RDF (0) and the mix RDF (2.0) at early ages of hydration up to 3 days.

5. Conflicts of interest

“There are no conflicts to declare”.

6. Acknowledgments

Praise and thanks be to **ALLAH,** the most merciful for assisting and directing me the right way

I would like to submit my gratitude, sincere thanks and appreciation to **Prof. Dr. Eisa El-Sayed Hekal,** Professor of physical chemistry and chemistry of building materials, Faculty of science, Ain Shams University, for suggesting the subject of this work, talented supervision and criticism, useful directions and valuable and fruitful discussion during all the steps of study.

‹I greatly appreciate **Prof. Dr. Wael Hussein Hegazy**, Professor of inorganic chemistry, Faculty of Science, Suez University for his deep concern in this work, brilliance and effort in guiding and encouraging for getting his always up towards success, continuous help and encouragement throughout the whole work.

‹My deepest gratitude and appreciation to **Dr. Rasha Mostafa Kamel**, Associate Professor of Analytical Chemistry, Faculty of Science, Suez University, for her kind help, continuous interest and fruitful discussion, support, direct supervision and valuable guidance throughout this work. And really thanks her excellency supporting me in different work aspects.

7.References

[1]-An, J.; Kim, J., and Nam B. H., (Sept.-Oct.2017) "Investigation on Impacts of Municipal Solid Waste Incineration Bottom Ash on Cement Hydration", ACI Materials Journal, 114(5).

[2]-Bosoaga, A.; Masek, O., and Oakey, J.E. (2009) " CO_2 capture technologies for cement industry" Energy procedia, 1(1), 133-140.

[3]-Chamurova, I.; Stanev, R., and Deliyski, N. (2017) "RDF as an Alternative fuel for the cement plants in Bulgaria" Journal of chemical technology and Metallurgy, 52(2), 355-361.

[4]-Chatziaras, N.; Psomopoulos, C.S. and Themelis, N.J. (2016) "Use of waste derived fuels in cement industry: a review"Management of Environmental Quality, An International Journal, 27(2), 178-193.

[5]-El-Didamony, H.; Moselhy and Ali (2011) "Utilization of an Industrial waste product in the preparation of low cost cement"Journal of American science, 7(9), 527-533.

[6]-Gendebien, A.; Leavens, A.; Blackmore, K.; Godley, A.; Lewin, K. and Whiting, K.J. (2003) Refuse Derived Fuel, current practice and perspectives final report; European commission.

[7]-Giddings, D.; Eastwick, C.N.; Pickering, S.J. and Simmons, K. (2000) "Computational fluid dynamics applied to a cement precalciner". Proc. Instn. Mech. Engrs. Vol. 214 Part A.

[8]-Halimehjani, E.Z.; Hajinezhad, A. and Tahani, M., (2016)" Utilization of Refuse Derived Fuel (RDF) from Urban Waste as an Alternative Fuel for Cement Factory: a Case Study", inter.J.of Renew. Energy Resh. 6(2),702-714.

[9]-Hashem, F.S.; Abd-El-Razek, T.A.M.; Selim, F. and Mashhout, H. (2018) " Characterization of various kinds of refused derived fuel and their effects on cement properties " Journal of Environmental science, 42(2), 59-83.

[10]-Hashem, F.S. and Mashhout, H.A. (2019) "Rubber and plastic wastes as alternative refused fuel in cement industry" Construction and Building Materials, 212, 275-282.

[11]-Junior, L.M. (2003) " Sustainable development and the cement and concrete industries" PhD thesis, universite de Sherbrooke,Quebec.

[12]-Madlool, N.A.; Saidura, R.; Hossaina, M.S. and Rahim, N.A. (2011) "A critical review on energy use and savings in the cement industries" Renewable and sustainable energy reviews, 15(4), 2042-2060.

[13]-Mokrzycki, E.; Uliasz-Bochenczyk, A. and Sarna, M. (2003) " Use of alternative fuels in the polish cement industry" Applied Energy, 74(1), 101-111.

[14]-Reza, B.; Soltani, A.; Ruparathna, R.; Sadiq, R.; and Hewage, K. (2013) "Environmental and economic aspects of production and utilization of RDF as alternative fuel in cement plants." A case study of Metro Vancouver Waste Management. Resour Conserv Recycl; 81:105-14.

[15]-Roy, G.R. (2002). Petcoke combustion characteristics. World Cement.

[16]-Singhi, M.K. and Bhargava, R., (2010) " Sustainable Indian cement industry" Workshop on International comparison of Industrial Energy Efficiency, New Delhi, 27-28 January.

[17]-Wirthwein, R and Emberger, B. (2010) " Burners for alternative fuels utilization: Optimization of kiln firing systems for advanced alternative fuel Co-firing " Cement International, 8(4), 42-46.

[18]-Zieri, W. and Ismail, I., (2018) "Alternative fuels from Waste Products in Cement Industry" Springer Inter Publishing AG L.M.T. Martinez et al.(eds.), Handbook of Ecomaterials.