8358

M. R. Ismail et al./ Elixir Appl. Chem. 46 (2012) 8358-8364

Studies on γ-irradiated polymer-nano calcined clay blended cement mortar composites

M. R. Ismail[a], H.A. Abdel-Rahman[a], M.M. Younes[a], E. Hamed[a] and S.H. El-Hamouly[b]

[a]Department of Radiation Chemistry, National Center for Radiation Research and Technology, Egyptian Atomic Energy Authority, Cairo, Egypt.

[b]Department of Chemistry, Faculty of Science, El-Menoufia University, Shebin El-Kom, Egypt.

ABSTRACT

This paper presents an experimental investigation on the effect of γ-irradiation dose, polyvinyl alcohol content and nano-calcined clay ratios of PVA-NCC-cement mortar composite. PVA-NCC-cement mortar composite was prepared by the addition of PVA on blended cement mortar with different percentages namely 2, 4, 6 and 8% by wt. of blended cement. The fresh composites were first cured at 100% relative humidity for 24 hours and then subjected to γ-irradiation dose namely 10, 20, 30 and 50 KGy. The irradiated composites were cured in water for 28 days. Physico-mechanical properties such as compressive strength, bulk density, total porosity and water absorption were tested according to standard specifications. XRD, SEM, TGA were carried out on some selected samples to evaluate the effect of different factors on crystallinity, microstructural and thermal behaviour of the composites. Results showed that, compressive strength and bulk density of the composites increased with increasing the absorbed dose and PVA contents for certain values and then decreased while, total porosity and water absorption behave in an opposite direction. XRD, SEM, TGA confirmed these conclusions.

Introduction

Blended cements based on industrial by-products pozzolanic materials like fly ash, calcined clay, granulated blast furnace slag are known for their improved long term strength and durability [1-3]. Metakaolin has been recently introduced as a highly active and effective pozzolan for the partial replacement of cement in concrete. It is an ultrafine material produced by the dehydroxylation of a kaolin precursor upon heating in the temperature range of 700-800 °C [4]. Research results have shown that the incorporation of metakaolin in concrete significantly enhances early strength [5]. Replacement of ordinary Portland cement by 6% exfoliated nano-metakaolin in cement mortar increases compressive strength by 18% compare to control mix [6]. The addition of carbon nano-tubes (up to 0.02%) to nano-metakaolin cement mortar improves the compressive strength of the composite. The improvement was 11% higher than that of blended cement mortar containing 6% nano-metakaolin but the addition of carbon nano-tube by 0.1% leads to a decrease in the compressive strength. The polymer modified cement mortars show good property in different aspects when a different polymer is used. The addition of PVA to cement paste has induced a number of changes. One means of strengthening the aggregate-paste bond is to add fine particles such as, silica fume [7, 8] and polymer dispersions [9-12]. These particles are able to fit between the cement grains and densify the porosity of the zone. These materials need to be used at the level of 10-20-% based on cement to be effective and at that rate, they can add considerably to the cost. The admixing of a small amount of water soluble polyvinyl alcohol (PVA) was recently reported to have doubled the pullout strength and friction of steel fibers in cement paste [13]. The microstructure

of the interfacial zone around steel fiber was found to have been considerably altered by PVA [14]. Previous work [15] has suggested that, the presence of PVA during the hydration of cement may increase the amount of calcium silicate hydrate (C-S-H) while, it decrease the amount of calcium hydroxide. When PVA is used however the PVA molecules are able to adsorb on the aggregates surface and this may prevent the growth of calcium hydroxide crystals on the surface possibly by inactivating crystal nucleation sites. The changes in the interfacial transition zone seem to have arisen from the tendency for PVA to retard flocculation of the cement grains and to increase the efficiency of deflocculation by shear and vibration because of the increased viscosity. The reduction in calcium hydroxide crystallization on the aggregate surface arose from the inhibition of nucleation of calcium hydroxide crystals by adsorbed PVA [16].

The aim of this work is to investigate the effect of γ-irradiation dose, PVA percentages and nano-calcined clay particles on the physico- mechanical, thermal stability mineralogical and structural properties of PVA-NCC-cement mortar composite.

Experimental

Materials

A freshly produced sample of ordinary Portland cement (OPC) obtained from National Cement Company (Egypt) was used. Nano-calcined clay (NCC) obtained by heating for 2 hrs at 750 °C with particle size 60.6 nm was also supplied by National Cement Company (Egypt). The oxide composition of OPC and NCC used in this investigation are shown in table (1). Polyvinyl alcohol (PVA) powder with particle size 0.0449µm, degree of polymerization (1700-1800), viscosity (25-32), hydrolysis (mole

%) (98-99), volatiles (max 5%) and PH value of water solution (5-7) was obtained from El-gomhoria Company (Egypt).

Preparation 0f PVA-NCC-cement mortar composite

Partially substitution of ordinary Portland cement with nano-calcined clay by ratios of 5 % and 10 %. PVA latex was added to the mixing water and PVA-NCC-cement mortar composites were prepared with sand/cement ratio of 3.0, water/cement mass ratio (w/c) of 0.45 and using different percentages of PVA namely 2, 4, 6 and 8% by wt. of cement. After thoroughly mixing of the mixture, the resulting mortar was moulded into cubic specimens by using cubic molds with dimensions 25 x 25 x 25 mm. the fresh samples were cured at 100% relative humidity for 24 hours. The cubic samples demolded after one day then subjected to various γ- irradiation doses namely 10, 20, 30 and 50 KGy under γ- rays from a cobalt- 60 source manufactured by the Atomic Energy Authority of India (dose rate 10 KGy/hr). After irradiation process the specimens were cured under tap water for 28 days. Physico-mechanical properties of the composites such compressive strength, bulk density, total porosity and water absorption were carried out using standard specifications.

X- ray diffraction (XRD)

The samples were examined by X- ray diffractometry (XRD) after curing for 28 days using powdered samples ground in porcelain and agate mortar. XRD were recorded on Shimadzu Corporation X- ray diffractometer, coupled with automatic data recording DP-DI system (ver.1.1), Tyoto, Japan. Cu Kα radiation was used during scanning, and patterns were recorded at a scanning speed of 8°/min.

Scanning electron microscopy (SEM)

The morphology and microstructure of some selected samples of PVA-NCC-cement mortar composites were studied using SEM technique. Surface fracture was covered with thin layer of gold. SEM micrographs were obtained with a JSM-5400 (Jeol/Japan).

Thermal gravimetric analysis (TGA)

The thermal decomposition behaviour of PVA-NCC-cement mortar composites were investigated by thermo- gravimetric analysis (TGA) using a TG-50-instrument from Shimadzu (Japan) at heating rate 10 °C/min.

Results and discussion

Compressive Strength

The effects of PVA percentages, γ- irradiation dose and NCC contents on the compressive strength of PVA-NCC-cement mortar composites are graphically shown in Figs (1, 2). The results indicate that, the compressive strength values of PVA-NCC-cement mortars samples increase with the increasing of γ-irradiation absorbed dose up to 30 KGy and then start to decrease with more absorbed dose. Also, the compressive strength values increase at lower PVA percentages (2-4%) and decrease with an excess of PVA percentages. It was also observed that, the compressive strength values decrease with a higher NCC content. These are attributed to the chemical reactions between the composite components during irradiation process. Some researchers have noted that when PVA was added, there was a decrease in the compressive strength of concrete due to the increase in air voids content [17]. Others, however, have found improvements of compressive strength and reduction of porosity when PVA was used with fly ash blended cement [18]. An important modification observed with the use of PVA in concrete was the significant increase in the bond strength between cement paste and the aggregates [16]. The

improvements in the compressive strength of PVA-NCC-cement mortar composites with using PVA from 2-4% may be attributed to the following (i) PVA was able to fill up the pores of the composites. (ii) Some chemical reaction may take place between PVA and calcium (Ca^{+2}), silica (SiO_2^{-2}) ions, $Ca(OH)_2$ and silicate surfaces, this leading to an improvement in the adherence between the PVA-NCC-cement mortar composite. The decrease of compressive strength of PVA-NCC-cement mortar composites after 4% of PVA addition is essentially related to the sealing effect of the PVA latex, which is associated with a reducing of the hydration cement process and consequently, the interaction between the composite components, also decreases and the compressive strength of PVA-NCC-cement mortar composite reduces as shown in the figures (1, 2).

It is well known that, the radiation of polymers include the degradation of the initial structures by scission and emission of atoms, molecules and molecular fragments [19, 20]. It generates a number of changed species, ions, free radicals and induce either scission or cross-linking or both. At any given PVA ratio, it is clearly seen that compressive strength of PVA-NCC-cement mortar composites improved as the absorbed dose of γ-irradiation increased up to 30 KGy as a result of the formation of number of changed species which are interacted with hydrated cement NCC materials during the irradiation process. The main reason of this behaviour may arise from the catalytic effect of NCC particles, Beeson et al [21] reported that the presence of the kaolin clay either in air or inert gas, was found to have a catalytic influence on the polymerization reaction of the polymer at 25°c and constant dose rate. Wang et al [22] found that clay components and their amorphous state were the two fundamental factors to govern the copolymerization rate of the copolymers onto clay, the majority of grafting was confirmed to occur on silica atom in the amorphous silicate in clay to form Si-C bond. Theng [23] reported that the amorphous minerals in clay particularly those of silicates, were found to be effective to radiation in situ graft copolymerization of vinyl monomer system and crosslinking of their graft copolymer. The amorphous aluminosilicate clay was also recognized as affecting an increase in the number of crosslinks to form a three dimension of copolymer network, resulting an enhancement of the mechanical strength. It was also observed that the rate of formation of polymer in the methyl methacrylate-kaolin clay system was faster when compared to a bulk methyl methacrylate system at the same dose rate. This behaviour showed that the clay had a catalytic effect on the formation of polymer [24]. Generally it can be observed that irradiated PVA-NCC-cement mortar composites showed higher values in compressive strength as compared to unirradiated PVA-NCC-cement mortar composites, this may be attributed to the presence of NCC particles distributed between the cement grains has a higher ability to retain PVA molecules on its surface.

During the irradiation process, PVA molecules transfer to a changed free radicals species, which reacted with the silicon atom to form Si-C bond on the surface of the NCC particles. At the same time free radicals species reacted with the hydrated cement components such calcium silicate hydrated (C-S-H) and $Ca(OH)_2$ formed during hydration process of cement grains. Finally, these reactions lead to the formation of crosslinking-network structure in the composite, the fast and numbers of crosslinks are essentially related to the presence of NCC

particles during the γ-irradiation process as a result their catalytic effect.

The compressive strength of irradiated PVA-NCC-cement mortar composites was found to be decreased with increasing γ-irradiation dose after 30 KGy, this is mainly due to the degradation process of irradiated PVA latex during irradiation process for all the composites. These are leading to a weak bonding between the constituents of the composites consequently, the interfacial adhesion forces between the composites components also reduced. These are associated with reducing in the compressive of the irradiated PVA-NCC-cement mortar composites at higher irradiation dose.

On comparing results obtained at 4% of PVA latex and 30 KGy of irradiated dose in fig (1) and fig (2), it is clearly seen that the compressive strength of PVA-NCC-cement mortar composites containing 5% of NCC were 320 Kg/cm^2 for curing age 28 days, while its values for composites containing 10% NCC prepared at the same condition were 240 Kg/cm^2 for curing age 28 days. This behaviour is directly related to the effect of amount of NCC on the hydration process of cement particles in the composites. At 10% of NCC, the NCC particles are distributed between the cement grains; this is accompanied with retarding of the water molecules to contact with cement grains, leading to reduction of hydration rate of cement grains and compressive strength values of composites also reduced.

Bulk Density, Total Porosity and Water Absorption

Figs (3, 4) demonstrate the influence of γ-irradiation dose on the bulk density of irradiated PVA-NCC-cement mortar composites containing different percentages of PVA latex as well as NCC ratios. The results indicate that, the bulk density increases with increasing the absorbed dose up to 30 KGy, then starts to decrease beyond this dose. It is also observed that the bulk density values of PVA-NCC-cement mortar composites containing 4% of PVA latex have higher values for all irradiation doses as well as different NCC ratios.

These are mainly attributed to chemical reactions between the composite constituents during irradiation process. The bulk density is directly governed by the solid part precipitated in the pore system of the composites. When the prepared PVA-NCC-cement mortar composites subjected to γ-irradiation, the chemical reaction between the composite constituents took place, as a result the effect of nano-calcined clay particles (catalytic effect), solid part of reaction products deposited in the pore system of the composite. With increasing irradiation dose more of reaction products precipitate in the spaces of the composites and the bulk density also improved. At higher irradiation dose and NCC contents, a slightly decrease in the bulk density is observed for the same reasons mentioned before.

Figs (5, 6) show the variation of the total porosity of PVA-NCC-cement mortar composites as a function of irradiation dose when using 5% and 10% NCC. The results display that, the total porosity of PVA-NCC-cement mortar composites decreases with increasing the irradiation dose up to 30 KGy, then starts to increase with higher irradiation dose. The total porosity of PVA-NCC-cement mortar composites containing 5% of NCC were higher than those containing 10% of NCC and also the optimum values of total porosity have been obtained for the composites with using 4% of PVA latex. This behaviour is essentially dependent on the volume of solid part precipitated in the pores system of the composites as a result of the chemical reaction between composites components during the irradiation process. The reduction in porosity may be due to filling of pore space

with hydration products. Singh et al [18] studied the effect of 3.0% PVA on the hydration of ordinary Portland cement in the presence and absence of 10% rice husk ash (RHA) by employing different techniques. The results have shown that PVA increases the strength and decreases the porosity. The increase in strength is due to the interaction of PVA with cement, forming some new compounds that fill the pores or improve the bond between the composites. Polymer modifies the pore structure of mortar or concrete by producing a polymer film to fill the capillary pores left by the mixing water [25]. Accordingly, with increasing PVA up to 4% and irradiation dose of γ-irradiation up to 30 KGy lead to an increase of polymer filling or sealing effect of PVA as a result of the catalytic effect of NCC particles, thus the total porosity of PVA-NCC-cement mortar composite reduces. The increase of total porosity of the composites after 4% of PVA and 30 KGy of γ-irradiation as well as higher content of NCC are attributed to a more voids and micro-cracks inside the composites also the degradation process which is taken place at high absorbed dose of γ-irradiation and the amount of water in the PVA latex, which causes a large voids and cracks inside the samples after dried.

The variations in water absorption percentages of PVA-NCC-cement mortar composites using different ratios of PVA latex as well as various content of NCC particles and irradiated at different absorbed dose of γ-irradiation are graphically represented in figs (7, 8). The experimental data in these figures show that, water absorption percentages decrease with increasing absorbed dose up to 30 KGy and then start to increase with higher absorbed dose more than 30 KGy, also 4% of PVA latex and 5% NCC particles give the lower values of water absorption as compared to the composites containing 10% NCC particles and other ratios of PVA latex. This behaviour is mainly related to the reduction in the pores and microcraks volumes of the composites resulting in the deposition of chemical reaction products during the irradiation process. It was also observed that, water absorption of irradiated composites prepared at the same condition and cured for 28 days are reduced by 13.7, 17.6% for 28 days as compared to unirradiated composites prepared at the same conditions. These reductions in water absorption percentages of PVA-NCC-cement mortar composites are essentially dependent upon the chemical reaction between PVA molecules or atoms and hydrated cement during irradiation process in the presence of active clay (as catalytic), which precipitated in the pores system consequently, the diffusion of water inside the composites also reduced. Unexpected results obtained at 10% of NCC particles in water absorption percentages of irradiated composites may be attributed to the presence of excess of fine NCC particles distributed around the cement grains and fill a part of pore system and decrease the diffusion of water inside the composites.

X-ray Diffraction (XRD)

The XRD patterns of hydrated blended cement mortar, unirradiated PVA-NCC-cement mortar and irradiated at 30 KGy of PVA-NCC-cement mortar composites containing 5 and 10% of NCC particles are shown in figs 9 and 10 respectively. XRD results show an important peaks of $Ca(OH)_2$ around 18.1, 34.2 and 47.1 (2Θ). It has been reported that, the peak intensity in the region of 2Θ=18.1° considered as a measurement of the intensity of $Ca(OH)_2$ for the comparison between the samples [26]. It can clearly seen that the lowest intensity of $Ca(OH)_2$ peak around 2Θ=18.1° for the irradiated PVA-NCC-cement mortar composite, this may be attributed to chemical reactions between

the composite constituents during irradiation process as shown in figs (9, 10) and consumption of hydrated $Ca(OH)_2$ through these reactions. The $Ca(OH)_2$ content of hardened blended cement pastes decreased as the pozzolan content increased for a given age of hydration [27]. Accordingly, a slightly decrease in the intensity of $Ca(OH)_2$ peaks of the samples containing 10% of NCC as compared to its intensity for the samples containing 5% of NCC particles. The higher reduction of $Ca(OH)_2$ peak for irradiated PVA-NCC-cement mortar composite is confirmed by physico-mechanical properties data obtained before.

Scanning electron microscopy (SEM)

Fig. (11) shows the microstructural characterizations of unirradiated and irradiated PVA-NCC-cement mortar composites containing 5 and 10% NCC particles irradiated at 30 KGy. SEM micrographs of unirradiated PVA-NCC-cement mortar composite containing 5% of NCC particles shows PVA film formed around CSH and CH crystals, it seems that the PVA film may act both as an adhesive and reinforcement of the porous interface layer (fig. 11a). Due to the catalytic effect of NCC particles during the irradiation process, the irradiated PVA-NCC-cement film was generally covered by thin layers of CH and clusters of needle-like CSH particles were also observed as shown in fig. (11b). it have been reported that [28], the latex-cement surface was also covered by a layer containing CH and CSH. Numerous large of CH crystals (5-10 μm) and plate-like CH crystals (10-100 μm) were found on PVA and AVA-cement surface respectively. Also, the irradiated composite show a dense and compact structure as compared to unirradiated composite. The microstructural features of unirradiated and irradiated PVA-NCC-cement mortar composites containing 10% of NCC particles are shown in fig. (11 c and d), these figures displayed a lower amount of CH crystals and needle-like CSH particles and large amounts of holes and voids also appeared. Irradiated PVA-NCC-cement mortar containing 10% NCC particles has lower holes and voids as compared to unirradiated composite prepared under the same conditions.

Thermogravimetric analysis (TGA)

Thermal analysis is the term used to identify a group of methods and techniques in which a physical property of a substance is measured as a function of temperature. Thermogravimetric (TG) and derivative thermogravimertry (DTG) have proven to be an invaluable tool for evaluating the nature of hydration products according to different stages of cement hydration, as well as to quantify the different phases [29-31]. Figs (12-15) show the Thermogravimetric (TG) and derivative thermogravimertry (DTG) of NCC-cement mortar (blank), unirradiated and irradiated PVA-NCC-cement mortar composites containing 5 and 10% of NCC particles. As seem in the figures, there is no significantly difference between the behaviour of NCC-cement mortar containing 5% of NCC particles and NCC-cement mortar samples containing 10% of NCC particles. In these two samples free water will evaporate lowering the mass of samples as temperature raised from room temperature to about 100°C. The samples will also lose some of water bound in hydration products, particularly some of water in the alumina hydrates. Between about 100 °C and 400 °C water bound in hydration products, primarily the C-S-H gel will be lost, together with the remainder of water in the aluminate hydrate. Between about 400 °C and 550 °C, calcium hydroxide provides relatively weight loss as it decomposes to calcium oxide (solid) and water vapor. Above 550°C a small amount of additional water may be lost from hydration products.

Carbonated phases lost carbon dioxide around 800 °C as shown in figs (12, 14).

A similar behaviour has been obtained in thermograph curves of unirradiated and irradiated PVA-NCC-cement mortar composites containing 5% and 10% of NCC particles, as seem in the figures (12, 14), there is evidence that the presence of PVA latex interferes with the behaviour of the residual weight of the PVA-NCC-cement mortar composites as compared to NCC-cement mortar (blank). TGA of unirradiated and irradiated PVA-NCC-cement mortar composites show that, the weight loss that emerges around 100 °C is a consequence of losing physically absorbed moisture. The thermal degradation of composites mainly consist of two steps, the first one appears in the range between 250-430 °C, the dominate processes during this degradation stage are elimination of OH groups and chain-scission reaction [32]. During the second degradation step that occurs between 450 and 550 °C depend on the particles shape, chain-scission reaction and reaction of Diels-Alder intramolecular and intermolecular cyclization prevailed [33, 34]. Between 550 °C and 800 °C shows the weight loss of the composites as a result of the decarbonation of $CaCO_3$. It was also observed that, the remaining weight of unirradiated and irradiated PVA-NCC-cement mortar composites are lower as compared to blank sample.

DTG curves of NCC-cement mortar (blank) and PVA-NCC-cement mortar composites before and after irradiation containing 5 and 10% of NCC particles are shown in figs (13) and (15) respectively. In these figures, it can be seen that the rate of thermal decomposition of NCC-cement mortar containing 5% of NCC located at 350, 550 and 650 °C while, the maximum rate of thermal decomposition of NCC-cement mortar containing 10% lied at 330, 540 and 635 °C that means the maximum rate of thermal decomposition of NCC-cement mortar containing 5% of NCC shifted to higher temperature as compared to the maximum rate of thermal decomposition of NCC-cement mortar containing 10% NCC particles, i.e. the samples containing 5% NCC are more thermally stable as compared to the samples containing 10% NCC. The maximum rate of thermal decomposition of unirradiated PVA-NCC-cement mortar composites located at 350, 430 and 620 °C, but for irradiated one displayed at 360, 450 and 640 °C, for the composites containing 5% of NCC particle (fig 13). Also the maximum rate of thermal decomposition of PVA-NCC-cement mortar composites containing 10% of NCC particles lied at temperature 380 °C and 650 °C while, for irradiated composites at temperature 380 °C and 660 °C. Based on these observation, it can be seen that the irradiated PVA-NCC-cement mortar composites is thermally stable as compared to the unirradiated one. These conclusions are in good agreement with the physico-mechanical properties.
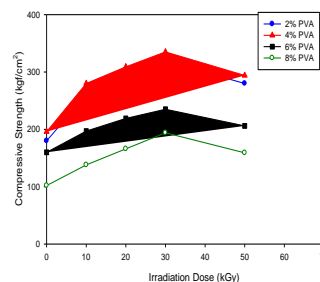

Fig (1) Effect of γ - irradiation dose on compressive strength of polyvinyl alcohol modified mortar containing 5% nano-calcined clay cured for 28 days.
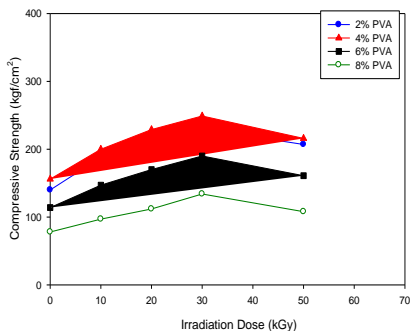
Fig (2) Effect of γ - irradiation dose on compressive strength of polyvinyl alcohol modified mortar containing 10% nano-calcined clay cured for 28 days.
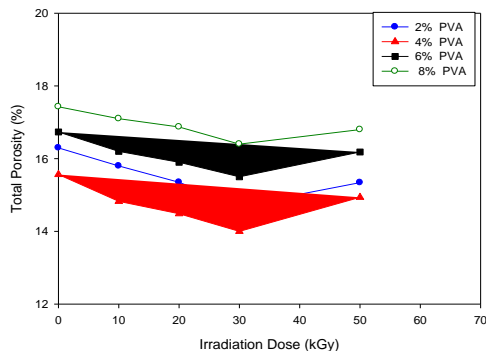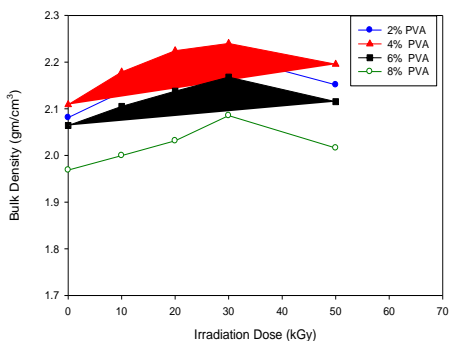

Fig (3) Effect of γ - irradiation dose on bulk density of polyvinyl alcohol modified mortar containing 5% nano-calcined clay cured for 28 days.
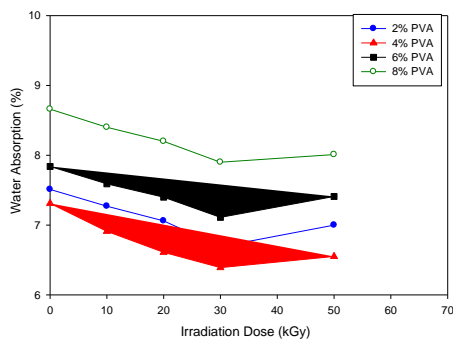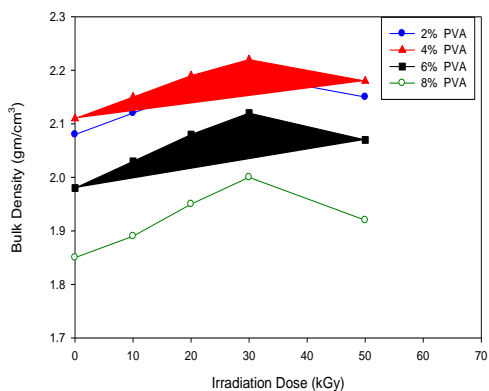

Fig (4) Effect of γ - irradiation dose on bulk density of polyvinyl alcohol modified mortar containing 10% nano-calcined clay cured for 28 days.
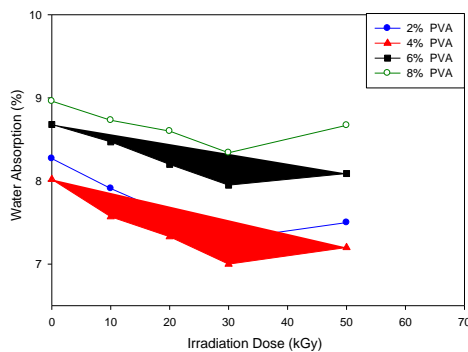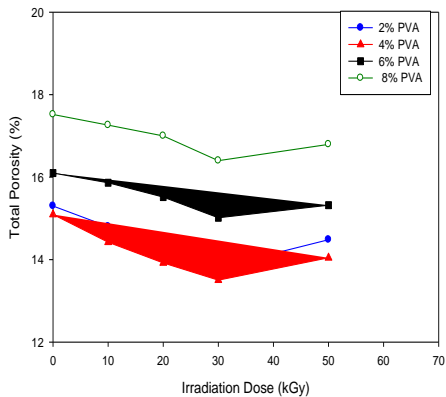

Fig (5) Effect of γ - irradiation dose on total porosity (%) of polyvinyl alcohol modified mortar containing 5% nano-calcined clay cured for 28 days.

Fig (6) Effect of γ - irradiation dose on total porosity (%) of polyvinyl alcohol modified mortar containing 10% nano-calcined clay cured for 28 days.

Fig (7) Effect of γ - irradiation dose on water absorption (%) of polyvinyl alcohol modified mortar containing 5% nano-calcined clay cured for 28 days.

Fig (8) Effect of γ - irradiation dose on water absorption (%) of polyvinyl alcohol modified mortar containing 10% nano-calcined clay cured for 28 days.
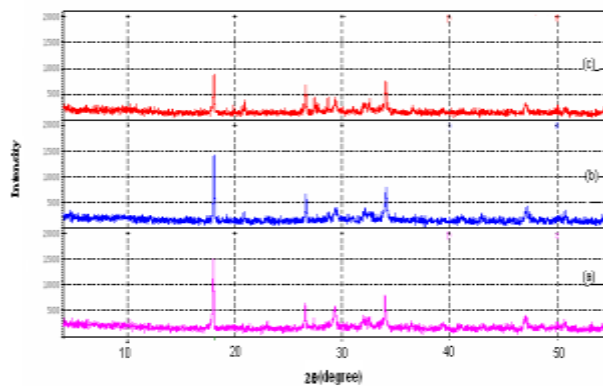

Fig (9) : X-ray diffraction for (a) mortar containing 5% nano-calcined clay (b) unirradiated PVA modified mortar containing 5% nano-calcined clay (c) irradiated PVA modified mortar containing 5% nano-calcined clay at 30 KGy.
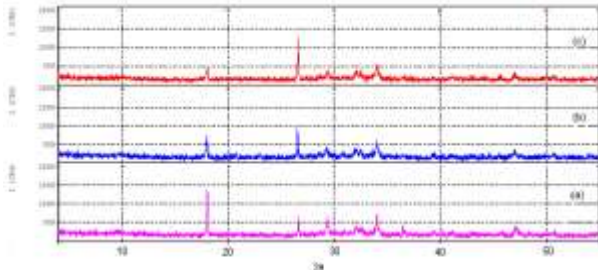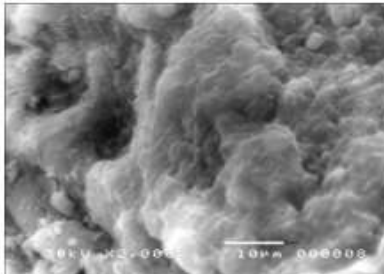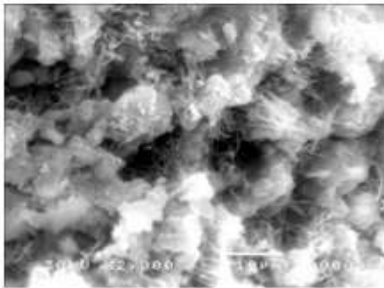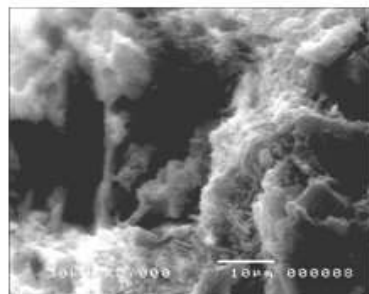
Fig. (10)X -ray diffraction for (a) mortar containing 10% nano-calcined clay (b) unirradiated PVA modified mortar containing 10% nano-calcined clay (c) irradiated PVA modified mortar containing 10% nano-calcined clay.
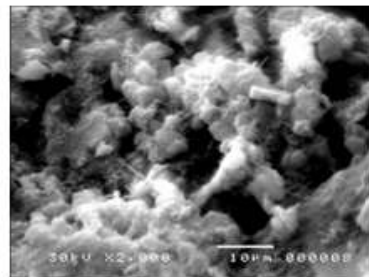

(a)

(b)

(c)

(d)

Fig. (11): Scanning electron microscopy micrographs for (a) unirradiated PVA modified mortar containing 5% nano-calcined clay(b) irradiated PVA modified mortar containing 5% nano- calcined clay (c)) unirradiated PVA modified mortar containing 10% nano- calcined clay (d) irradiated PVA modified mortar containing 10% nano-calcined clay.
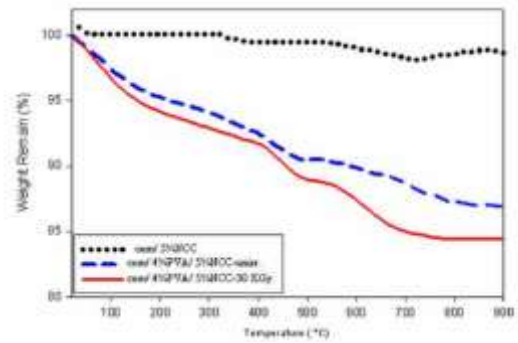

Fig (12): TGA thermograms for a) blended cement mortar containing 5% NCC b) unirradiated PVA modified mortar containing 5% NCC c) irradiated PVA modified mortar containing 5% NCC at 30 KGy.
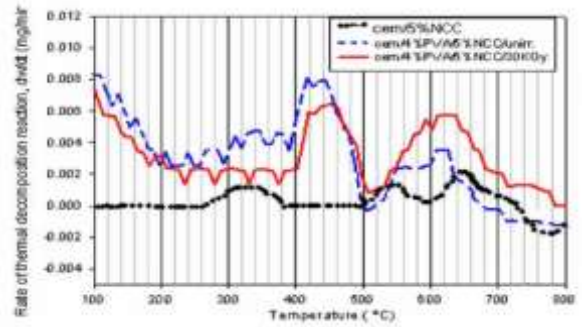

Fig (13): DTG for a) mortar containing 5% NCC b) unirradiated PVA modified mortar containing 5% NCC c) irradiated PVA modified mortar containing 5% NCC at 30 KGy.
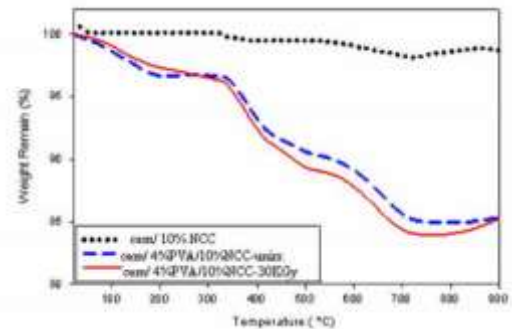

Fig (14): TGA thermograms for a) mortar containing 10% NCC b) unirradiated PVA modified mortar containing 10% NCC c) irradiated PVA modified mortar containing 10% NCC at 30 KGy.
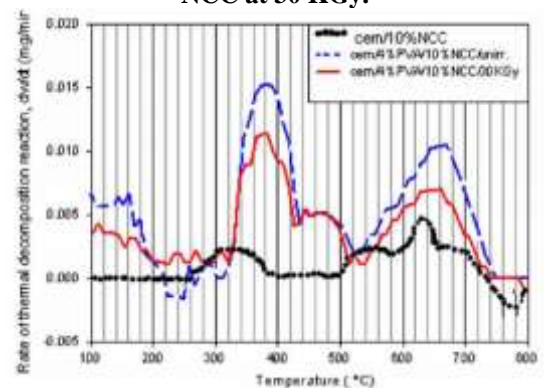

Fig (15): DTG for a) mortar containing 10% NCC b) unirradiated PVA modified mortar containing 10% NCC c) irradiated PVA modified mortar containing 10% NCC at 30 KGy.

Conclusions

Based on the experimental data obtained in the present study, the conclusions can be summarized as follow:-

• Compressive strength and bulk density of PVA-NCC-cement mortar samples increase with increasing the absorbed dose and PVA content at certain values and then decrease with a higher irradiation dose and PVA content.

• Compressive strength and bulk density of irradiated composites are higher than the blank specimens prepared under the same conditions.

• Total porosity and water absorption percentages decrease with an increase the absorbed irradiation dose as well as PVA content, also its values are higher as compared to blank samples, these due to deposition of solid materials in the pore system of the composites.

• XRD, SEM and TGA observations confirmed that, chemical reactions between the composite components took place with application of γ- irradiation.

References

[1] Pandey SP, Singh AK, Sharma RL , Tiwari AK. Studies on high performance blended / multiblended cements and their durability characteristics. Cem Conc Res 2003;23:1433-46.

[2] Chakchour A, Samet B, Mnil T. Study on potential uses of Tunisian clay as pozzolanic material. Appl Clay Sci 2006;33:79-88.

[3] Samet B, Chabeuni M. Characterization of the Tunisian blast furnace slag and its application in the formulation of cement. Cem Conc Res 2004;34:1153-59.

[4] Klimesh DS, Ray A. Autoclaved cement-quartz pastes with metakaolin addition. Adv Cem based Mater 1998;7:109-118.

[5] Wild S, Khatib YM, Jones A. Relative strength, pozzolanic activity and cement hydration in superplasticised metakaolin concrete. Cem Conc Res 1994;26:1537-44.

[6] Morsy MS, Alsayed SH, Aqel M. Hybrid effect of carbon nanotube and nano-clay on physico-mechanical properties of cement mortar. Constr and Build Mater 2011;25:145–49.

[7] Mehta PK, Monterio PJM. Cement structure, properties and materials. Second Edition. Prentice Hall: Englewood Cliffs: NJ ;1993.

[8] Mitsui K, Li Z, Lange DA, Shah SP. ACI Mater J 1994;30:91-144.

[9] Zivica V, Bulletin RIEM. 1965;28:121.

[10] Hosek JJ, Am Concr Inst 1966;1411:62-3.

[11] Su Z, Bigen JM , Larbi JA. Cem Conc Res 1991;12:727.

[12] Ohama Y. Handbook of polymer-modified concrete and mortars. Noyes Publication: Park Ridge: NJ ;1995.

[13] Najm H, Naaman AE, Chu TJ, Robertson RE. Adv Cem Based Mater 1994;1:15.

[14] Chu TJ, Robertson RE, Najm H, NaamanAE. Adv Cem Based Mater 1994;1:122.

[15] Kim J, Robertson RE, Chu TJ. unpublished manuscript.

[16] Kim J, Robertson RE. Effects of PVA on aggregate-paste bond strength and the interfacial transition zone. Adv Cem Based Mater 1998;8: 66-76.

[17] Santos RS, Rodrigues FA, Segre N, Joekes I. Macro-defect free cements Influence of poly vinyl alcohol, cement type, and silica fume. Cem Conc Res 1999; 29:747-51.

[18] Singh NB, Rai S. Effect of polyvinyl alcohol on the hydration of cement with rice husk ash. Cem Conc Res 2001; 31:239-43.

[19] Muzeodi P, Arnold G. Ion beam modification of insulators. Elseiver, Amsterdam;1987.

[20] Ichikawa T, Yoshida H. Mechanism of radiation-induced degradation of poly (methyl methacrylate) as studied by ESR and electron spin echo methods. J of Polym Sci 1990;28:1185-96.

[21] Beeson JJ, Mayhan KG. Characterization of poly(methyl methacrylate) from radiation-induced polymerization in the presence of a kaolin clay substrate. Appl Poly Sci 1972;16:2777–94.

[22] Ung-Ping Wang. Clay plastic composite prepared by gamma-radiation. Radiat Phys Chem 1981;18:1167-84.

[23] Theng BKJ. The Chemistry of Clay-Organic Reactions. John Wiley and Sons ;1974.

[24] Beeson JJ, Mayhan KG. Kinetic analysis of the radiation polymerization of methyl methacrylate–kaolin clay composites. Appl Poly Sci 1972;16:2765-75.

[25] Chandra S. Polymer cement composite, Acritical review, Engineering Foundation Conference. July 24-29, New York: American Society of Civil Engineers; 1994, 15-36.

[26] MUK, Afridi, Ohama Y, Zafar IQBAL, Demura K. Behaviour of $Ca(OH)_2$ in polymer modified mortar. Inter J of Cem Comp and Lightweight Conc 1989;11:235-44.

[27] Turanli L, Uzal B, Bektas F. Effect of large amounts of natural pozzolan addition on properties of blended cements. Cem Concr Res 2005;35:1106– 11.

[28] Nakayama JJ, Beaudoin JJ. Bond strength development between latex-modified cement paste and steel. Cem Conc Res 1987;17:562-72.

[29] Chandra S, Flodin P. Interactions of polymers and organic admixtures on Portland cement hydration. Cem Concr Res 1987;17:875-90.

[30] Dweck J, Buchler P, Coelho A, Cartledge F. Hydration of a Portland cement blended with calcium carbonate. Thermochimica Acta 2000;346:105–13.

[31] Tsivilis S, Kakali G, Chaniotakis E, SouvaridouA. A study on the hydration of Portland limestone cement by means of TG. J of Thermal Analysis 1998;52:863-70.

[32] Gilman JW, Vanderhart DL, Kashiwagi T. Acs Symp Ser 1994;599:161.

[33] Peng Z, Kong LX. A thermal degradation mechanism of polyvinyl alcohol/silica nanocomposites. Polym Degrad Stab 2007;92:1061-71.

[34] Krklješ AN, Marinović-Cincović MT, Kačarević-Popović ZM Nedeljković JM. Dynamic thermogravimetric degradation of gamma radiolytically synthesized Ag–PVA nanocomposites. Thermochimica Acta 2007;460:28-34.