Effect of Fine Materials in Local Quarry Dusts of Limestone and Basalt on the Properties of Portland Cement Pastes and Mortars

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***ABSTRACT*- Quarry dust (QD) is one of the materials that have recently gained attention to used as concreting aggregates or as a replacement of cement. These dusts are composed by particles which pass 75 µm BS sieves. Effect of fine materials content in aggregates on properties of pastes and mortars of Portland cement are not known very well. An experimental study was undertaken to find out the effects of various properties of dust content on properties of pastes and mortars. Different pastes, mortars were prepared with different quarry dust (Limestone, and Basalt dust) contents 4, 8, 12 and *16* mass, %. In cement pastes preparation, QDs were used as cement replacement materials. But, in mortars preparations, QDs were used as a replacement of fine aggregates.**

Key words: basalt dust, limestone dust, paste, mortar, Portland cement

I. INTRODUCTION:-

Quarry dust (QD), is a byproduct from the crushing process during quarrying activities. It is one of the materials that have recently gained attention to be used as concreting aggregates, especially as fine aggregates (FAs). QD consists of excess fines and is considered as a waste material which is normally dumped in bulk quantities around the quarry plants and causes environmental pollution. QD has been used successfully in concrete and in controlled low-strength material **[1-3].** Quarry dust has been used for different activities in the construction industry such as road construction and manufacture of building materials such as light weight aggregates, bricks, and tiles **[4]**.The need to develop concrete with non-conventional aggregates is urgent for environmental as well as economic reasons. Additives are used to improve the workability, mechanical properties, durability and economy of concrete. A review of earlier research showed that, industrial as well as other wastes have been used in concrete-making to improve the properties of concrete and to reduce cost **[5]**. The additives used are basalt dusts investigated for their properties previously **[6]**. Abrasion resistance of concrete, which is largely dependent on the hardness of the aggregate used, is of crucial importance in pavements, floors and hydraulic structures such as tunnels and dam spillways. Compressive and tensile strengths are other vital factors controlling the abrasion resistance of concrete **[7]**. Presently large amounts of quarry dusts such as basalt, marble, granite and lime stone are generated in natural stone processing plants with an important impact on both environment and humans. The marble and granite stones processing is one of the most thriving industries. The effect of marble dust content on the physical and mechanical properties of fresh and hardened concrete was studied **[8].** This industrial byproduct up to 10, mass % is capable of improving hardened concrete performance.

Many previous researches **[9-19]** on the effect of inclusion of limestone fines (LSF) as either sand or cement replacements on fresh and hardened mortar and concrete have been developed. They concluded that, the inclusion of 12 to 18% of fines could be allowed in sand without harmful effects on the physical and mechanical properties of mortar and concrete. However, not much work is reported regarding the effect of LSF on the durability properties of crushed sand concrete **[20]**. A large amount of material in the size of mineral filler is produced during the course of crushing. The weak limestone (LS), in particular, which may well, be used as aggregate. If the fine materials are not of a clay type, their applications are beneficial to improving concrete composition **[21]**. The extent of improvement in concrete properties with different amounts of mineral filler was studied **[22]**. It was reported that, the low cohesion of the weak concrete compositions produced by using the crushed calcareous aggregate lead to some problems. It is

not always possible to place and compress the concrete on grounds of the difficulty confronted in the workability. The European standard for aggregates **[23]** allows four levels of fine content in fine aggregate (3, 10, 16, and 22 mass, %). If the fine content exceeds 3 mass, % it's harmfulness must be assessed using methods that determine the presence of clay in the fines. Additionally, specific limits can be established at different locations within the European community, according to local conditions. The authors of the standards realize that, in the case of manufactured sand, it is difficult to produce sand with very low fine content, although its effect on concrete is critical. Therefore, somewhat higher amounts of fines are allowed in manufactured sand, as long as it is free from clay. ASTM C33 limits the fines content to 7, mass % (mild condition) or 5, mass % (severe condition), the excess fines must normally be removed. One of the highest priorities of the aggregate industry is to find uses for the material passing the No. 200 (75 μm) sieve, but it is with user's intent to more effectively use these materials, especially when they are capable initially of producing high quality concrete **[24]**. Basalt is one of igneous rocks, which are formed during the cooling and recrystallization of magma. Most of igneous minerals are present in active states, which are changed under environment conditions to more stable clay minerals. The pozzolanic activity of fresh basalt was studied and it was concluded that, basalt has slightly pozzolanic at early ages and increases with the time. Limestone dust (LD) is an important material for cement manufacture. The addition of LD to Portland cement may significantly improve several cement properties such as compressive strength, water demand, workability durability and can also decrease the production costs of cement. There is evidence that, the influence of LD on concrete properties depends on C_3A content of cement clinker, because $CaCO_3$ in LD reacts with C_3A to produce mono carboaluminate hydrate (AFm), which has moderate binding properties. It causes a better packing of cement specimens. In addition, the amount of LD increases the heat of hydration and decrease the total porosity of cement specimens. Limestone dust (LD) is an important material for cement manufacture. The addition of LD to Portland cement may significantly improve several cement properties such as compressive strength, water demand, workability, durability **[25-30]**, and can also decrease production costs. The effects of small LD additions on both compressive strength and heat of hydration are relatively well known. There is evidence that, the influence of LD depends on C_3A content of clinker, because $CaCO_3$ produces calcium carboaluminate hydrate during the reaction with C_3A **[31]**. In France, because of its low price and wide availability, limestone powder (LSP) is being increasingly used. The specifications of European standard EN 206-1 **[32]** show that, the maximum mass of LSP in a concrete design can reach 33 mass, % of the cement. Although the publication of standard EN 206-1, many designs of self-consolidating concrete (SCC) reported in the literature include more than this limit quantity (43 up to 65 mass, %) **[33]**. In general, limestone fillers are incorporated for completing the granulometric distribution of cement decreasing the water demand, to enhance its granular packing factor and to block up capillary pores. Moreover, filler particles improve the hydration rate of cement compounds and consequently increase the strength at early ages. From a chemical point of view, limestone filler does not have pozzolanic properties, but it reacts with the alumina phases of cement to form an AFm phase (calcium monocarboaluminate hydrate) with significant changes in the strength of blended cement. The main effects of limestone filler are of physical nature. It causes a better packing of cement granular skeleton and a large dispersion of cement grains. In addition, the amount of limestone increase the heat of hydration and the free lime contents enhance slightly. On the other hand, the total porosity decreases and the compressive strength enhances at early age **[34]**. Some researchers **[35-45]** studied the effect of inclusion of LD as either sand or cement replacements on fresh and hardened concrete. They concluded that, the inclusion of 12 to 18 mass, % of fines could be allowed in sand without harmful effects on the physical and mechanical properties of concrete. However, not much work is reported regarding the effect of LD on the durability properties of crushed sand concrete **[46]**. It was demonstrated that **[47]**, increasing the fines content of the fine aggregate can produce concrete of desirable workability and strength. Thus, it can be reasoned that, higher fine contents are desirable and should be encouraged in PCC mixes containing manufactured sand **[48].** The effects of various percentages of basalt and limestone dusts (BD & LD) in the range from 0 to 20.5% of each on the compressive and flexural strengths of blended cement at different curing ages (1, 3, 7, 28 and 90 days) were studied. It was concluded that, LD enhances the hydration reaction of cement clinker phases at the early hydration ages, while BD improves the strength properties at later ages **[49]**. Marble powder (MP), which is an inert material obtained as an industrial byproduct during sawing, shaping, and polishing of marble has been used successfully as an additive in self-compacting mortar and concrete (SCM, SCC). MP is used as mineral additive of cement to improve some properties of fresh and hardened concrete **[50]**.

Objective of the Research-The main objective of this work aimed to study the effect of fine materials in coarse aggregates on the properties of Portland cement (PC). Therefore, three local quarry dusts of limestone and basalt were used. Different pastes and mortars were prepared with different QD contents (4, 8, 12 and 16 mass, %). In cement pastes preparation, QDs were used as cement

replacement materials. But, in mortars preparations, QDs were used as a replacement of fine aggregates. The physico-mechanical characteristic of the blended mixes (QD-modified cement mixes) as well as the control mixes (PC) were studied by measuring the compressive, flexural strengths. To identify the hydration products at different curing times, QD types and QD contents, some selected samples were analyzed using XRD, DTA and SEM techniques.

II. MATERIALS

A. Cement

The cement used in this study was the ASTM type (I) Portland cement (PC cem I 42.5N). The Blain surface area of PC was 3000±50 cm^2/g. It's chemical oxide analysis obtained by X-ray fluorescence spectrometry is given in Table (1). The mineralogical composition of PC is listed in Table (2).

B. Quarry dusts (QDs)

The QDs used were limestone (Dolomite) and basalt dusts. The particles of aggregate dusts passed through 75 µm sieve. Their chemical analyses are given in Table (1). The salts content for chlorides and sulphates were determined for coarse aggregates (limestone (Dolomite) and basalt) according to BS 812: part 117, 118 respectively and the results shown in Table (4).

C. Fine aggregate

Sand was used as fine aggregate with fineness modulus of 2.81. It's sieve analysis is shown in Table (3). The results of sieve analysis are in accordance with the British standard (BS.882:1992). The salts content for chlorides and sulphates were determined for sand according to BS 812: part 117, 118 respectively. And the results have shown in Table (4).

III. METHODS AND EXPERIMENTS

A. Preparation of cement pastes

It is known that fresh pastes were first carried out to assess the effect of fine materials in aggregates (basalt, and limestone) on the water of standard consistency (W/C, %) and setting times. The paste with total powder (i.e., cement + fine materials) , the fine materials powder (basalt, and limestone) were used to replace 4, 8, 12 and 16 mass, % of Portland cement. The terminology for cement pastes containing fine aggregate dusts is given in Table (5). The required water of standard consistency and setting times were measured according to ASTM C191 specification **[51]**.

B. Preparation of cement mortars

The mortars were prepared by mixing 1 part of cement and 3 parts of standard sand (by weight) with water content sufficient to obtain a flow of 110 ± 5mm with 25 drops of the flowing. The fresh mortars were moulded into 70.6 mm cubes and 40 x 40 x160 mm prisms for compression and flexural tests. The specimens were cured under water until the time of testing for 3, 7, 14, 28 and 90 days.

C. Compressive and flexural strength tests

The strength properties (compressive and flexural) of hardened mortars were measured for compressive according to ASTM (Designation: C-150, 2007) **[52]**, a set of three cubes and prismes of the same composition and age was tested on a compressive strength machine of SEIDNER, Riedinger, Germany, with maximum capacity of 2000 KN force (Fig. 1).

A total of 9 mortar mixtures were prepared. The first is the control (M_0), the remaining eight mortars contain different dusts as sand replacement materials in percentages of 4, 8, 12, and 16 mass, %. The terminology for cement mortars containing fine aggregate dusts is given in Table (5).

D. XRD technique

For XRD, a Philips diffractometer PW 1730 with X-ray source of Cu kα radiation (λ=1.5418Å) was used (Fig.2). The scan step size was 2θ in the range from 5 to 65^o at collection time 1s. The X-ray tube voltage and current were fixed at 40 KV and 40 mA respectively. An on-line search of a standard database (JCPDS database) for X-ray powder diffraction pattern enables phase identification for a large variety of crystalline phases in a sample **[53]**. Some selected mortars are tested after different curing ages by XRD technique. X-ray diffraction is based on constructive interference of monochromatic X-rays and a crystalline sample. These X-rays are generated by a cathode ray tube, filtered to produce monochromatic radiation, collimated to concentrate, and directed toward the sample. The interaction of the incident rays with the sample produces constructive interference (and a diffracted ray) when conditions satisfy Bragg's Law ($n\lambda=2d \sin\theta$) where *n* is an integer, λ is the wavelength of the X-rays, d is the interplanar spacing generating the diffraction and θ is the diffraction angle. λ and d are measured in the same units, usually angstroms. This law relates the wavelength of electromagnetic radiation to the diffraction angle and the lattice spacing in a crystalline sample. These diffracted X-rays are then detected, processed and counted. By scanning the sample through a range of 2θ angles, all possible diffraction directions of the lattice should be attained due to the

random orientation of the powdered material. Conversion of the diffraction peaks to d-spacing allows identification of the mineral because each mineral has a set of unique d-spacing. Typically this is achieved by comparison of d-spacing with standard reference patterns. All diffraction methods are based on generation of X-rays in an X-ray tube. These X-rays are directed at the sample, and the diffracted rays are collected. A key component of all diffraction is the angle between the incident and diffracted rays. Powder and single crystal diffraction vary in instrumentation beyond this.

E. DTA technique

The DTA analysis was carried out in air using a DT-30 Thermal Analyzer Shimadzu Co., koyoto, Japan (Fig.3). To follow up the rate of hydration, some selected mortars are tested after different curing ages by DTA technique. Differential Thermal Analysis (DTA) is concerned with the measurement of energy changes in materials. The principle of the "classical" arrangement is readily explained with reference to the following. S and R are containers holding the Sample and an inert reference material. In these are thermocouples measuring their respective temperatures. By connecting the thermocouples in opposition, the difference in temperature ΔT ($= T_S - T_R$) is also measured. If S and R are heated at the same rate, by placing them in the same furnace, their temperatures will rise. T_R rises steadily, as the reference material is chosen to have no physical or chemical transitions. T_S also rises steadily in the absence of any transitions, but if for instance the sample melts, its temperature will lag behind T_R as it absorbs the heat energy necessary for melting. When melting is complete, steady heating is resumed. The DTA curve - a plot of ΔT (heat transfer measured by mille watt (mW) or mille joule second) against time, or more usually, sample temperature. The curve shows an endothermic (heat-absorbing) peak. If an exothermic (heat-producing) event had occurred, the curve would show a peak in the opposite direction.

F. SEM examinations

SEM is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample's surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam's position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, and (in environmental SEM) in wet conditions. SEM was used to study the morphology and pore structures. To verify the mechanism predicted by the compressive and flexural strength tests, SEM examinations were performed. The microstructures of control mortar (M0) and some selected blended mortars containing BD and LD were investigated by the scanning electron microscope (SEM) for samples, model quanta 250 FEG (Field Emission Gun) attached with EDX unit (Energy Dispersive X-ray Analyses), with accelerating voltage 30 K.V., with magnification power 14x up to 1000000 and resolution for Gun.1n). FEI Company, Netherlands (Fig. 4). Backscattered electron detector (BSED) imaging was used to study the specimen's morphology without any coating. Tabular hexadecimal-shape Portlandite crystals, needle-shaped Ettringite crystals and leaf-shaped Calcium- Silicate-Hydrate-phases. The latex films between Ettringite, Portlandite and CSH–phases are an important element of the microstructure of a cementitious mortar and improve the flexibility between the brittle crystal structures.

III. RESULTS AND DISCUSSIONS

A. Effect of fine aggregate dusts (FADs) on the properties of pastes

** Effect of FADs on the water of standard consistency (W/C, %)*-The variations of the required water of standard consistency (W/C, %) of the investigated cement pastes are graphically represented in Fig. (5). It can be seen that, the water demand (W/C, %) increases with aggregate dust content. This is due to the acceleration of the hydration process of cement clinker phases under the nucleating effect of dusts (LD and BD). The pastes containing LD have higher W/C, % than those containing BD. It is well known that, CaO is more hydraulic than silicon oxides. Therefore, LD which contains higher CaO, % ≈ 56.09 is more hydraulic and needs higher W/C, % to attain the standard consistency than BD, which contains 6.42 mass, % of CaO, as mentioned in table (1).

*** Effect of FADs on the initial and final setting times (IST & FST)*- Fig. (6) Represents the values of setting times of PC and blended pastes containing two types of FADs with different percentages of each (4, 8, 12 and 16 mass, %). It is apparent that, the setting process is retarded and the setting times are elongated with FADs content. This is mainly attributed to the increase of water of consistency with the increase of FADs mass, %. Also, cement pastes incorporating LD have longer setting times than those containing BD. This due to the higher W/C, % of LD pastes than those containing BD.

B. Mechanical properties, XRD, DTA and SEM of the tested mortars

Mechanical properties (compressive and flexural strengths)*-The compressive and flexural strength (CS & FS) results of the investigated cement mortars, which hydrated in water at different curing ages (3, 7, 14, 28 and 90 days). It is observed that, the types and dosages of FADs affect the CS and FS of cement mortars. The effect of hydration age on the CS and FS values of PC and blended mortars is graphically depicted in Figs. (7, 8). The variations of flexural values with curing time for the individual FAD-cement mortars in comparison with the control mortar are graphically shown in Figs. (9, 10). Generally, the strength properties (CS & FS) for all hydrated Portland cement specimens increases with curing time, due to the continuous hydration of cement clinker phases, leading to the formation of successive amounts of hydrated calcium silicates (CSH), aluminates (CAH) and aluminosilicates (CASH), which accumulate; precipitate in the open pores originally filled with water; homogenize and densify the internal microstructure of cement mortar. The hydrated silicates, aluminates and aluminosilicates are the main source of strength **[54-57]. The results also show that, the blended cement mortars containing fine aggregate dusts have higher relative strength properties (CS & FS) values than the control mortar (M0) at all curing ages. It seems to be due to that, the fine aggregate dusts behave not only as micro-fillers to improve the microstructure of cement mortars, but also as activators to promote the hydration of cement clinker phases. The fine aggregate dusts (FADs) may be pozzolanic or nonpozzolanic additives. Limestone dust (LD) is one of nonpozzolanic quarry dusts. On the other hand, basalt dust is active pozzolana **[58]**. Therefore, basalt dust (BD) has two effects work together to enhance the compressive and flexural strength values of cement specimens, the first is the filling action and the second is the pozzolanic activity. But, limestone dust has no pozzolanic affinity and enhances the mortar strength by nucleating and filling effects. Figs. (11 and 12), respectively represents the variations of compressive and flexural strengths of hardened PC and blended mortars incorporating fine aggregate dusts (FADs) and hydrated at the same curing time (28 days). It can be seen that, the strength properties of control mortar (M0) are observed to be much lower than those of dust mortars. This is attributed to the activation effect of quarry dusts (LD, and BD) to increase the hydration reaction rate of cement phases, specially C_3S and β-C_2S. The results also indicate that, the BD-mortar have higher value of strength properties (CS & FS) than those with LD. This mainly due to the pozzolanic activity of BD to react with the liberated portlandite (CH) during the hydration of cement clinker, leading to the formation and accumulation of addition amounts of CSH, CAH and CASH, which tend to increase the gel/space ratio as well as the density of cement mortar. The effectiveness of FADs in improving the compressive and flexural strengths of cement mortars increases in the order BD > LD.

*** Interpretation of XRD results*

The effect of LD content on the hydration characteristics of LD-mortars can be seen from the representative XRD patterns in Fig. (13) in comparison with the control mortars in the same Fig. XRD patterns of LD-mortars show peaks of calcium silicate hydrate (CSH), portlandite (CH) and calcite ($CaCO_3$) at different positions with different intensities. But in the control diffractogram, these phases also present in addition to the ettringite phase (E). The intensity of CSH peaks increases with LD content up to 8 mass, % and then decreases to 16 mass, %. On the other hand, calcite and portlandite peaks decreases up to 8 mass, % of LD, then increase gradually with LD content. The increase of CSH peaks with LD percentage up to 8 mass, % may be due to the activation and nucleation effects of LD to increase the hydration reaction rate of cement clinker phases, leading to more consumption of free portlandite during cement hydration and more CSH production, i.e., the rate of consumption of CH exceeds the rate of its formation with the increase of LD dosage up to 8 mass, %. The calcite peaks behave in the same manner of portlandite and in the opposite manner of CSH. The beneficial influence of BD as a fine aggregate replacement material on the hydration behavior of cement clinker phases in BD-modified cement mortars can be seen clearly from the XRD patterns in Fig. (14). It can be observed that, all BD-mortars exhibit higher intensity of CSH and lower intensities of both calcite ($CaCO_3$) and portlandite (CH) than the corresponding peaks in case of the neat mortar. The intensity of CSH peaks increases and those of calcite and portlandite peaks decrease with the increase of BD replacement level up to 12%. This due to two chemical reactions, which take place with different rates, the first is hydration of cement phases (C_3A, C_3S, C_4AF and β-C_2S), liberating free lime (CH) and the second is the pozzolanic reaction of BD with the liberated lime (lime consumption and CSH production). The rate of portlandite consumption exceeds that of its production with the increase of BD percentage. This is attributed to that, BD doesn't act only micro-filler, but also as highly active pozzolana. The pozzolanic reaction of BD with the formed lime from the hydration of cement clinker results in the formation of additional amounts of tobermorite like phase (CSH) and more consumption of $Ca(OH)_2$.

****. Interpretation of differential thermal analysis (DTA) patterns*

The DTA patterns of the blended cement mortar containing 12 mass, % of basalt dust and hydrated at different curing ages are graphically shown in Fig. (15).

The results indicate that, very small endothermic peaks appear at low temperature up to 110ºC, may be due to the decomposition of hydrated silicates as tobermorite like phase. The endothermic peak located in the range 460-480ºC may be assigned to the dehydration of free portlandite, $Ca(OH)_2$. Whereas the broad endotherm at 560-580ºC may be related to the thermal decomposition of calcite phase ($CaCO_3$) or carbonated CSH and CH. The endothermic peak corresponding to the tobermorite like gel phase (CSH) increases with the time of hydration. On the other side, the characteristic peaks of both calcite and portlandite phases behave in opposite manner to that of CSH. The increase of CSH peaks intensity and the decrease of those of CH and $CaCO_3$ is mainly due to two processes, the first includes the hydration of cement phases (C_3A, C_3S, C_4AF and β-C_2S), leading to the formation of excessive amounts of free lime (CH), which is partially carbonated with the atmospheric CO_2, i.e., this process is the main source of portlandite, $Ca(OH)_2$. But the second process includes the pozzolanic reaction of BD with the liberated $Ca(OH)_2$ during the first process, resulting in the formation of additional ill crystalline tobermorite phase with low C/S ratio. The CSH is slightly carbonated but with lower ability than $Ca(OH)_2$. Indeed, the pozzolanic reaction rate is accelerated with curing time, i.e., the rate of lime consumption and CSH formation increases with the time. Figs. (16-17) represent, the DTA thermogrames of blended cement mortars containing LD or BD with different percentages (0, 4, 8, 12 and 16 mass, %). It can be seen that, the intensity of CSH peaks increases with FAD content up to the maximum limit, which mainly depends on the FAD type. The optimum level of LD and BD are 8 and 12 mass, %, respectively. In contrast with CSH peaks, the intensity of CH and $CaCO_3$ peaks decrease with FAD dosage up to the maximum level for each dust, and then the portlandite and calcite peaks increases with dust percentage up to 16 mass, %. The effect of fine aggregate dust (FAD) type as replacement material of sand on the hydration products of PC and different cement mortars containing 8 mass, % of FAD (LD or BD) and hydrated at the same age (28-days) is graphically represented in Fig. (18).The results show that, the endothermic peak corresponding to tobermorite phase (CSH) of PC mortar (the control mortar, M0) has lower intensity than those of FAD-modified mortars. This is essentially due to the filling and nucleation effects of FADs, in addition to the pozzolanic action of some FADs, such as BD to react with the formed lime from cement clinker hydration, producing additional hydrated calcium silicates. Also, the intensity of CSH peak, ascending increases in order: LD-mortar < BD-mortar. The endothermic peak area due to the decomposition of $Ca(OH)_2$ decreases with dust type in the following order: BD < LD.

**** *Interpretation of SEM micrographs*

A number of scanning electron microscopy (SEM) micrographs illustrating various characteristic features of PC and blended specimens containing different types and percentages of FADs (LD and BD) are shown in Figs. (19-30). The effect of curing time on the microstructure of cement mortars was illustrated from the comparative observations of two similar samples with the same chemical composition and hydrated at different curing ages (7 and 28 days), i.e., the following figures were compared with each other (19 & 20, 21 & 22, 23 & 24, 25 & 26, 27 & 28 and 29 & 30). It is clear that, the microstructures of the all cement samples are more uniform and denser at later ages of hydration (28 days) than those of the same samples at earlier ages (7-days). Figs. (19 and 20) represent the micrographs of hydrated control mortar at 7and 28 days. But the SEM micrographs of FADs-modified cement mortars hydrated at 7 and 28 days are shown in Figs. (21-30). At a given curing time, the microstructure of the control mortar (M0) has CSH gel existed in the form of «stand-alone» clusters, lapped and jointed together by many needle hydrates, especially ettringite needle crystals. The deposits of portlandite, $Ca(OH)_2$ crystals were distributed among the cement paste. On the other hand, the microstructures of the mortars containing FADs, which are of higher strength than PC mortar revealed pores filling with dense and compact structures, i.e., the texture of hydrated products was more dense, uniform and compact. Big crystals such as Ca (OH) $_2$ are gradually decreased with LD contents and sharply reduced with BD content. Limestone dusts act as micro-fillers to modify and improve the microstructure of cement specimens. But BD behaves not only as a micro-filler but also as pozzolanic additives to react with the liberated portlandite from the hydration of cement phases, leading to the formation of more hydrated silicates, which tend to homogenize and densify the microstructure of cement specimens. Thus, the number and size of $Ca(OH)_2$ crystals are reduced sharply with BD dosage up to 12 mass, %. Among the mortar groups used in this study, the mortar containing 12 mass, % of BD and hydrated at 28 days has the best micrograph. The maximum dust content, which gives a desirable strength properties and denser microstructure, is 8 and 12 mass, % of LD and BD, respectively.

V. SUMMARY AND CONCLUSIONS

In the present work, two different quarry dusts were used as cement, and fine aggregate replacement materials. The quarry dust-modified cement specimens were prepared with different QD types (LD and BD) and percentages (4, 8, 12 and 16 mass, %). The investigated cement pastes (PC and dust-modified pastes) were prepared with the water of standard consistency to attain the same workability. Also, the initial and final setting times for all pastes were determined according to ASTM

specifications. The all investigated mortars were hydrated at different curing ages (3, 7, 14, 28 and 90 days). At each curing time, the hydration reaction was stopped by during the hydrated cement specimens in oven drier at 100-110 C° for 4 hours, and then the mechanical properties were studied by measuring the compressive, flexural strengths for mortars.In order to identify the hydration products, some selected hydrated cement mixes were investigated using different techniques, i.e., XRD, DTA and SEM. From the previous results, it can be concluded that: i) For pastes specimens the substitution of PC by quarry dusts (LD and BD) tends to increase the water of standard consistency and elongates the setting times. This is mainly due to the higher fineness and the more hydraulicity of QDs in comparison with PC. ii) The compressive and flexural strengths of the hydrated cement mortars with the same chemical composition increases with curing time. This is mainly attributed to the continuous hydration of cement phases as well as the formation of hydrated carboaluminates, silicates and aluminosilicate from the reaction of LD and BD with the main cement clinker compounds. These hydrates precipitate and accumulate to fill up the open pores, originally filled with water, leading to the formation of more dense, compact, homogeneous microstructure. Therefore, the bulk density of cement specimens increases with curing time. iii) The strength properties (compressive and flexural strengths) of the blended cement mortars with quarry dusts are higher than those of the control mortars, especially at lower quarry dusts contents (4-12 mass, %). But, at 16 mass, % of LD the blended mortars give lower mechanical properties than PC mortar at the same curing age. The increase of strength characteristics of cement mortars with QD content up to 12 mass, % may be due to the filling and nucleation effects of quarry dusts. Also, BD act as pozzolana to react with the liberated portlandite during the hydration of cement clinker phases, especially C_3S and β-C_2S, leading to the formation and accumulation of additional amounts of hydrated silicates (CSH), which is the main source of strength. iv) For mortar specimens at a given time of hydration and the same fine aggregate dust content, the basalt dust containing mortars behave mechanically better than those LD mortars. The strength values increase ascendingly in the order LD-mortar < BD-mortar. The variation of strength properties of quarry-modified mortars with QD type is attributed to that, LD acts as a filler and non-pozzolanic fine material. It reacts with cement phases, especially C_3A to form calcium carboaluminate hydrate with mediate binding properties. On the other hand BD acts as fillers and pozzolanic materials with different pozzolanic activities. Basalt dust has higher pozzolanic activity due to the higher amorphous (vitreous) silica content of BD. The later contains higher content of crystalline silica (quartz) than BD. It is well known that, the hydrated silicates has higher binding properties comparing to carboaluminate hydrates, therefore the hydrated products of BD-mortars are more denser than those of hydrated LD-mortars. The maximum replacement level of each dust, which gives desirable mechanical properties, varies according to the QD type. This level is found to be 8 and 12 mass, % of LD and BD, respectively. v) The blended cement mortars with 8 and 12 mass, % of LD and BD, respectively showed the higher mechanical characteristics and better micrographs. The hydrated mortars with 12 mass, % of BD at 90 days has the best mechanical behavior than the others. vi) The results of compressive and flexural strengths of the all investigated mortars are in a good agreement with each other and with those of XRD, DTA, and SEM.

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Table (1): Chemical analyses of aggregate dusts and PC (mass, %)

Oxides	Basalt dust (BD)	Limestone dust (LD)	PC
SiO_2	56.33	7.58	21.16
Al_2O_3	7.53	2.03	5.50
Fe_2O_3	17.73	1.59	3.21
CaO	6.42	56.09	63.40
MgO	2.99	0.72	0.69
SO_3	1.10	0.88	2.40
K_2O	0.35	0.28	0.50
Na_2O	1.72	0.54	0.10
L.O.I	5.83	30.29	3.04

Table (2): Mineralogical composition of PC

Compound	Abbreviation	Chemical formula	Content, %
Tricalcium silicate	C_3S	$3CaO.SiO_2$	50.59
Dicalcium silicate	C_2S	$2CaO.SiO_2$	20.30
Tricalcium aluminate	C_3A	$3CaO.Al_2O_3$	7.70
Tetra calcium alumino-ferrite	C_4AF	$4CaO.Al_2O_3.Fe_2O_3$	9.55

Table (3): Sieve analysis of sand

Sieve size %	4.75	2.8	1.4	0.71	0.35	0.18
Sand	97.0	91.7	76.7	46.9	16.3	4.8

Table (4): Chloride and sulphate contents for used materials

Content / Sample	Chloride content	Sulphate content	Limits with Egypt code %	
			Chloride	Sulphate
Basalt dust	0.009	0.08	0.04	0.4
Limestone dust	0.02	0.1	0.04	0.4
Sand	0.01	0.1	0.06	0.4

Table(5): Terminology for cement pastes and mortars containing aggregate dusts

Paste No.	**Mortar No.**	**Dust content in mass, %**
P0	M0	0.0
PB1	MB1	4 B.D
PB2	MB2	8 B.D
PB3	MB3	12 B.D
PB4	MB4	16 B.D
PL1	ML1	4 L.D
PL2	ML2	8 L.D
PL3	ML3	12 L.D
PL4	ML4	16 L.D

Fig. (1): Compressive strength machine

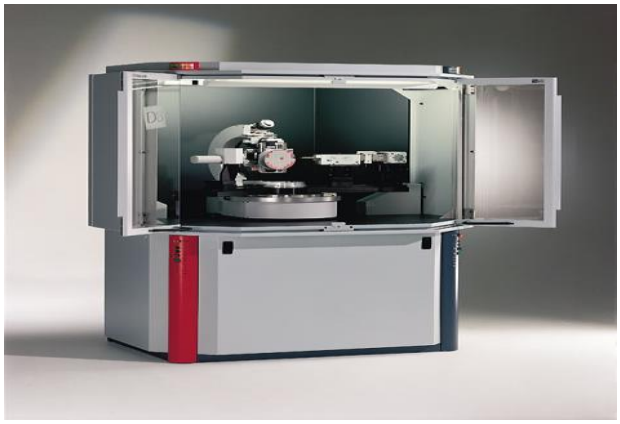


Fig. (2): XRD, diffract meter

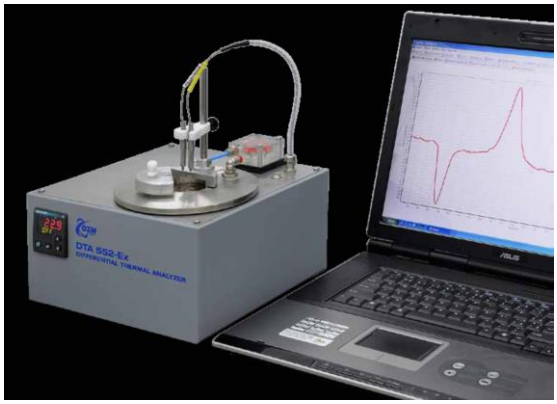


Fig. (3): DTA, thermal analyser

Fig. (4): Scanning electron microscope model 250 FEG

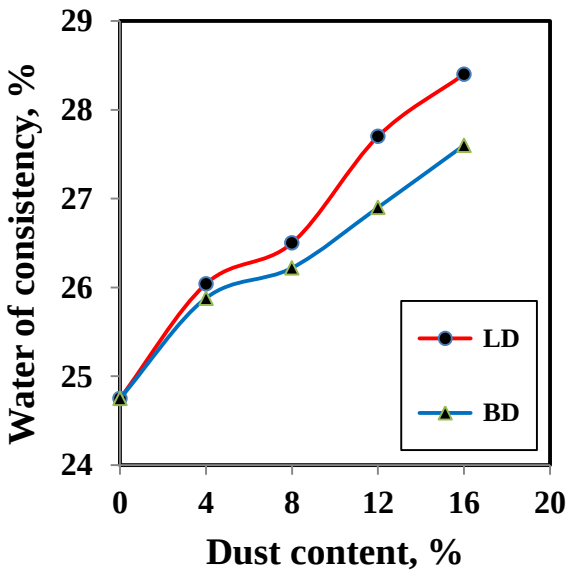


Fig. (5)

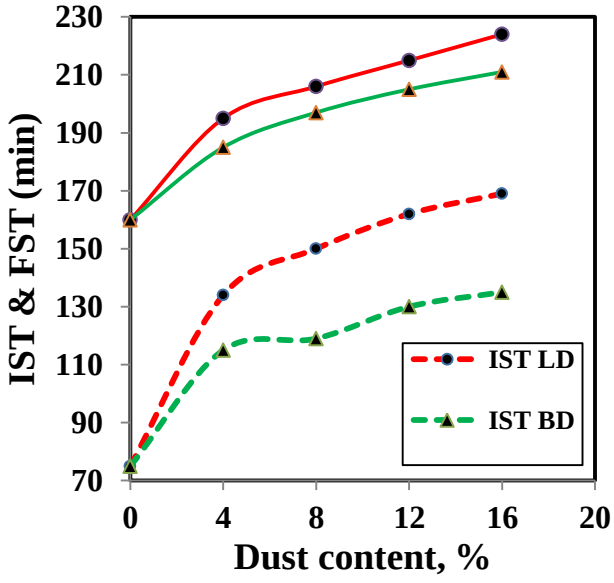


Fig. (6)

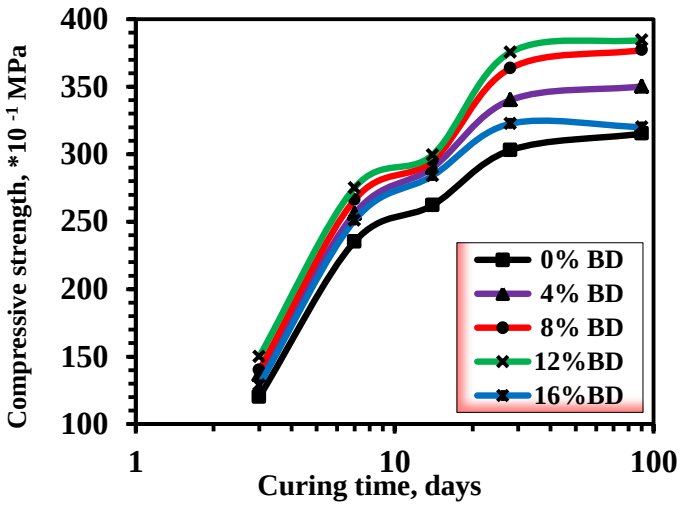


Fig. (7)

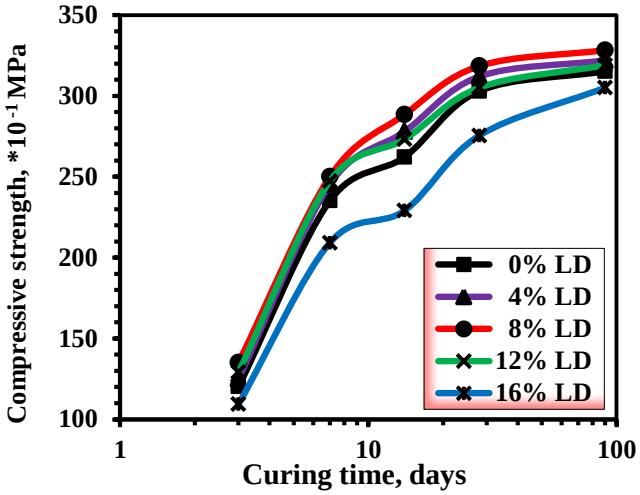


Fig. (8)

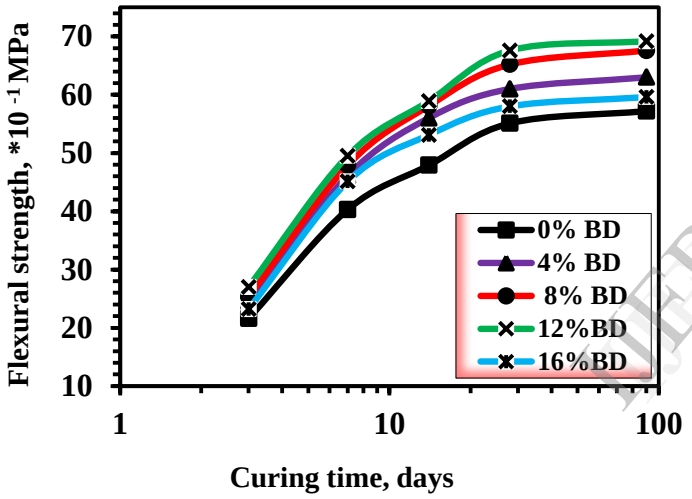


Fig. (9)

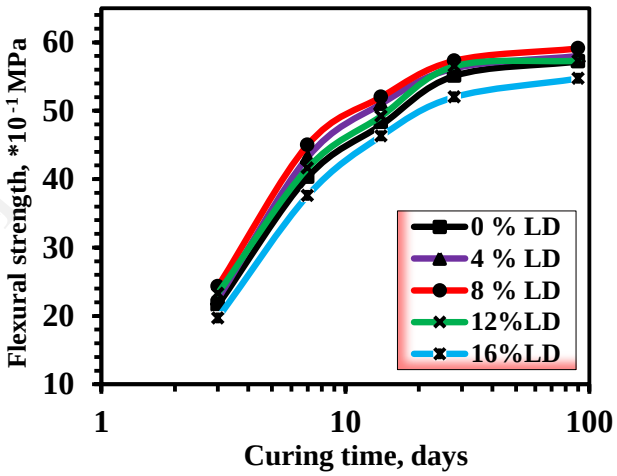
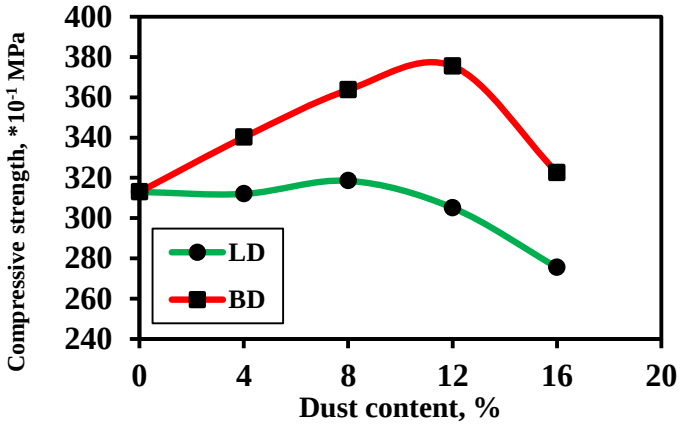


Fig . (10)



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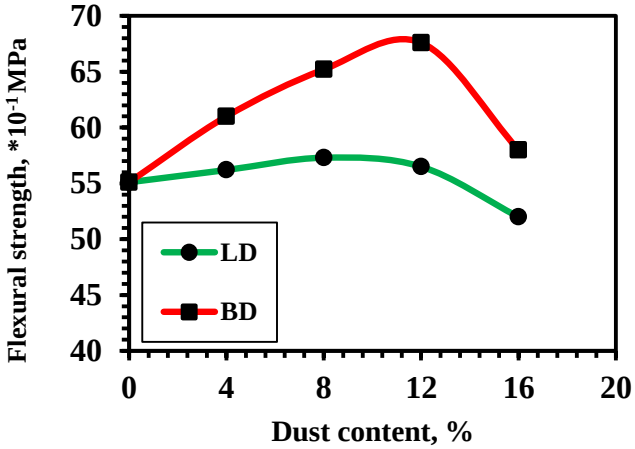

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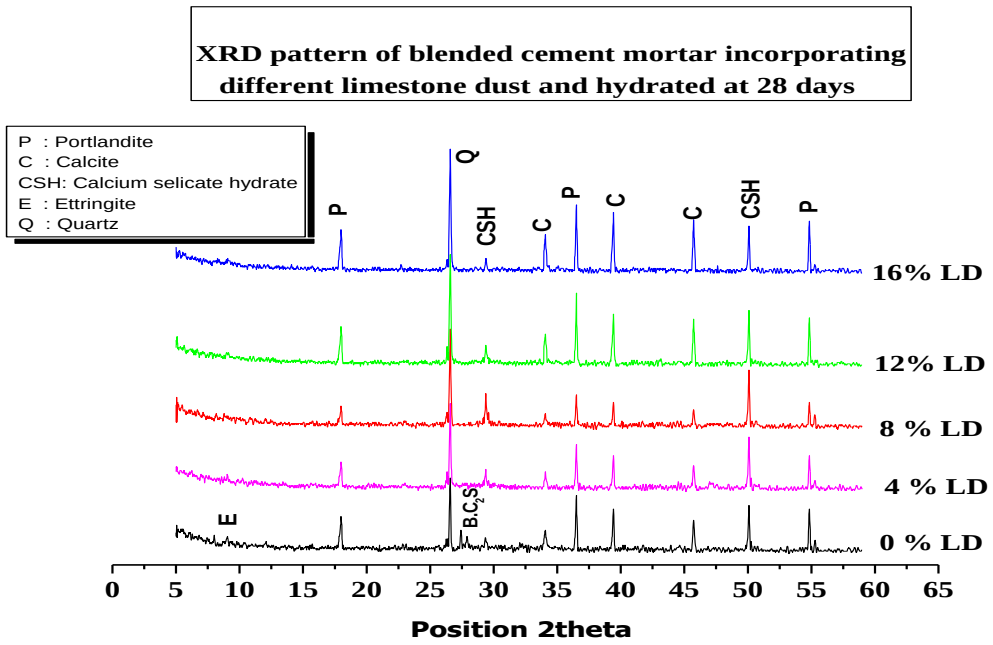

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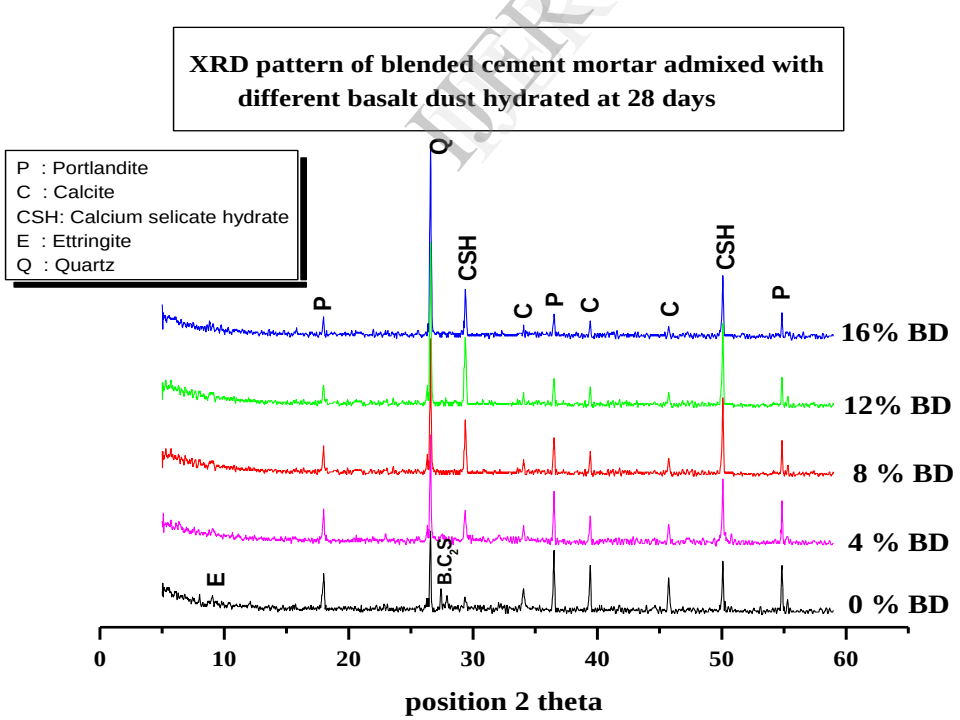

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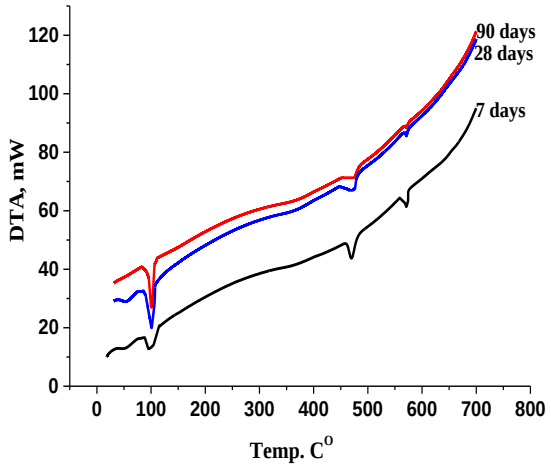

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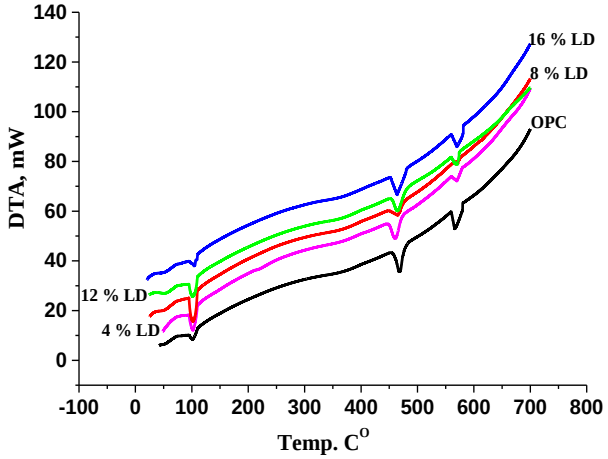

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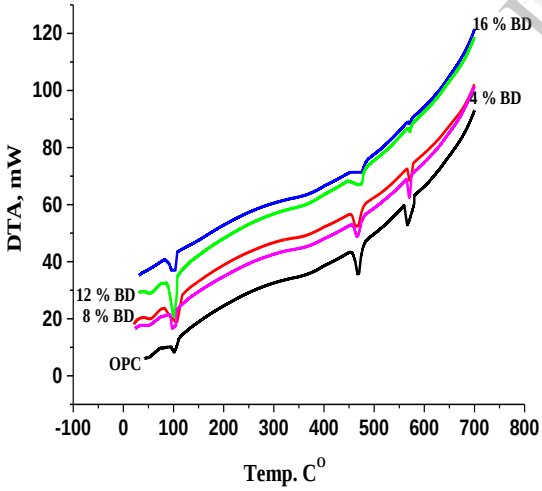
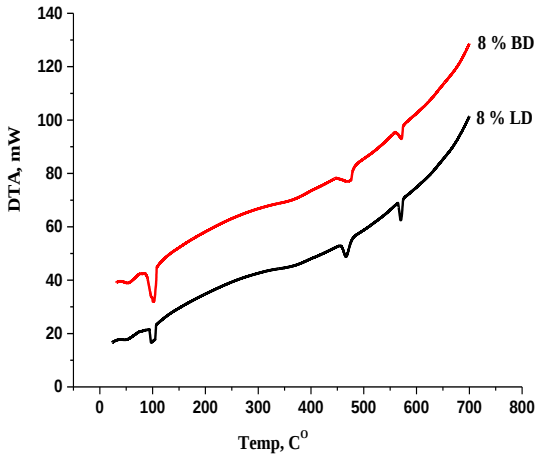


Fig. (17)



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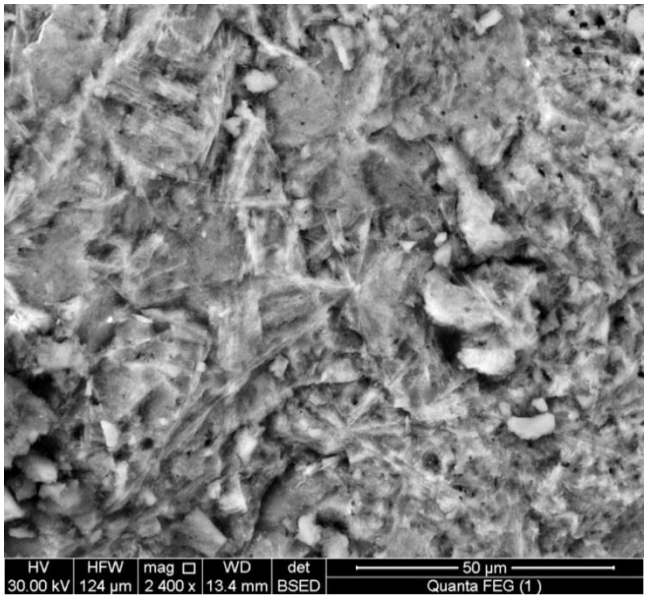

Fig. (19): SEM micrograph of hydrated PC mortar at 7-days

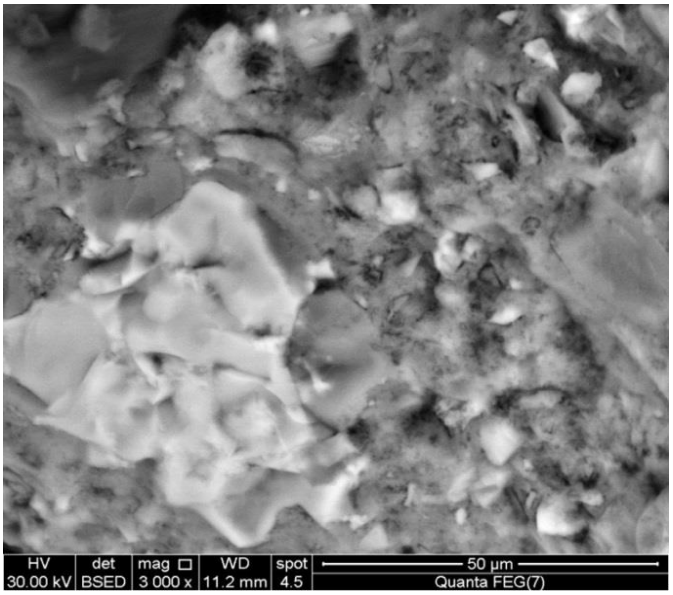

Fig. (20): SEM micrograph of hydrated PC mortar at 28-days

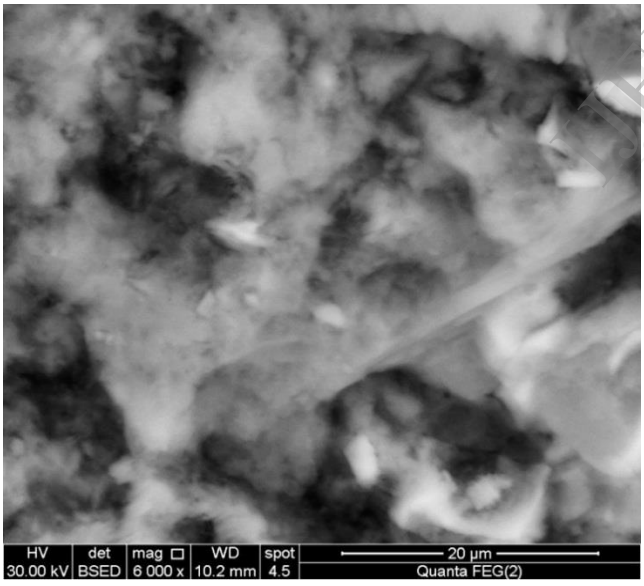

Fig. (21): SEM micrograph of hydrated cement mortar with 8 % GD at7-days

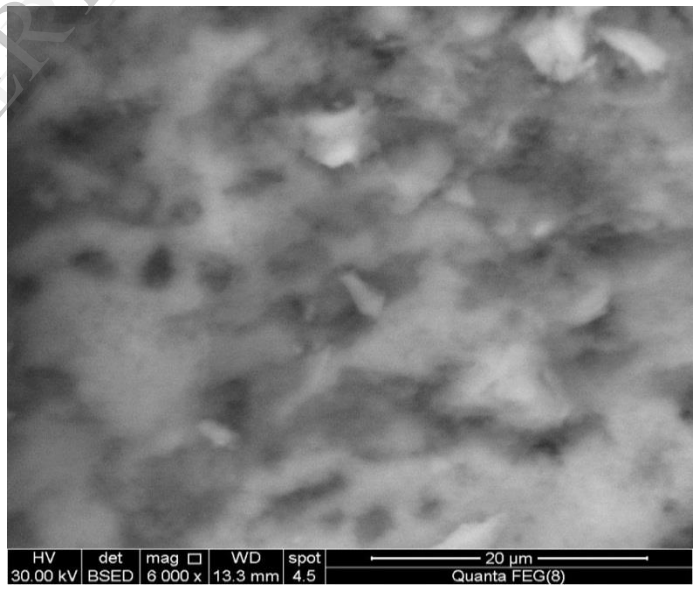

Fig. (22): SEM micrograph of hydrated cement mortar with 8 % GD at 28-days

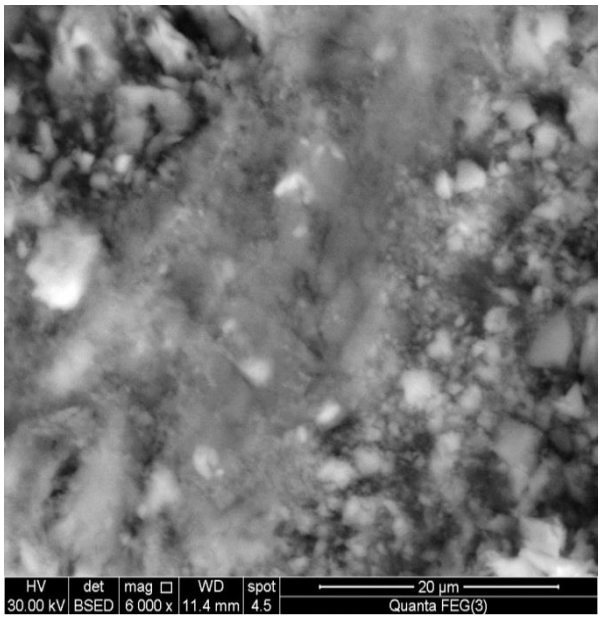

Fig. (23): SEM micrograph of hydrated cement mortar with 8 % LD at 7-days

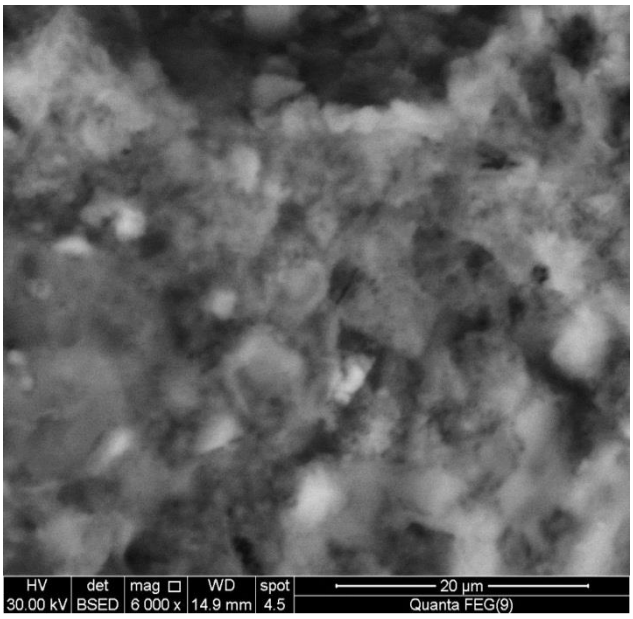

Fig. (24): SEM micrograph of hydrated cement mortar with 8 % LD at 28-days

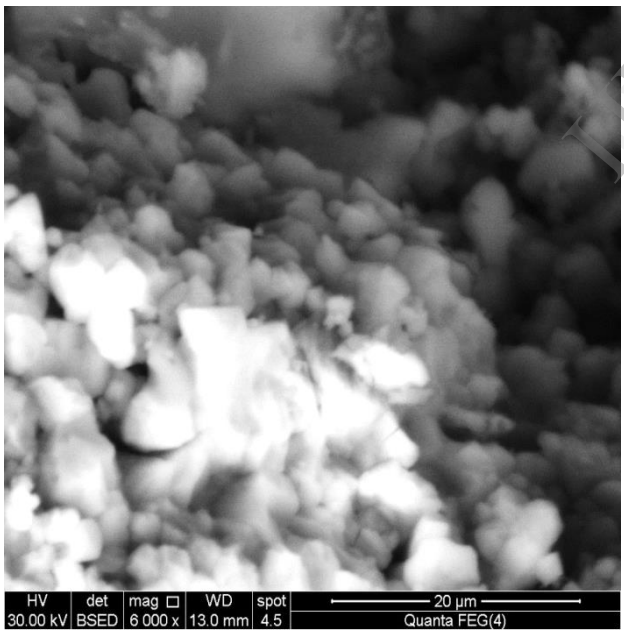

Fig. (25): SEM micrograph of hydrated cement mortar with 12 % LD at 7-days

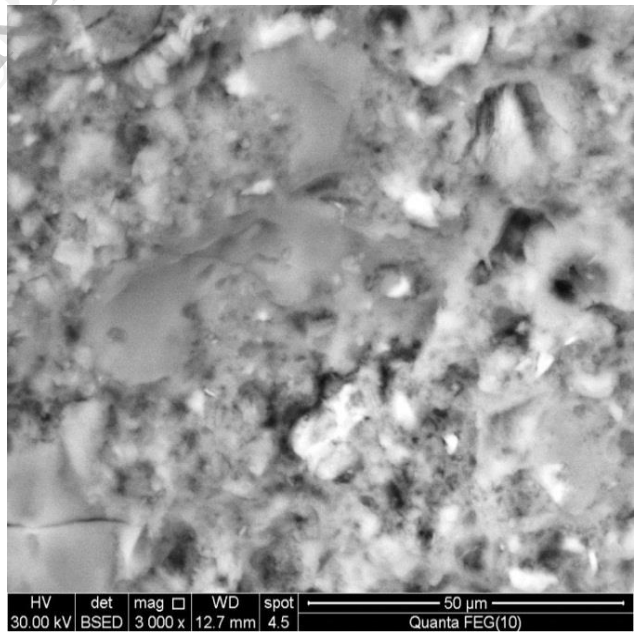

Fig. (26): SEM micrograph of hydrated cement mortar with 12 % LD at 28-days

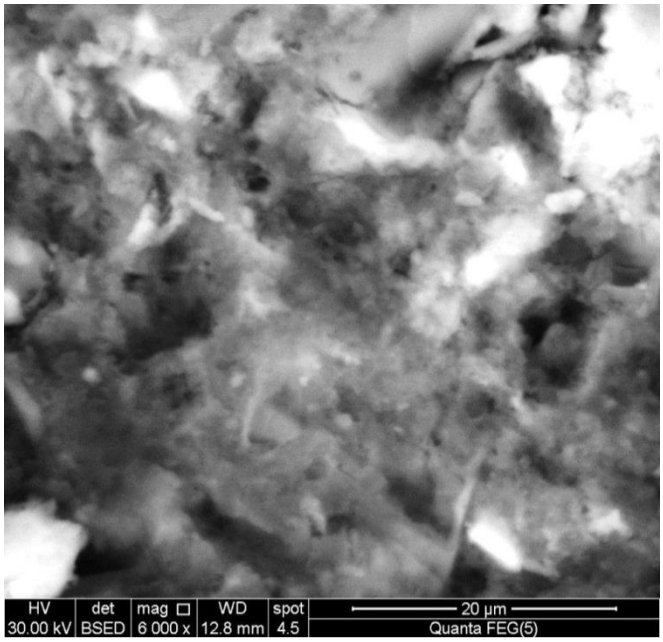

Fig. (27): SEM micrograph of hydrated cement mortar with 8 % BD at 7-days

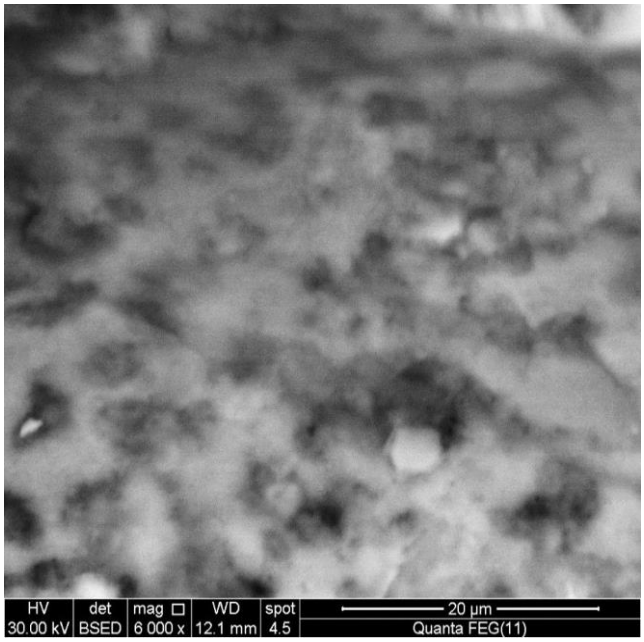

Fig. (28): SEM micrograph of hydrated cement mortar with 8 % BD at 28-days

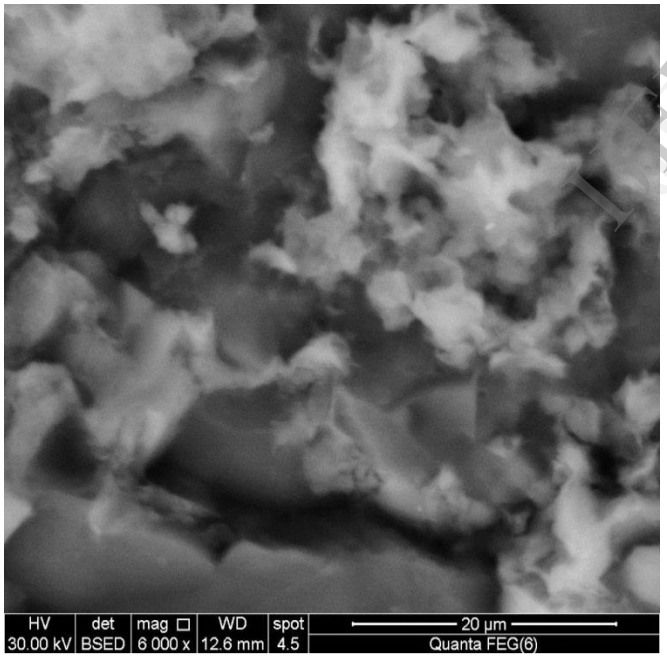

Fig. (29): SEM micrograph of hydrated cement mortar with 12 % BD at 7-days

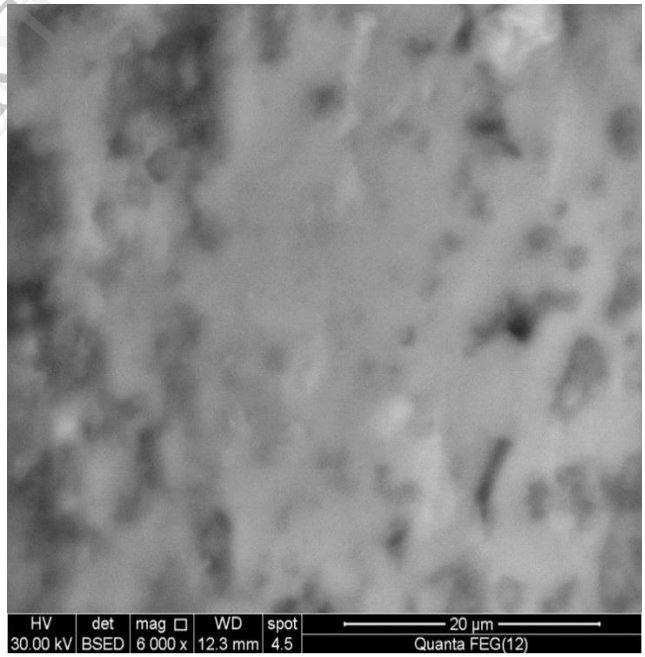

Fig. (30): SEM micrograph of hydrated cement mortar with 12 % BD at 28-days