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Development of Polymer Usage in the Concrete Composites for Building and Repairing Concrete Structures in KSA

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ABSTRACT

This research includes the usage of two types of epoxies (polymers) of different weight percentages to produce modified polymer/concrete study and their effects on the tensile, compressive and impact strengths to get the optimum weight percentage of the polymer for the best concrete quality. Also, mixtures of concrete and the optimum weight percentages of the polymers are investigated with respect to the flexural, tension, compression, impact strength tests and the resistance to the crack propagation. The experiments made were concrete with the water soluble polymer polyvinyl alcohol (PVA) that frequently used for the modification of concrete, belongs to the class of the water soluble nonionic polymers containing a vinyl group and the other is styrene-butadiene rubber (SBR) which is one of the bitumen modifiers that obtained from crude oil and improves low temperature performance at moderate concentrations. The polymers have been dissolved in water with five different proportions ranging from 2% to 20% with respect to cement's percent by weight in kg. The specimens formed were cured and tested to compressive, flexural and tensile strength up to 28th days after curing. Results proved that concrete mix having polymers gave greater strength results. The effects of water/cement ratio (W/C) and polymer concentration on the PLC density is carried out and investigated.

1. INTRODUCTION

Concrete is one of the most widely used construction material in the world, it is usually associated with ordinary Portland cement as the main component for making concrete, [1]. Nibudey et al. [2], showed that the lightweight concrete is one of the most widely used construction material in developed and developing countries. Cruz et al. [3] concluded that polymer concrete is becoming increasingly popular due to many advantages that it possesses. It is very strong, durable and cures very rapidly, an important factor in most of the civil engineering applications such as transportation, utility, marine and building components. It has superior physical and chemical properties such as a short curing time, impact resistance, chemical resistance, electrical insulation, waterproofness, and freeze–thaw durability. Ribeiro et al. [4] decided that worldwide volume production and consumption of fibre reinforced polymers (FRP) have increased in the last decades in several fields, mostly in the construction, automobile and aeronautic sectors. Ganiron Jr. [5] illustrated that an admixture of concrete is a material other than water, aggregates, cement, and fiber, added to plastic concrete or mortar to change one or more of its properties at the fresh or hardened stages. Mohamed et al.[6], investigated The effect of water/cement ratio, iron, lead and polypropylene on the mechanical properties of the cement paste taken into consideration the influence of mass percentages and age of cementitious composites. The optimum cementitious composite mixtures are detected with respect to the type and percentage of additives, bearing load, crushing time and strength. Also, Mohamed et al. [7] applied cementitious composites to characterize the using of composites in both seismic and corrosion repair of structural systems. The effect of iron powder, lead powder and polypropylene granulates mass percentages on the optimum cement paste composites are investigated. The effect of the number and conditions of the iron rods and the number of cans on the crushing loads of the cementitious composites is carried out and investigated, [8]. Sivaarunkumar et al. [9], showed that the concrete with 9.5% of epoxy and 10% of silica fume showed better strength when compared with other mixes. Tutikian [10], evaluated the acoustic performance of lightweight concrete with ethylene vinyl acetate copolymer (EVA) residues to reduce impact noise on floors. Daud et al. [11], found that the replacements of modified binder (cement) with a thermoplastic material and the replacement of the gravel by the whisker of PET (Polyethylene Terephthalate) resulting in lighter products with a low of the wet ability by water. Abed et al. [12], investigated some mechanical properties of polymer concrete using destructive and non-destructive methods at 35 KHz. Nassar [13] used polystyrene packaging. The aim of the present work is to discuss the effect of using two polymers; SBR and PVA with different concentrations on the concrete strength at different aging times. The effect of both the water/cement (W/C) ratio and the polymer wt.% on the concrete properties at various aging times.

2. EXPERIMENTAL WORK

2.1. Experimental Procedure

The research is a laboratory scale to determine the optimum composition of the manufacturing of concrete by using two thermoplastic materials which is PVA and SBR. Specimen was made up from constant sand ratio and different percentages of; W/C, and polymer weight ratios. This research involves compression, flexural, tension, density, porosity, and corrosion test. All concrete samples have undergone physical and mechanical properties tests at room. In addition, the sample best result which was the highest value of strength that they can stand has undergone corrosion test to determine the value of the corrosion resistivity. The Apparent porosity and density of specimens measuring diameter 57 mm by 60 mm high was estimated by the Archimedes method using kerosene (ASTM C 380-79).Subsequently their specific gravities were determined by dividing the unit weight of the sample by the unit volume.

Density, ρ = m/v

Where; m is the dry sample weight (Kg), v is the cylinder volume (m^3), and ρ is the concrete sample density (Kg/m^3). Cement ASTM type II Portland cement was used in this experiment. Chemical composition and physical properties of the cement are shown in Table 1.

Table 1: Chemical compositions of Portland cement

Components	CaO	SiO_2	Al_2O_3	SO_3	Fe_2O_3	MgO	Na_2O	K_2O	TiO_2	P2O5	Mn_3O_4
Weight%	66.36	20.36	4.9	2.57	3.17	2.09	0.14	0.64	0.35	0.18	0.14

2.2. Test Specimens

The W/C (water cement ratios) of specimen was 40, 50, 60, 70 and 80% respectively. The mass ratio of the cement and sand was a constant value of 1:3. Three specimens were prepared for each mix design to validate the reliability of test results. Ordinary tap water was used in this work for all concrete mixes and curing of specimens.

2.3. Polymer

Styrene butadiene rubber (SBR) is used as polymer modifier in this study. Styrene butadiene, an elastomeric polymer, is the copolymerized product of two monomers, styrene and butadiene. Latex is typically included in concrete in the form of a colloidal suspension polymer in water. This polymer is usually a milky-white fluid. The water soluble polymer polyvinyl alcohol (PVA), is used for the modification of concrete. The polymers SBR and PVA were used as a ratio by weight of cement of 2%, 5%, 10%, 15% and 20%.

2.4. Flexural strength

Both polymer and Portland cement concrete were mixed and molded. For flexural and tensile strength tests, cupped specimens of (50 × 50 × 50 mm) of both Portland cement and PC concrete are molded as shown in Fig. 1 and Fig.2

2.6. Compressive strength

Compression strength was measured for cylindrical specimens of both Portland cement and polymer light weight concrete samples (76.0 mm diameter and 152.0 mm height) as shown in Fig. 3 and Fig. 4. Six specimens of each mixture were tested and the mean value was reported.

2.7. Morphological characterization

The specimens surface of were observed with a scanning electronic microscope (SEM) in a JEOL model JSM-5200 machine, in the backscattering-electron mode.

Fig. 1. Flexural and tensile test specimens.

Fig. 2. Flexural test.

Fig. 3. Compression test specimen.

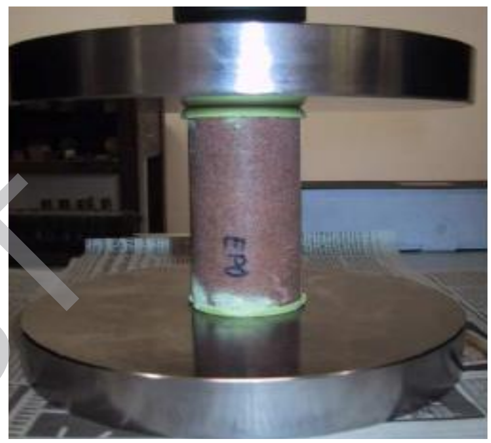


Fig. 4. Compression test.

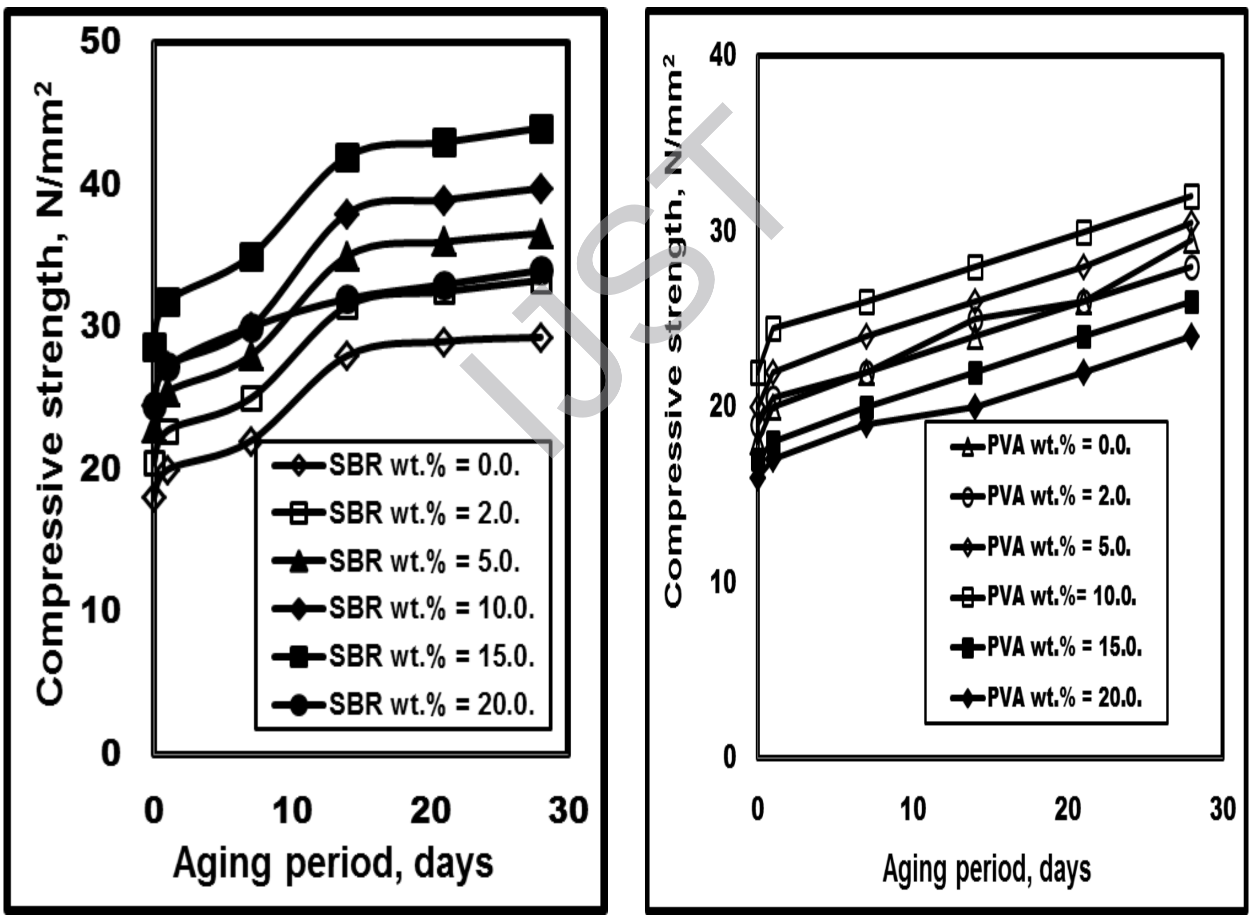
3. RESULTS and DISCUSSIONS

3.1 Compression Strength

Compressive strength development of SBR and PVA mixtures from 7 days to 28 days for different dosages of polymer content has been presented in Figure 5. For the case of SBR, It is clear that a rapid strength development is obtained by increasing the polymer dosage from 5wt.% to 15wt. %, after reaching its optimum percentage dosage around 15% it started decreasing. This show that the additives were reacts as binder between the raw materials when they mixing together. The more additives were applied to these samples the stronger bonds were existed between them. Thus it produced less porosity in the structure and increasing the compressive strength. After that, due to the residue of hydrated cement surface. This residue hinders cohesion between mortars as the matrix with the polymer material leading to the lack of cohesion between particles that leading to the lower compression strength. The same trends are shown in the case of PVA, but its optimum condition is at 10wt.%. The effect of SBR on the compression strength is found higher than PVA since SBR is superior at low temperatures. Also, it is clear that as the aging period increases, the strength increases due to the concrete bonding increment.

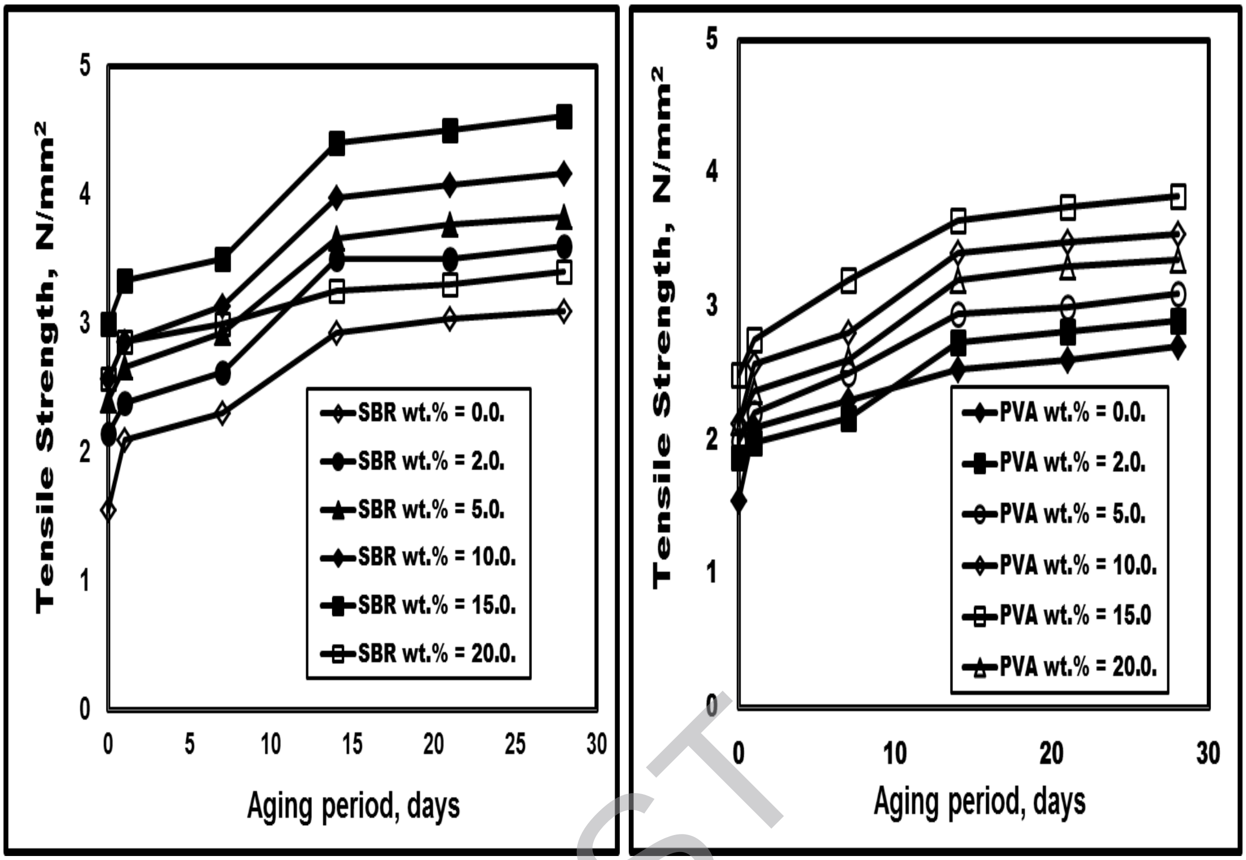
3.2 Tensile Strength

As concrete has high compressive strength but it is relatively weak in tension and adhesion, and its porosity can lead to physical and chemical deterioration. Polymers, on the other hand, are weaker in compression but can have higher tensile capacities, and provide good adhesion to other materials as well as resistance to physical (i.e., abrasion, erosion, impact) and chemical attack. So, Fig. 6 illustrates the increment of the polymer concrete samples tensile strength with various polymers wt.% over the original concrete. It was clear that as the polymers wt.% increases, the split tensile strength increases in both types of polymers with an optimum condition of 15wt.% for SBR and 10wt.% PVA. PVA reaches its optimum condition vastly than SBR due to its smooth and smaller particle but it has lower tensile strength compared to SBR due to its slower absorption of water in agreement with Sivakumar et al., [9].



(5.a) **(5.b)**

Fig. 5 Effect of SBR and PVA concentrations on concrete comp. strength at W/C = 0.46wt%



(6.a) (6.b)

Fig. 6 Effect of SBR and PVA on concrete tensile strength at W/C = 0.46wt%

3.3 Flexural Strength

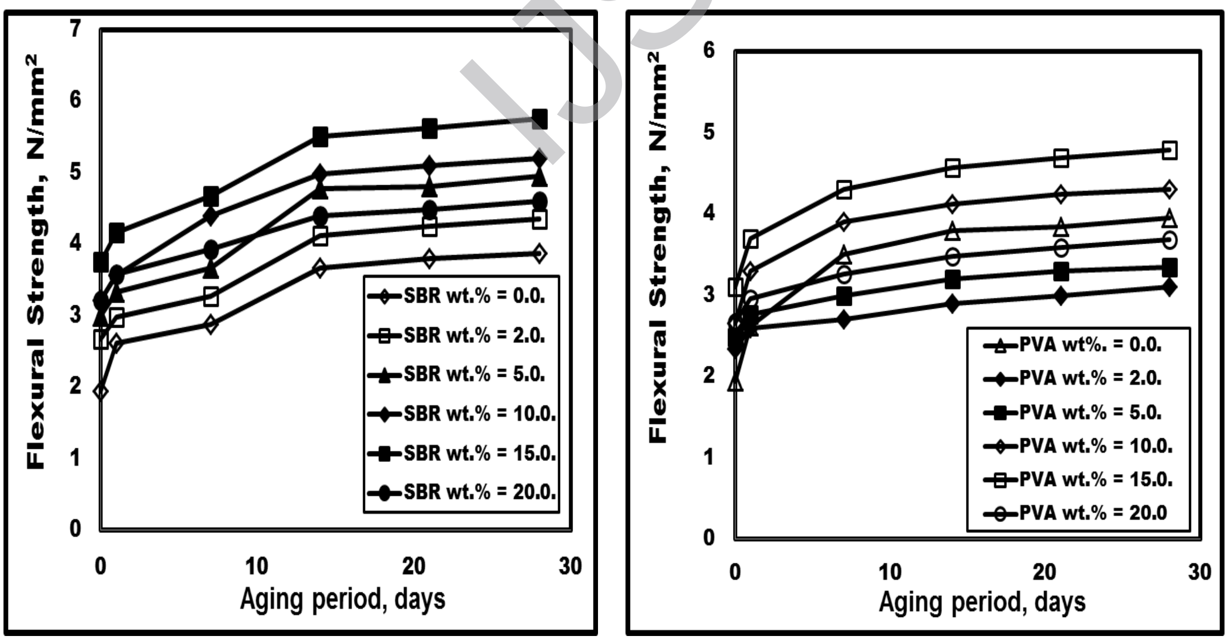
The flexural strength determined up to 28 days on beams is shown in Fig. 7. Three specimens of each mixture were tested and the mean value was reported. The performance of the polymer modified concrete increases as the polymer dosage increases from 5% to 15wt% in SBR and 10wt% for PVA due to that a large proportion of the void volume is filled with polymer, which forms a continuous reinforcing network. This results in a remarkable improvement in tensile, compressive and flexural strength of polymer modified Portland cement concrete. However, additional amount of resin (20%) had no positive impact but it rather caused reduction in the flexural strength.

3.4 Effect of (W/C) Ratio on the Concrete Density

Fig. 8 illustrates the effect of W/C ratio on the concrete density at various aging periods. As the different values of W/C lead to different size of micro voids within cement mortar, therefore, the effect of W/C on damage evolution is equivalent to the effect of average size of micro voids. For the cement mortar with high W/C, the average size of micro voids is large, so the density is low. This means longer time is needed for the delayed ettringite to reach the boundary of the void, and this may delay the appearance of damage. On the other hand, the tensile strength of the cement mortar with larger W/C is lower, once the delayed ettringite touches the boundary of void, the micro crack will expand rapidly. Therefore, the damage evolution depends not only on the size of micro voids, but also on both the W/C and the tensile strength of cement mortar. Therefore, in order to improve the durability of cement paste, both the void size and the tensile strength of the material should be taken into account. So, as a general outcome, it can be easily noticed that concrete mass density was inversely affected by the increase of water cement ratio in agreement with [5] and [10].

3.5 Effect of Polymer wt.% on the Concrete Density

Figure 9 shows the density values for both polymers. The density values obtained showed that sample PVA has the lowest concrete density due to the PVA low weight. This shows that the additives reacted as binder between the raw materials when they were mixing together. The more additives applied to these samples the stronger bonds were existed between them. Thus it produced less porosity in the structure[8-9]. However, it is clear that as both SBR and PVA wt.% increases, the mortar concrete density decreases due to the lower weight of both polymers that takes the place of water in the cement paste voids. It is clear that the SBR concrete has lower density compared to PVA concrete which means that lower amount of water in the cement gaps that result in the enhancement of concrete properties with optimum concentration of 10wt.% SBR. With the aging period increment due to the density decrement with the trapped water evaporation.



(a) (b)

Fig. 7 Effect of SBR and PVA on concrete flexural strength at W/C = 0.46wt.%

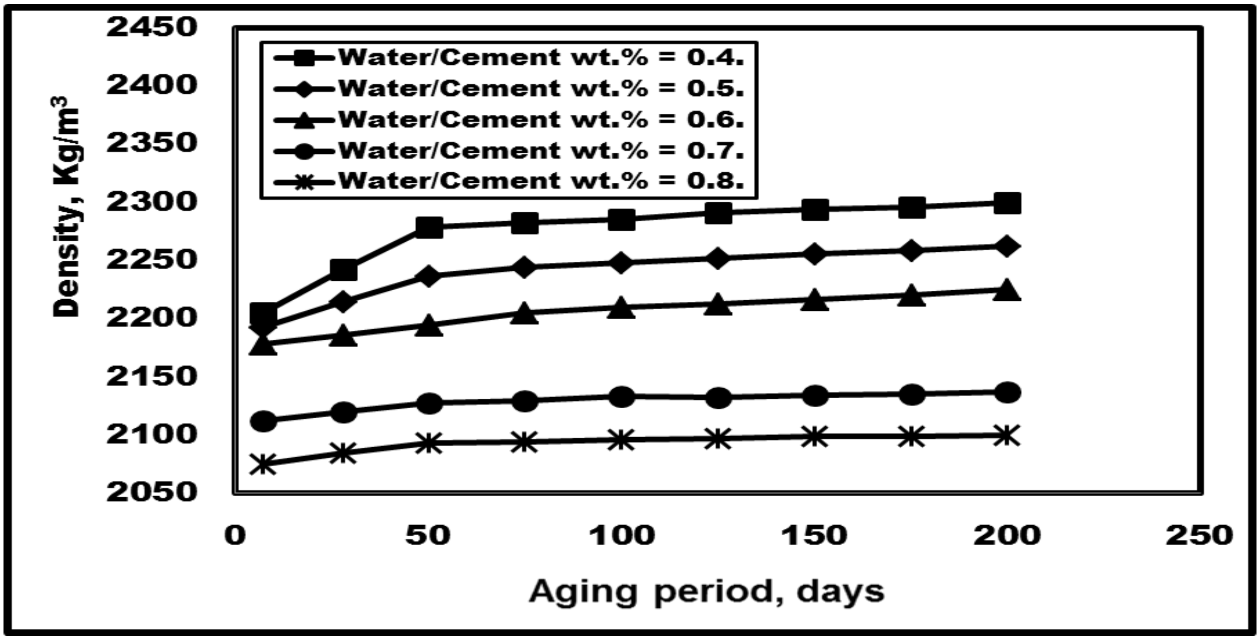


Fig. 8 Effect of W/C weight ratio on the concrete density at different aging periods.

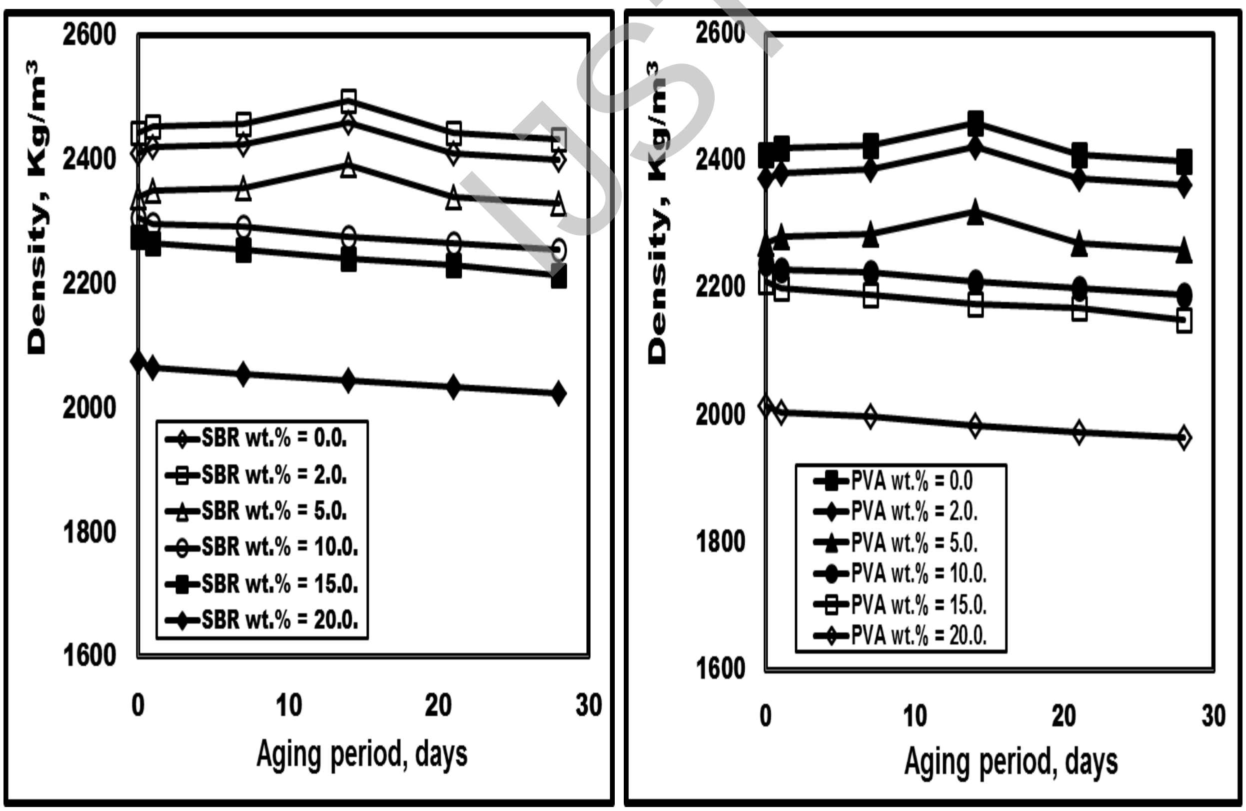


Fig. 9. Effect of SBR and PVA wt.% on the concrete density at different aging periods.

3.9. SEM Observations

SEM observations of the unmodified concrete are shown in Fig. 10.a. The air void surfaces have a smooth surface at the micrometer scale, Fig. 10.b. The presence of polymers in WLC can influence the microstructure building as shown in Fig. 10.c and 10.d for both 1.0wt.% of PVA and SBR respectively. It is clear that the rate of cement hydration and the nature and morphology of the hydrate crystals can be changed. The polymer acts as an admixture for concrete and no continuous polymer film is formed. Because of the low amounts of water-soluble polymers added to the fresh mixture, these polymers are generally considered as rheological additives and polymer film formation is not mentioned. Furthermore, polymer film formation can take place. For polymer dispersions of 10 wt.% SBR shown in Fig. 10.e, an adequate film formation throughout the cement matrix. The film can play an important role in sealing the high porosity of the adhesive layer. Meanwhile the polymer films are intertwined to form a space network structure. This internal force can make the adhesive concrete as a whole to improve its cohesive strength. So, the gaps are sealed in the contact surface and the bonding between the cement and polymer becomes more dense and firm. When subjected to external force, the emergence of micro-cracks will be prevented due to the flexibility and elasticity of the polymer film.

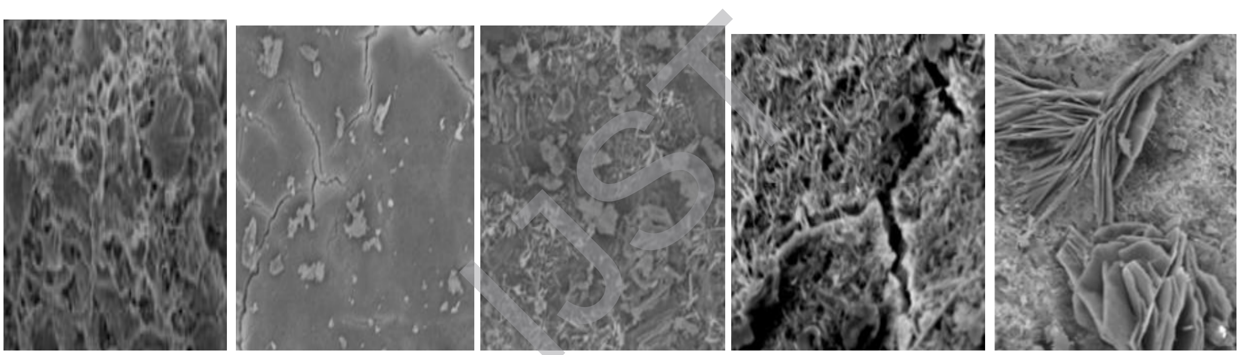


Fig. 10.a Fig. 10.b Fig. 10.c Fig. 10.d Fig. 10.e

Fig. 10. SEM observation of immersed PVA and SBR for the concrete.

(a) Cement paste, (b) 1.0 wt.%PVA, (c) 1.0 wt.%SBR, (d) 15wt.%PVA and (d) 10wt% SBR .

4. CONCLUSIONS

Experimental investigation on the effect of PVA and SBR polymers on lightweight concrete was carried out. Based on the results the following conclusions are made:

1. Both polymers types have a good effect on the compression, flexural and tensile strength of the produced lightweight and with an optimum wt% of SBR and PVA of 10.0wt% and 15.0wt.% respectively.
2. SBR effect on the mechanical properties of concrete is found higher compared to PVA.

3. As the W/C increases, the PLC density decreases.
4. The optimum W/C wt% is 46% with respect to the cement weight.
5. SEM observations deduced that the polymer acts as an admixture for concrete.
6. Also, SEM shows that the gaps are sealed in the contact surface and the bonding between the cement and polymer becomes more dense and firm.

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