Development of Polymer-Modified Concrete Using Ethylene Vinyl Acetate Copolymer

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ABSTRACT: *Coastal area construction provides the biggest challenges in the country's development. Mechanical strength and durability are the two main challenges in coastal areas when compared to conventional construction. The proposed study explores the effect of recycled melamine powder and poly (vinyl-co-ethylene) copolymer on workability, setting time, aggregate-to-cement adhesion, and the effect of moisture and saline water on concrete mechanical properties. Portland cement was sieved and dried sand, and aggregate was mixed in the ratio of 1:2:4 (cement: sand: aggregate) by weight. The three constituents were manually mixed with 40-45 wt. % tap water, based on cement content, until a homogenous mixture was visibly observed. Cylindrical samples with continuous tampering to avoid voids were cast in standard molds of 4"x 8" (100 x 200 mm) dimensions. The molds were covered and left for 24 hours for setting. Unmolded concrete samples were cured for 7 and 28 days in tap water. The concrete samples were dried and stored for further testing. The same concrete samples were prepared with an additional 1 wt. % and 3 wt. %, based on the cement content, of melamine and poly(vinyl-co-ethylene) copolymer. The samples were subjected to water slump height, water permeability, compressive strength and flexural tests, and carbonation test. The results showed a 10 % and 16 % decrease in slump height for 1 % and 3 % loadings, respectively for both polymers when compared to controlled samples. Reinforced concrete showed less water penetration for both polymers due to their hydrophobic nature. Higher compressive and flexural strengths and low carbonation depth were obtained for reinforced concrete irrespective of the polymers used in this research.*

KEYWORDS: *Carbonation test, Compressive test, flexural test, Melamine powder, Portland cement, Poly (vinyl-co-ethylene).*

INTRODUCTION

The addition of polymers has gained worldwide appreciation in the construction industry as they impart enhanced mechanical properties, durability, and lifetime to building structures. On the other hand, high humidity and saline water near coastal areas cause severe damage to constructions and buildings. Even though Pakistan's

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government's new policies have drawn research into the construction industry, the primary focus of current research in Pakistan's construction industry is more on the source of sand and aggregate, their particle sizes, and their proportions. The addition of conventional polymers is also reported in some current research articles for normal building constructions or roads but their use in concrete for harsh environments is overlooked [1, 2]. Coastal areas development is essential for human activities notably for the tourism industry, sea transportation, seawall construction, offshore oil drilling, and many more. Therefore, the coastal area's constructions must follow proper building construction material that will withstand the harsh environmental factors that could lead to severe deterioration in concrete and metal bars used in their construction. Modern concrete admixtures are developed to meet the demands of coastal areas construction such as improved workability, curing agents that shorten or extends the curing times, and reinforcing materials that enhance the mechanical properties of the concrete. Various colors are also added as admixtures to make concrete more attractive and appealing [2, 3].

Polymer-reinforced concretes are prepared in various ways such as Polymer Concrete (PC), Polymer-Impregnated Concrete (PIC), Fiber-Reinforced Concrete (FRC), and Polymer-Modified Concrete (PMC) with improved properties. In addition to the mineral contaminations of cement and aggregates, chloride and sulphate ions in oceans increase the rate of corrosion in concrete in coastal areas. The effect of mineral contaminations, chloride, and sulphate ions is further enhanced due to the porosity of concrete. The porosity of concrete also provides a path to the moisture, carbon dioxide (CO_2), and oxygen that leads to the corrosion of steel reinforcement in the presence of the above ions and severe damage to the constructions of the coastal area. Carbonation, the chemical reaction between CO_2 and calcium hydroxide and hydrated calcium silicate in concrete, decreases the pH of concrete and depassivation in the presence of a high concentration of chloride ions in steel which results in steel corrosion. The corrosion of steel leads to severe damage to concrete. It is reported that CO_2 is enhanced in the presence of high coastal winds and moisture content in the air [2, 4].

The ability of a porous material to absorb and transfer water through its capillaries can be measured by water absorption. A higher capillary force results in a faster rate of water absorption which is observed for the lower degree of saturation and larger pores volume and number of empty pores. The effect of water-to-cement ratio, aggregate/sand-to-cement ratio, and quantity of admixture on the morphology of concrete. The authors revealed that an increase in porosity was observed for a higher water-to-cement ratio. The authors claimed that higher porosity leads to more water absorption and hence loss of concrete strength due to the crack initiation and propagation in the concrete which ultimately causes concrete failure [5, 6].

Ethylene-vinyl acetate copolymer (EVA) is synthesized *via* free radical polymerization from ethylene and vinyl acetate monomers at high pressure. The properties of EVA can be varied by varying vinyl acetate content in copolymer. It is reported that EVA not only increases the setting time and workability but also reduces crack initiation. The adverse effects in tensile properties and density are observed for higher loadings of EVA in concrete. On the other hand, EVA is also not cost-effective being a commercial product. Recycled melamine powder with a small quantity of polyvinyl alcohol (PVA) is used as an alternative to EVA to reduce the cost and compare its effect on concrete properties with EVA. Melamine possesses excellent hardness, scratch and abrasion resistance, thermal stability, and moisture resistance. The properties of melamine can be combined with excellent water solubility and film-forming characteristics of PVA to improve the dispersion of melamine in concrete. Hard concrete is obtained by the hydration reaction by the three main ingredients of concrete namely aggregates or gravel, cement (most commonly Portland cement) and water. The effect of recycled coarse aggregate and sea sand on the mechanical properties of freshly prepared concrete was studied. The authors reported a higher flexural strength but the concrete could not resist the early crack propagation. In another study variation in the strength and durability of concrete notably for the aggressive environment is reported for changes in the mix design ratio and the water-cement ratio [7, 8].

The ratio substantially affects the workability of concrete due to the increased number of voids. The increased voids provide easier penetration of aggressive ions consequently causing a loss of concrete strength. Additional materials that are added to normal ingredients of concrete to improve its properties in freshly prepared concrete or hardened concrete are called admixtures. The admixture is used to modify hydration time or setting time, dispersion, workability and reduction in moisture, aggressive ions and CO_2 or air penetration, chemical resistance, and mechanical properties. Previous literature reported that superplasticizers can be used instead of plasticizers for the reduction in water usage by up to 30 % in concrete with enhanced homogeneity, cohesiveness, strength, and performance [3, 9]. Retarders are also reported as admixtures to slow down the hydration process that improved the workability of concrete for an extended period. The increase in compressive strength is also observed in the concrete containing retarders. The early strength development in concrete is reported for accelerating admixtures, mostly sulphates other than calcium sulphate. The accelerator admixture reduces the curing time for fast construction notably emergency repair work [10, 11]. Segregation in concrete is reported for a higher cement-water ratio which leads to poor workability. The authors used a combination of water reducer and plasticizer to improve workability and reduce the water-cement ratio. Pore-forming agents or air-entraining agent compounds are added during cement manufacturing or preparation of admixture concrete to entrain air in the concrete. The pore-forming agents improve the properties of fresh and hardened concrete by integrating millions of non-coalescing air bubbles (< 0.55 mm diameter) that act as a flexible bearing consequently modifying the workability, segregation, bleeding quality of fresh concrete, and finishing quality of hardened concrete [2, 12, 13].

To avoid pores in conventional concrete, polymer concrete uses polymers as a supplement for cement binders in conventional concrete is explored in the literature. The researchers used polymer impregnation to avoid voids in their polymer concrete. They used polymer fibers as reinforcing material for the preparation of their fiber-reinforced concrete (FRC). They observed an increase in the structural integrity of their concrete due to the uniform distribution and random orientation of their polymer fibers in the concrete matrix. The authors claim retardation of the crack propagation and improved service life [14, 15]. In PMC concrete polymers are added during the mixing of concrete in the form of an emulsion or re-dispersible powders and this is the cheapest method of polymer reinforcement. Improvement in mechanical properties, abrasion resistance, high durability, aggressive ions, and weather resistance are reported for PMC. [16, 17]. The corrosion of concrete can be avoided using PMC is reported. The author showed that the addition of EVA polymer drastically reduces slump height and density, reduces its pore size, and increases workability in fresh concrete. In a very recent study polymer powders are used in concrete as cement modifiers and binders to decrease the average pore size. The decrease in pore size reduces the penetration of aggressive ions in the concrete consequently rebar corrosion, a type of corrosion in concrete where chloride ions corrode steel bars, is reduced or avoided. A substantial decrease in carbonation depth (approx. 50%) is reported in concrete using only 2 5 nano-silica used 2 % nano-silica to reduce the in their concrete [3, 9, 11].

An increase in concrete compressive and flexural strengths below 4% EVA content is reported. The increase in properties is attributed to the dispersion property of the polymer which forms an insoluble film in the cementation medium of concrete whereas the decrease in concrete properties at 4% or above is due to the decrease in concrete density. In another study, a decrease in the voids is reported by the addition of EVA forms an adhesive layer between cement and aggregates. The adhesive layer increases the binding force between the two ingredients of concrete. The decrease in tensile strength and reduction in crack propagation is observed at higher loadings of the EVA. However, crack propagation is much lower when compared to conventional concrete. Some researchers used melamine powder as a partial replacement for cement in concrete in the range of 5 to 30 %. The highest compressive strength was observed at 25 % melamine loading. It is concluded that the use of additives notably recently discovered EVA is essential for future concrete with enhanced mechanical properties, durability, and service life of constructions. However, limitations of EVA include its high cost, low loadings, and availability of less literature notably for its applications in coastal areas. The present study not only explores the possibility of EVA applications in coastal areas but also makes use of recycled melamine powder along with a small amount of water-soluble PVA to reduce the cost of the concrete [4, 18].

Table 1: Mixing proportion and sieving of concrete

Mixing Proportion of Concrete	
Weight of cylinder	3.5 to 3.8 kg [ideal 3.5 kg]
Total weight of the mixed design	70 kg
Weight of cement	70/7 = 10 kg (1+2+4=7 sum of ratios)
EVA powder / Recycled melamine powder	1 wt. % (100 g) or 3 wt. % (300 g) based weight of the cement
Remaining	70 – 10 = 60 kg (aggregates = sand +gravel)
Weight of sand	70 x 2/7= 20 kg sand
Weight of gravel	70 x 4/7 = 40 kg
Weight of empty mold	Approx. 1 kg
Sieving of Concrete	
Sieve mesh size (aggregate)	½ inch
Sieve mesh size (sand)	10 mesh

EXPERIMENTAL SECTION

All the ingredients used in this research were commercial grade and used as received. The ingredients include ordinary Portland cement (OPC), aggregate (½ inch), sand (10 mesh), EVA (Vinnapas® 4115N, Wacker Chemie AG, Germany) powder, and melamine powder. Polymer samples were dried till constant weight in an oven and stored in a desiccator before use. The focus of this study is to explore the mechanical strength and durability of concrete for coastal areas applications. Material selection, mixed design proportion, and standard testing procedures for coastal areas are the main focus of the study. Preparation of concrete samples followed a mix design of M15(a grade of concrete), curing timings of 7 and 28 days were selected as standard curing timings, and standard ASTM, and DIN testing procedures were followed as desired by the required test [2, 3]. The controlled samples (samples without polymers addition) will be compared with reinforced concrete (containing 1% and 3% of polymers that is commercial EVA powder and melamine powder based on the weight of cement). The materials used in concrete are ordinary Portland cement, silica stoneware (coarse aggregate), silica sand (fine aggregate), and water. The proportions of Portland cement, fine aggregate, and coarse aggregate were 1:2:4 by ASTM C150 [19, 20]. All ingredients were mixed via physical mixing using the conventional concrete method. Details of mixing proportion and sieving of concrete are shown in Table 1.

Fourier Transform InfraRed (FT-IR) spectroscopy

By observing the unique radiation retention of each particle in the sample, a variety of tools can be used to identify the presence of a functional group in a particle. FT-IR spectroscopy is perhaps the most widely used spectroscopic technique due to its versatility in defining comparison, tacticity, adaptation, and crystallinity among other characteristics. Numerous spectroscopic techniques are now available to get to these highlights. However, to fully investigate this method's capabilities, a few skills are required for developing a method that will streamline the examination. This commitment presents an exploratory method for obtaining spectra that examines the capabilities of the required Nicolet iS50 FT-IR, including a variety of different finders and the possibility of working in a vacuum, which improves the quality of the spectra and reduces impedances and spectral commotion caused by carbon dioxide and moisture retention in the environment.

Slump test

The slump test is an indirect method to check the correct amount of water by measuring its consistency and fluidity. The slump test was performed as per guidelines provided in ASTM C143/C143M [10, 21]. The testing mold of the slump cone has a 20 cm diameter of the opening where the paste is first poured. The height of the cone is 30 cm and the base side is 10 cm in diameter. A metal plate is also used where the slump cone is inverted and measured. The tampering rod of 16 mm diameter and 0.6 m is also used. First, thoroughly grease the mold and fill the fresh concrete, now invert the mold on the metal plate. Measure the slump height of the concrete plate from the scale and subtract it from the original height of the slump cone. The greater the difference the more workable the fresh concrete paste.

Compressive strength

The standard of this test is ASTM C39/C39-M [2, 4]. The test specimen has a size of 100mm x 200mm. Generally, compressive strength depends on respective mixed proportions and required grades ranging from M15 to M70. In this research, we are following M15 standards which give an average strength of 2200 psi. Cylindrical molds are greased first to avoid any sticking of freshly prepared concrete. The freshly repared concrete is filled in the mold in four layers with each layer uniformed by tampering from the vibrator. After the mold is filled level up the surface. After 1 day the mold is removed and two samples from each batch were prepared and cured for 7 and 28 days with an average temperature of 30 ˚C. Then the sample is placed on a compression testing machine. The load is applied at a rate of 140 kg/min. Note the reading where the sample ruptures. The dimensions of the cylinder were 100x200 mm. The testing condition should be at room temperature. Compressive strength is determined using the formula in Eq. (1).

$$Compressive\ Strength = \frac{Load}{Area} \quad (1)$$

Flexural test

This test is an indirect method for measuring the tensile strength of concrete. The test is performed with a sample size of 100mm x 100mm x 500mm. The flexural strength of concrete is determined by two-point loading or central point loading. Here are following the two-point method. In the case of two-point loading, the upper set of rollers is set at 200 cm or 133 cm center to center. The flexural test was performed as per the standards of ASTM C293/C293M-16 [2, 3]. Flexural beams are prepared in 100 mm x 100 mm x 500 mm prism. Freshly prepared concrete is filled in this prism followed by tampering through the vibrator. After 1 day the prism is detached and the sample is placed in the curing tank where it stays for 28 days with an average temperature of 30 °C. T he loading is applied from the testing machine at the rate of 180 kg/min with a loading rate of 0.005 mm/min. Finally, note down the load where the beam cracks. Mark the point where the crack propagates and measure its distance from the nearest lower knob, call this distance ‘a’. If ‘a’ > 130 mm for 100 mm then flexural strength or modulus of rupture is calculated by Eq. (2). If ‘a’<130 mm and ‘a’>110 for 100 mm then flexural strength or modulus of rupture is calculated by Eq. (3) [4, 22].

$$f_b = \frac{P*L}{bd^2} \quad (2)$$

$$f_b = \frac{3Pa}{bd^2}. \quad (3)$$

Where; P= maximum load applied, L= supported length, d= failure point depth, b = width of the beam in mm, and a=distance between the line of fracture and nearest support.

Water permeability

The water permeability test was executed as per the standards of DIN-1048 [4, 10]. The permeability test measures the case with which liquids ions and gases can penetrate the concrete. The concrete permeation apparatus consists of a permeation cell, pressure gauge, supply of de-aired water, vacuum pump, and hollow rubber. Place the sample in the permeation chamber after 28-day curing, de-aired water is supplied at a constant pressure of 5 bar. The samples are left in these chambers for 72 hours after that the samples are broken by the split tensile method. Measure the depth of water permeated into the sample. Take the average of the samples.

Carbonation

The carbonation test was executed as per the standards of RILEM CPC-18 [9, 14]. Carbonation may be simply known by spraying a core’s surface with a suitable indicator to identify the loss of alkalinity which is associated with the protection of the rebar enforcement in the concrete structure. Future progression of carbonation can also be predicted in an accelerated carbonation chamber where samples are placed after 28 days of curing. Phenolphthalein solution is used as an indicator. Phenolphthalein simply gives purple color if there is any presence of carbon dioxide gas absorption in the sample that part of the concrete will not be purple. It can simply measure the depth of carbonation by measuring the length of the uncolored area of the sample. The work aims to analyze the mechanical strength of the concrete under normal conditions. This will help us to predict and compare the differences between normal and coastal conditions. The aim is to enhance the properties of concrete while making it durable against harsh coastal conditions [21, 22].

RESULTS AND DISCUSSION

These results show the comparison between the EVA (commercial polymer) and melamine powder (replacement) and in what ways this replacement is compatible with the commercialpolymer. For this purpose, five batches with different percentages of EVA and melamine powder were cast.

Table 2: Peak positions of FTIR for ethylene vinyl acetate

Functional groups	Peaks (literature)	Peaks (results)
–OH (hydroxyl group)	3300	3355
-C-H (methylene group)	2956, 2887	2938, 2871
–C=O (carbonyl group)	1736	1730
$-CH_2$ (near ester group)	1237	1229

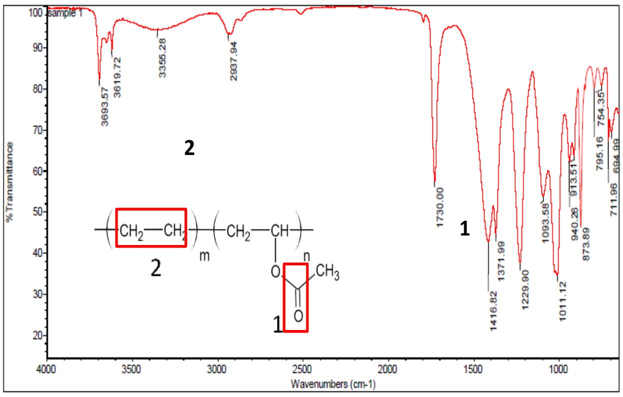

Fig. 1: FTIR of ethylene vinyl acetate where the number 1 represents the position of a carbonyl group and number 2 represents the ethylene unit in the marked EVA structure

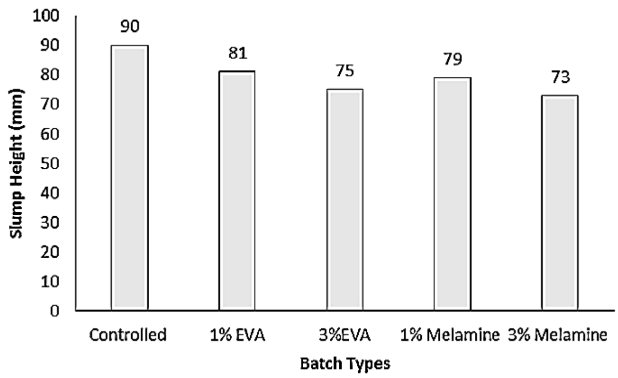

Fig. 2: Slump height of different batches

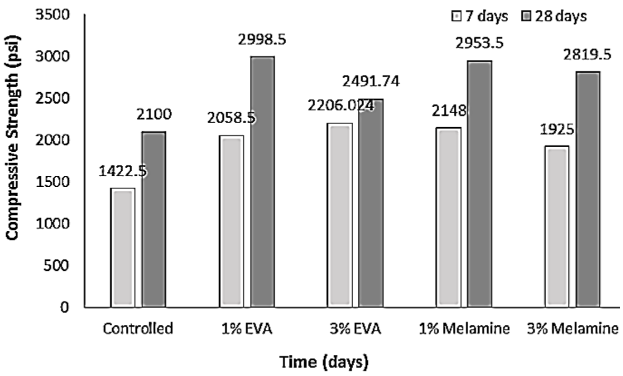

Fig. 3: Compressive strength comparison of different batches

Comparison of EVA FT-IR with literature

The functional groups in EVA were verified using FT-IR in ATR mode. The solid sample (resin powder) was placed below the FT-IR probe and the spectra were recorded with 32 scans with a resolution of 4 cm^{-1}. The wavelength range is from 690 to 4000 cm^{-1}. The characteristic peaks recorded for –OH (the hydroxyl group), the –C=O (carbonyl group), –C–H (methylene group), and $-CH_2$ (the methylene group) near the ester group are obvious in Fig. 1. Table 2 summarizes the characteristic peak positions along with their functional group. The trend of the FTIR shows that the peaks of the sample FTIR are much similar to the EVA containing 18% vinyl acetate content [23].

Slump height

Slump height is an important property for determining the workability of concrete. The slump height of the five batches was measured and shown in Fig. 2. It is observed that the slump height decreases with an increase in polymer content irrespective of the nature of the polymer at least for those polymers that have been used in this study. The decrease in a slump due to the higher loadings of polymers might be attributed to the dispersion of water in the concrete. Similar behavior is also reported in the literature for the higher loadings of EVA. However, the decrease in their slump height was more than 50 % for 5 % loadings of EVA. This research reports a 10 % and 16% decrease in slump height for 1% and 3% EVA loadings, respectively. A similar decrease in melamine-reinforced samples is observed. The decrease in slump height by the addition of polymers might be attributed to the increased workability of concrete which will give us several advantages without any negative impact on the mechanical strength of concrete [9, 13, 16].

Compressive strength

Compressive strength is the most vital factor for analyzing the quality of concrete prepared. Either for load-bearing or non-load-bearing applications. The dimension of the cylinder is 4x8 $inches^2$. Fig. 3 presented compressive strength and the curing time (7 and 28 days). It shows that the average compressive strengths of the polymer-reinforced batches attain early strength than the controlled batch and after complete curing the compressive strength of polymer-reinforced batches is EVA and melamine

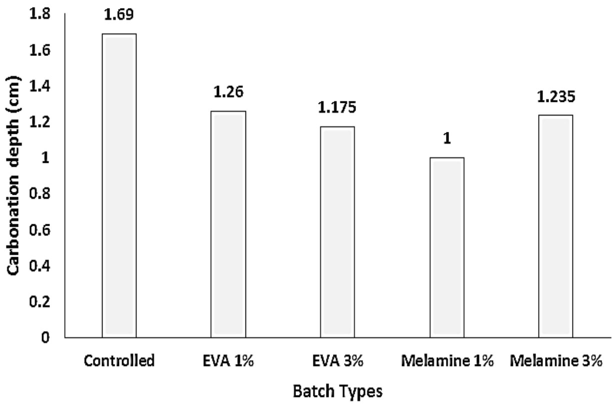

Fig. 4: Carbon dioxide gas resistivity of different batches

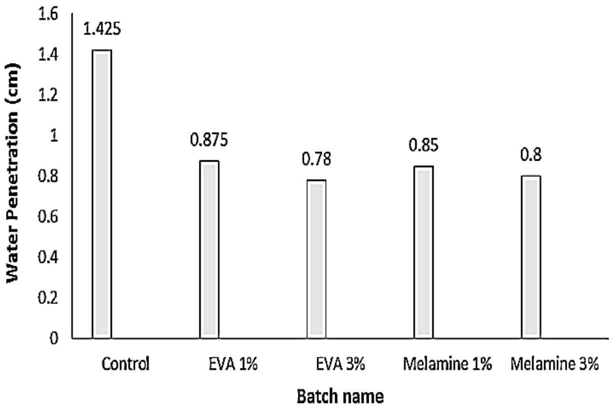

Fig. 5: Water permeation of different batches

powder respectively. It also documented a similar behavior for higher compressive strength of EVA-reinforced batches than the controlled batches shown in the literature [23, 24]. This is due to the binding properties of both polymers that reduce the void spaces in concrete and strengthen the bindings of the cementations medium in concrete [7, 11].

Carbonation

The carbonation test shows the penetration of CO_2 gas in the concrete sample with time. Penetration of CO_2 is greatly affected by the cement loadings and their type, moisture, CO_2 concentration, and water-to-binder ratio. However, there are no limits defined for the penetration of CO_2 as different values are reported by several researchers. The test was performed in an accelerating carbonator apparatus. The samples were kept for 67 hours equivalent to 3 months in a carbonation chamber to determine the CO_2 penetration depth. The obtained results for the carbonation test for 5 different batches are presented in Fig. 4. It is evident that both the polymers show lower penetration of CO_2 at 1 wt. % and 3 wt. % loadings when compared to the control sample. Melamine powder shows better penetration resistance of CO_2 when compared to commercial EVA powder notably at 1 wt. % loading. The better performance of polymer-loaded samples is attributed to the uniform dispersion and reduced pore size of the voids in the concrete [25, 26]. Similar results are also reported in the literature for the various EVA loadings. It is concluded that melamine powder can be used instead of commercial EVA for the reduction of cost and improved performance even at lower loadings, especially where CO_2 penetration resistance is essential [9, 11, 14].

Water permeability

The water permeation test determines the water penetration resistance of the concrete sample. If the resistance of the sample is not good enough, the concrete will lose its mechanical properties drastically. A water permeability test is performed in a permeation chamber where the samples are placed and adjusted. Water at a constant pressure of 5 bar is sprayed at the top smooth surface of the concrete. The samples are left for 72 hours (3 days) in the permeation chamber. Then the samples are taken out for a split tensile test where the sample is split into two halves from the surface. The wet areas are marked with chalk and the mean is taken for all the samples. Tests were performed on 5 different batches. Fig. 5 shows that reinforced polymer samples (EVA and melamine powders) have less water penetration than the control batch. The reason behind this result is the hydrophobic nature of both polymers as shown in the literature previously, especially for melamine powder. In addition, EVA also possesses the dispersion property which enables it to form insoluble films in the cementations medium. Both polymers are moisture resistant and will hinder water propagation in the concrete samples [9, 10, 18].

Flexural strength

Flexural strength indicates the resistance to impact loading. The loading is applied from the testing machine at the rate of 180 kg/min with a loading rate of 0.005 mm/min. Finally, note down the load where the beam cracks. Table 6 Flexural Strength Test Results. Fig. 6 shows that the flexural strength increases with an increase in polymer content

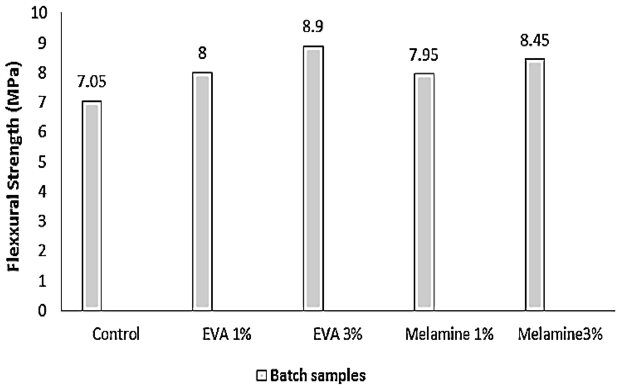

Fig. 6: Flexural strength of different batches

irrespective of the nature of the polymer at least for those polymers that have been used in this study. Reported in the literature similar results for the higher loadings of EVA. A similar increase in melamine-reinforced samples is observed. The increase in flexural strength by the addition of polymers might be attributed to the impact properties of the polymer irrespective of the type used in these samples [7, 9, 11, 17, 20].

CONCLUSIONS

It was perceived from the results, that the slump height decreases with an increase in polymer content making it more workable irrespective of the nature of the polymer at least for those polymers that have been used in this study that as EVA and Melamine. This research reported a 10 % and 16 % decrease in slump height for 1 % and 3% EVA and melamine loadings, respectively. The following results show the higher workability of freshly prepared concrete paste. The results we obtained after curing the concrete for 7 and 28 days for polymer-reinforced batches (EVA and melamine) at different loadings (1% and 3%) were better as compared to controlled samples. The obtained results prove the concept of the binding property of polymers in cementations mediums which ultimately increased the strength of concrete. Improved flexural strength was observed for polymer-containing concrete. For water permeability, the obtained results show that reinforced polymer samples (EVA and melamine powders) have less water penetration than the control batch. The reason behind this result is the hydrophobic nature of both polymers. Both polymers possess good moisture resistance. Finally, carbonation results show that the EVA polymer gives better penetration resistance against CO_2 gas. This is because the EVA polymer forms dispersion in the cementations medium due to its re-dispersible properties in water which will result in reduced pore size distribution. Melamine as a replacement also showed good carbonation resistance as it also reduces the pore size distribution in the cementation mixture in concrete. However, there are some future recommendations; the Half-cell potential test is the only corrosion observing method standardized in ASTM C876 – 15. It is used to determine the possibility of corrosion within the rebar in reinforced concrete structures. Before the half-cell potential test, another test is performed called the salt spray test. This test is performed as per the standards of ASTM B117-2009. The specimen used was a 100 x 200 mm sized cylinder embedded with a 450 cm steel rod. The embedded depth is about 100 cm, while 350 mm will remain outside the cylinder. A pull-out test measures the force required to pull out the shaped rod whose one end has been cast into the concrete from that concrete. The stronger concrete more force is required to pull out concrete. The pull-out forces applied by the pull-out tester are resisted by shear stress and normal stress of concrete. As the pullout force overcomes these stresses the rod moves apart from the concrete. The reading is noted from the machine gauge. The specimen used was a 100 x 200 mm sized cylinder embedded with a 450 cm steel rod. The embedded depth is about 100 cm, while 350 mm will remain outside the cylinder. Polymer-modified concrete develop that is resistive to water penetration and CO_2 absorption with good mechanical properties, which have been achieved successfully.

List of abbreviations

PIC	Polymer impregnated concrete
PMC	Polymer modified concrete
FRC	Fibre reinforced concrete
PC	Polymer concrete
SP	Super plasticizers
ASTM	American Society for Testing and Materials
RPC	Reinforced polymer concrete
PE	Polyethylene
EVA	Ethylene vinyl acetate
RDP’s	Re-dispersible polymers
VAEC	Vinyl acetate and ethylene copolymer
SSC	Sea water and sea sand cement
W/C	Water to cement ratio
S/C	Sand to cement ratio

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