




Research Article

Production of Plastic Cement Concrete from PVC Waste

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Abstract: The disposal of plastic wastes into the environment is a serious concern due to its limited biodegradability and production in excess quantity. The accumulation of enormous volumes of plastic waste is considered to be a major pollution problem and it is essential to find an alternate method to address such issues in an environmental-friendly and cost-effective way. The current research focused on the production of plastic cement concrete from waste polyvinyl chloride (PVC) generated from a polymer processing industry in varying proportions, and to modify the concrete properties. Polyvinyl chloride was partially replaced with Ordinary Portland Cement (OPC) by varying its compositions from 15% to 35% by weight (i.e. 15%, 20%, 25%, 30% and 35% OPC). The curing period was kept for 7 days after casting process. The produced plastic cement concrete was tested for compressive strength through Universal Testing Machine (UTM). Density and water absorption tests were also carried out on hardened concrete to assess the application of plastic cement concrete as a building material. The other characterization techniques employed are Fourier Transform Infrared Spectroscopy (FTIR) and X-Ray Diffraction (XRD) analyses. It was observed that up to 15% by weight of polyvinyl chloride could be replaced with OPC which exhibited higher compressive strength (19.25 MPa) compared to other mix proportions. A maximum density of 2.051 g/cm³ was obtained at a concrete mix composition corresponding to 25% replacement. The maximum water absorption percentage (5.86%) was observed at 35% plastic waste replacement. The studies demonstrate that the waste plastic material is considered to be a cost-effective, viable and sustainable way of reducing the environmental pollution.

Keywords: non-biodegradability, concrete mix, disposal, plastic cement concrete, Portland cement, polyvinyl chloride

Nomenclature

PE	Poly Ethylene
PVC	Poly Vinyl Chloride
PP	Poly Propylene
EP	Expoxide
PUR	Polyurethane
PF	Phenol Formaldehyde

OPC	Ordinary Portland Cement
UTM	Universal Testing Machine
XRD	X Ray Diffraction
FTIR	Fourier Transform Infrared Spectroscopy
ACI	American Concrete Institute

1. Introduction

The consumption of plastics in the world has increased to 5 million tons every year. Consequently, a huge amount of plastic is discarded as waste, which leads to environmental and health issues due to the lack of environmental-friendly disposal methods. Environmental and Civil/Construction engineers and researchers are trying to find appropriate remedial measures to address this issue by adopting eco-friendly methods for the disposal and recycling of waste. The majority of the countries is employing land filling method for disposing of plastic wastes, which is harmful to the environment.¹ The usage of plastic and its composites is still intensifying quickly due to their easy-availability, low-cost and simple processing techniques. Therefore, a large quantity of waste plastics are being dumped into the atmosphere, thereby experiencing major challenges in the disposal techniques.² The disposal of plastics by landfills results in the contamination of ground water with the generation of methane gas, which is one of the main causes of global warming. The recent statistics indicate that nearly 5 trillion tons of toxic plastic waste materials are being dumped into the ocean, posing a threat to marine life, animal and birds. One of the eco-friendly methods employed in the disposal of high-density polyethylene waste was to use the combination of polyethylene waste and ordinary Portland cement. The outcome of the study demonstrates that the production of plastic cement concrete using 60% polyethylene waste and 40% OPC generated good quality cement concrete. Quarry dust and polyvinyl chloride powder as a fine aggregate were added into the concrete mix and the results illustrated a reduction in the production cost and an increase in the strength and durability of concrete. The best result after two processing stages indicated a 20% replacement of polyvinyl chloride. These results showed an increase in the compressive strength and elastic modulus of the concrete.^{3,4} Oil Refinery waste was considered as an additive in concrete mix to enhance the mechanical and physical properties. The research results revealed that the presence of the additives will enhance the resilience of the concrete and increase its density, frost resistance, porosity, compressive strength, and water absorption capability. The study supported lowering the unit cost, limiting waste generation and reusing the same in an eco-friendly way.⁵ The catalysts from the fluid catalytic cracking unit are mixed with cement to enhance the compressive strength of concrete and the study indicates a rise in compressive strength.⁶ A number of studies have been carried out to enhance the properties of self-compacting concrete using varieties of fly ash, slag, and fumed silica coupled with recycled coarse aggregates.⁷⁻¹¹ However few studies have been reported on the application of natural pozzolana in the form of volcanic ash (VA) for the production of vibrated cement concrete VCC as well as self-compacting concrete SCC.¹²⁻¹⁴

Due to the larger demand for plastics for various applications, many polymer processing industries face difficulties in disposing of huge volumes of waste materials. Dumping plastic waste into the environment by domestic and landfills is considered a major challenge. The sustainability of most of the polymer processing industries depends on the selection of recycling and reuse options and hence, reusing plastic wastes can be helpful to solve major environmental issues and also can limit the wastage of resources.¹⁵⁻¹⁷ The key advantage of plastic recycling in concreting is to enhance the tensile strength, creep strength, chemical resistance, and shrinkage during dry.² Sustainable and green techniques can minimize the adverse effects of greenhouse gas emissions by maximizing profit and also protecting the environment.¹⁸ The compressive strength and workability of the concrete were diminished due to the changing proportions of concrete mix with plasticizers. Application of polyethylene terephthalate waste as a partial replacement to cement showed a reduction in compressive strength and weight of the concrete.^{19,20} Also if the proportions of polyethylene terephthalate exceed 50% by volume of sand, then there was a decrease in the density and compressive strength of concrete.²¹ The main approach to suppress carbon dioxide emission is recycling and reuse of building materials and use of environmentally friendly and low-cost substances.^{22,23}

Aluminium powder and plastic wastes are commonly mixed with concrete for the preparation of lightweight concrete Aravind and Abdulrehman²⁴, Based on the study conducted by Sifatullah et al.²⁵, plastic wastes can be used as a substitution material (plastic aggregate) or an additional material (plastic fibers) to mortar/concrete mixtures. A recent

study conducted by Castillo et al.²⁶ reported that synthetic aggregate manufactured from plastic waste can be used to prepare lightweight concrete. Mustafa et al.²⁷ have demonstrated an experimental and numerical investigation of the influence of partial replacement of coarse aggregates by plastic waste. Ravikumar et al.²⁸ selected polyvinyl chloride (PVC) to replace the coarse aggregate in the concrete to increase its strength. The replacement percentages were 15%, 20% and 25%, and tested for three different time periods of 7 days, 14 days and 28 days. It was observed that the higher compressive strength for the concrete at 20% after the periods of 7 days and 14 days, with 22.22 N/mm² and 25.88 N/mm² respectively. Therefore, the partial replacement of coarse aggregate with PVC showed an increase in compressive strength and split tensile of concrete with the increase in PVC percentage. Kolhapure et al.²⁹ studied the capability of making eco-friendly concrete by replacing the fine aggregate with waste bottles made of polyethylene terephthalate. The replacing percentages that have been studied are 1%, 1.5%, 2%, 2.5%, 3%, 4%, 5% & 6%, and the curing period was 28 days. The results of the study showed an increase in the compressive strength at 4% replacement and an increase in split tensile and flexural strength at 2% replacement. Shadrack et al.³⁰ studied the possibility of mixing the oil sludge with demolition waste as a building material in Tanzania. The Aqua regia digestion extraction method was employed to determine the elemental concentration of the oil sludge, where 3 parts of hydrochloric acid and 1 part of nitric acid have been used. The resulting sludge was mixed with cement and water to form the cement paste. The test result showed an increase in the compressive strength on the cement and the suggested solution helped Tanzania to reduce the area needed to dump the waste oil sludge. Therefore this research focus on the prospects of utilizing plastic waste discarded from polymer processing industries as a construction material in a technologically feasible, economically viable, eco-friendly, and socially acceptable manner. The study also focused on the effect of replacing cement with powdered polyvinyl chloride waste at different compositions on enhancing the mechanical properties.

2. Experimental details

2.1 Materials

Waste Polyvinyl chloride powder was collected from a leading polymer processing company in Oman. PVC powder offers excellent corrosion resistance, good fatigue and wears resistance. The lightweight, non-toxic nature, better resistance to stain, excellent impact resistance, and high tensile strength properties of PVC have attracted considerable attention in the preparation of plastic cement concrete. The fine aggregate, coarse aggregate, and OPC were purchased locally. The concrete mixing process was carried out using a mixer machine. 100T UTM was used to test the compressive strength of concrete. Grain size and crystalline structure was detected using X-Ray Diffraction (Rigaku, and Mini Flex 600), Fourier Transform Infrared Spectroscopy (FTIR- Frontier is Perkin Elmer's) analysis was performed to determine the functional groups present in the sample. The concrete mix was prepared by mixing different proportions of fine aggregate, coarse aggregate, and water as indicated in Table 1. The mix design was prepared using grade C30 normal concrete with a ratio 1:1.7:2.34 as per American Concrete Institute (ACI) code. The required quantity of materials for C30 concrete mix is given in Table 1.

Table 1. The amount of concrete ingredients required for C30 Mix

Ingredients	Cement	Fine aggregate	Coarse aggregate	Water
Quantities, kg	410	699.48	960	205
Ratio by weight	1	1.7	2.34	0.5
Size/Properties	Specific gravity = 3.15	Maximum size = 5 mm	Maximum size = 20 mm	TDS = 400 ppm pH = 7.0

The partial replacement compositions of cement by polyvinyl chloride (PVC) are 15%, 20%, 25%, 30%, and 35% by weight (Table 2). The control mix containing 0% polyvinyl chloride (PVC) was used as a reference for comparison

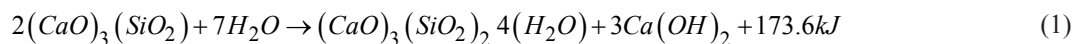
purpose. Three cubes with the total volume of 0.01 m³ were used as a control mix to minimize the errors. In order to avoid cracking or breaking of the cubes, the inner surface of the moulds are coated with oil and hence the concrete mixes can be easily demoulded after the drying process.

The mix design was prepared as per the proportions shown in Table 2. The required weights of all materials are transferred to the concrete mixer machine and mixed for 1 minute followed by manual mixing to get a homogenous concrete mix. The casting of the mould was carried out by filling the three moulds with the concrete mix followed by compacting the concrete and allowed to dry for 24 hours. The concrete mixes are taken out from the mould after drying for a specified period and soaked in water for 7 days (Figure 1) for curing and to examine their stability. Curing is one of the important steps to enhance the strength of the concrete by protecting it from moisture loss during hydration. The hydration of concrete will augment the strength and reduce its permeability and thermal cracks. During the first 7 days, the tri-calcium silicate present in cement is responsible for altering the strength. The hydration reaction releases hydroxide ions, calcium ions, and hence liberates a high amount of heat. As a result, the value of pH increased rapidly to 12.0, due to the presence of alkaline hydroxide (OH⁻) ions.

Table 2. Partial replacement percentages

Batch Design	Weight per cubic meter	Plastic waste replacement					
		0% (Control Mix)	15%	20%	25%	30%	35%
Cement (kg)	410	4.1	3.49	3.28	3.08	2.87	2.67
Plastic waste (kg)	0	0	0.62	0.82	1.03	1.23	1.44
Fine aggregate (kg)	699.48	7	7	7	7	7	7
Coarse aggregate (kg)	960	9.6	9.6	9.6	9.6	9.6	9.6
Water (lit.)	205	2.05	2.05	2.05	2.05	2.05	2.05

The chemical transformation taking place during the curing process is shown in the stoichiometric equation (1).



2.2 Density and water absorption test

After the curing, the cubes are immediately removed from the water for measuring the wet weight (m_w). Then the cubes are taken out and kept for 24 hours to dry it completely, and measure the dry weight (m_d). Figure 1 and Figure 2 represent the images of wet and dry concrete cubes.

The percentage water absorption was calculated using equation (2).

$$W_{Abs}, \% = \frac{m_w - m_d}{m_d} \times 100 \quad (2)$$

Where,

$W_{Abs}, \%$ = Water absorption percentage;

m_w = total wet mass of the cubes in kg;

m_d = total dry mass of the cubes kg.



Figure 1. Wet concrete



Figure 2. Completely dried concrete cubes

2.3 Compressive strength test

The compressive strengths of the cubes are tested using Universal Testing Machine (UTM) as shown in Figure 3. The compressive strength is calculated using equation 3.

$$\text{The compressive strength} = \frac{P \times 10^3}{A}, \text{MPa} \quad (3)$$

Where,

P -Maximum compressive force applied to the concrete cube at which it breaks in kN;

A -Cross sectional area in m^2 .



Figure 3. Compressive strength test on concrete

3. Results and discussion

The production of plastic cement was facilitated by partial replacement of the Portland cement with the polyvinyl chloride (PVC) in cement concrete. The partial replacement of PVC would help to regulate the concrete properties and also to reduce the cost of production. The polyvinyl chloride (PVC) and concrete mix of different proportions were tested using X-Ray Diffraction (XRD) and Fourier Transform Infrared spectroscopy (FTIR). The compressive strength of the resulting product was tested using Universal Testing Machine (UTM).

3.1 Concrete density

The wet and dry densities of the produced plastic cement were estimated and the results are expressed in Table 3. The results indicate that there is a decrease in the density values.

When the plastic waste, Polyvinyl chloride was partially replaced with Ordinary Portland Cement (OPC) by varying its compositions from 15% to 35% by weight, the density of concrete is decreasing in trend. When compared to the control specimen, the dry densities of concrete with 15%, 20%, 25%, 30% and 35% OPC by weight is decreased by 1.91%, 2.40%, 3.24%, 1.90%, 3.52% and 4.87% respectively. The reason for the density reduction is due to the density of plastic waste, which is less than the density of cement. Hence, the concrete with plastic waste can be used as lightweight concrete and the total weight of the structure will be reduced. However, the density of concrete with 25% plastic waste as partial replacement of cement is almost similar to 15% plastic waste replacement. The major factors affecting the densities are the concrete ingredients and compaction. Because of improper compaction, the density behaviour of 25% plastic waste is different from others. The density of concrete mainly depends on the concrete ingredients and porosity in the concrete. In brief, approximately 1% to 2% air content is available in the concrete. Apart from that dry density of cement and polyvinyl chloride are 3150 kg/m³ and 1300 kg/m³ respectively. Porosity and density difference are the major reasons for the reduction in density of concrete with various percentages of PVC waste.

Table 3. Wet and dry densities of plastic cement concrete

Plastic waste replacement in %	Wet density, g/cm ³	Dry density, g/cm ³	Decrease in density (%)
0	2.155	2.114	1.91
15	2.087	2.037	2.40
20	1.983	1.919	3.24
25	2.051	2.012	1.90
30	1.962	1.893	3.52
35	1.970	1.874	4.87

3.2 Water absorption

The water absorption properties of the concrete mix after a curing period of 7 days was determined as indicated in Table 4. The best water absorption percentage was obtained at a proportion of 35% plastic waste replacement, this is due to the higher amount of polyvinyl chloride (PVC) resulted in higher surface area availability compared to the Portland cement. Due to this the polyvinyl chloride (PVC) particles will result in partial coverage of partial aggregate surface and left some empty spaces.

Table 4. Water absorption properties of plastic cement

Plastic waste replacement (%)	0	15	20	25	30	35
Water Absorption (%)	1.92	0.98	3.20	1.93	3.52	5.86

Water absorption property of the concrete with 25% plastic waste as partial replacement of cement is lesser than the 20% plastic waste. There established a relation between concrete compaction and voids in the concrete. Because of improper compaction, the water absorption behaviour of 25% plastic waste is different from others.

3.3 Compressive strength test

The compressive strength of the produced concrete mix of grade C30 was tested after a specified curing period and the results are shown in Table 5. Table 5 indicates that the compressive strength ranges from 21.64 to 12.22 MPa for 0% to 35% mix respectively. The 7 days curing could reduce the compressive strength by 20-30% of the real concrete strength when it was kept for a curing period of 28-day. Therefore, the optimum compressive strength in this test must be kept in the range of 21-24 MPa rather than 30 MPa. The results showed that the compressive strength of the plastic cement exhibited a decreasing trend for an increase in percentages of polyvinyl chloride in the concrete mix. The compressive strength of concrete is depending upon the density of concrete ingredients and additives. The density of plastic waste is lesser than the density of cement. And hence, the compressive strengths of concrete with higher percentages of PVC are reduced when compared to the control mix without any plastic waste. The maximum forces applied to varying compositions of plastic waste are indicated in Table 5. As shown, there is a difference in the strength of the cubes of the same percentage. This may be due to error occurred during the process of mixing, compaction type, type of cement used, quality of the aggregate used, and curing days (7 days).

Table 5. Maximum force & compressive strength of the produced concrete mix

Plastic waste replacement	Maximum force (kN)	Average Compressive strength (MPa)
0%	536.5	21.64
	486.9	
	437.5	
15%	419.8	19.25
	446.5	
	246.8	
20%	336.6	15.18
	441.2	
	283.9	
25%	433.7	16.77
	414.3	
	253.4	
30%	301.3	12.40
	282.3	
	291.0	
35%	239.7	12.22
	294.2	

3.4 Characterization using XRD

The XRD analysis was employed to evaluate the crystalline structure of polyvinyl chloride (PVC) with a diffraction angle (2θ) ranging from 10° to 90° . The diffraction pattern of polyvinyl chloride (PVC) is shown in Figure 4. The highest diffraction peak was observed at a diffraction angle of 24.4° and intensity corresponding to 422 counts. Figure 5 to Figure 10 represents the X-Ray diffraction spectra of the concrete mixes at varying proportions of PVC (i.e. from 0% PVC to 35% PVC). Strong diffraction peaks were seen in the spectra and the peak intensity was observed at 30.60° for 0% mix, 48.4° for 15% mix, 54.16° for 20% mix, 61.2° for 25% mix, 30.16° for 30% mix and 29.20° for 35% mix respectively.

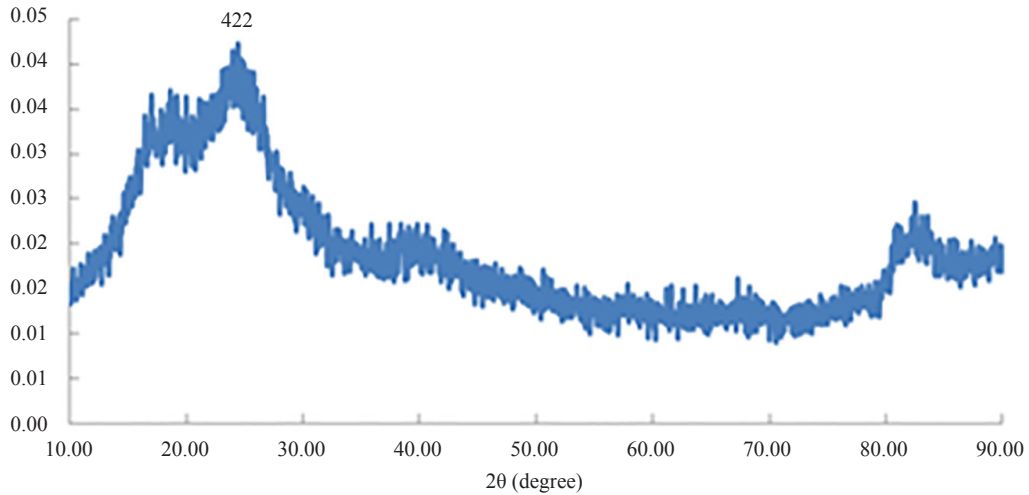


Figure 4. X-ray diffraction pattern of PVC

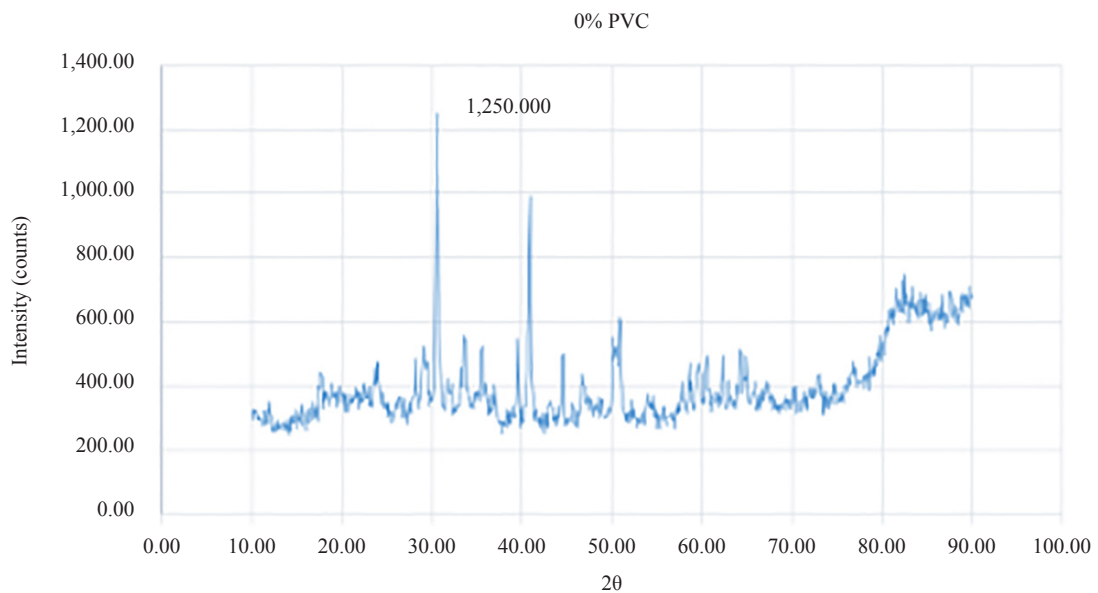


Figure 5. X-ray diffraction pattern of concrete mix with 0% PVC

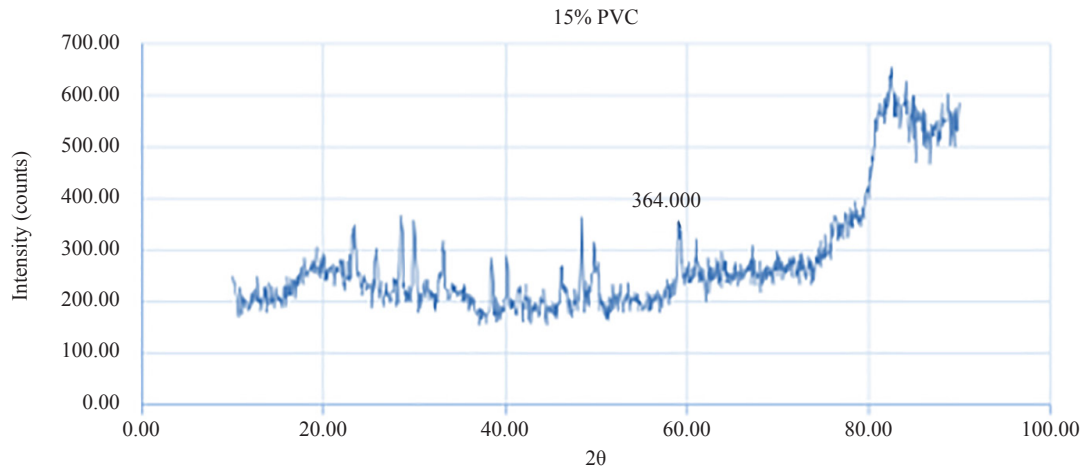


Figure 6. X-ray diffraction pattern of concrete mix with 15% PVC

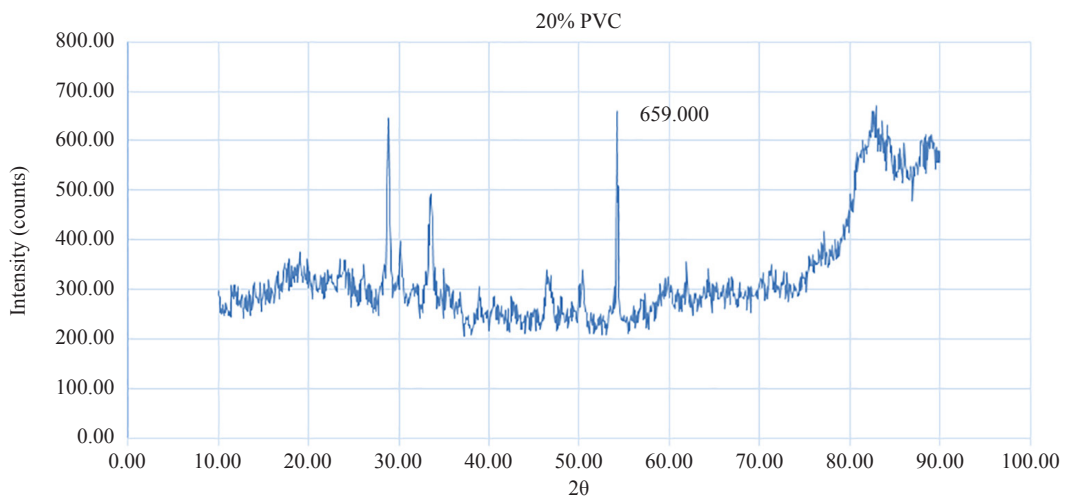


Figure 7. X-ray diffraction pattern of concrete mix with 20% PVC

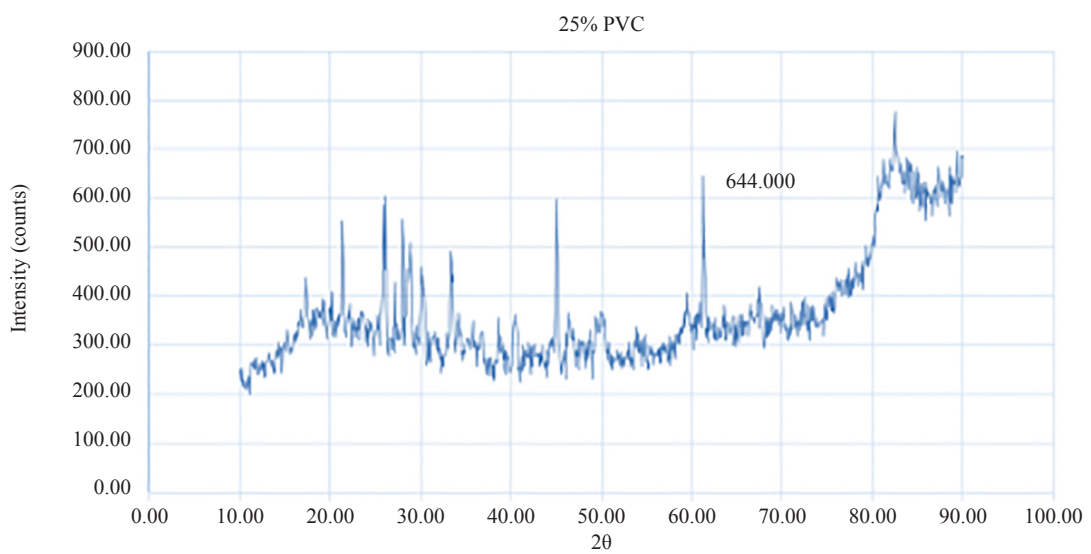


Figure 8. X-ray diffraction pattern of concrete mix with 25% PVC

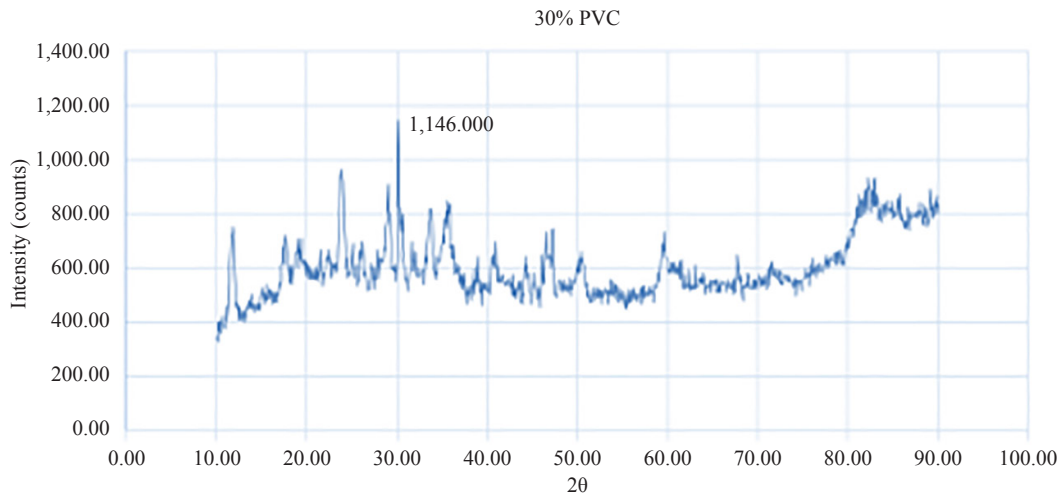


Figure 9. X-ray diffraction pattern of concrete mix with 30% PVC

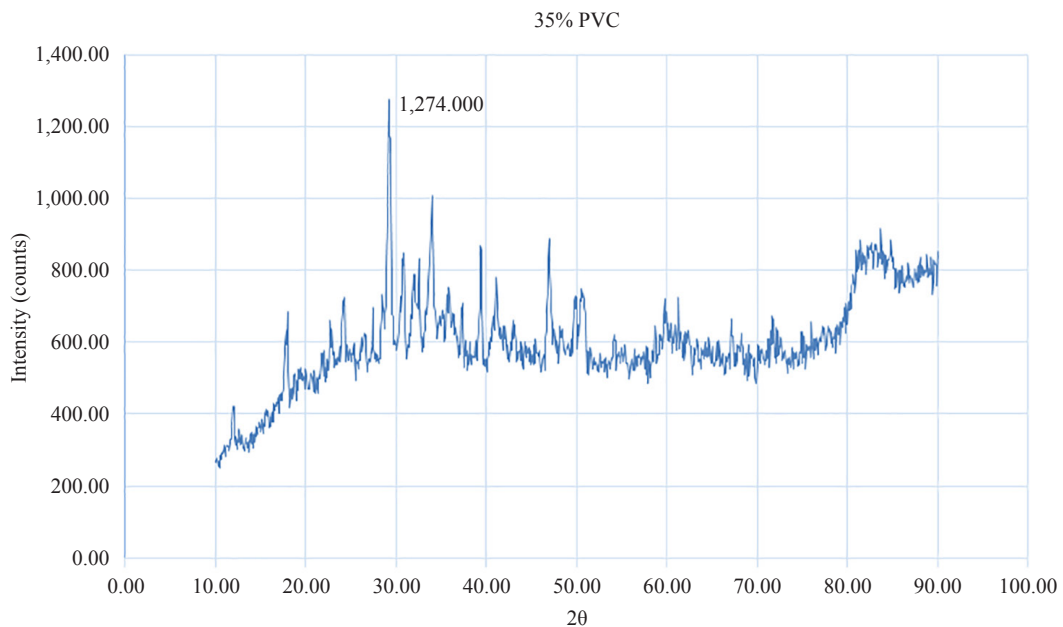


Figure 10. X-ray diffraction pattern of concrete mix with 35% PVC

The intensity has highest and reached approximately 1250 counts at 30.60° for 0% mix, 364 counts at 48.4° for 15% mix, 659 counts at 54.16° for 20% mix, 644 counts at 61.2° for 25% mix, 1146 counts at 30.16° for 30% mix and 1274 counts at 29.20° for 35% mix.

3.5 Fourier-Transform Infrared Spectroscopy (FTIR)

FTIR spectroscopic analysis provided the properties of concrete mix and in-situ monitoring of hydration reactions. Figure 11 shows the FTIR spectra and characteristic absorbance bands of pure polyvinyl chloride. The spectroscopic analysis was conducted at room temperature with wavenumber ranges from 4000 cm^{-1} - 400 cm^{-1} . The FTIR analysis showed a stretching vibration of SiO_4 tetrahedra for slag at 956 cm^{-1} .

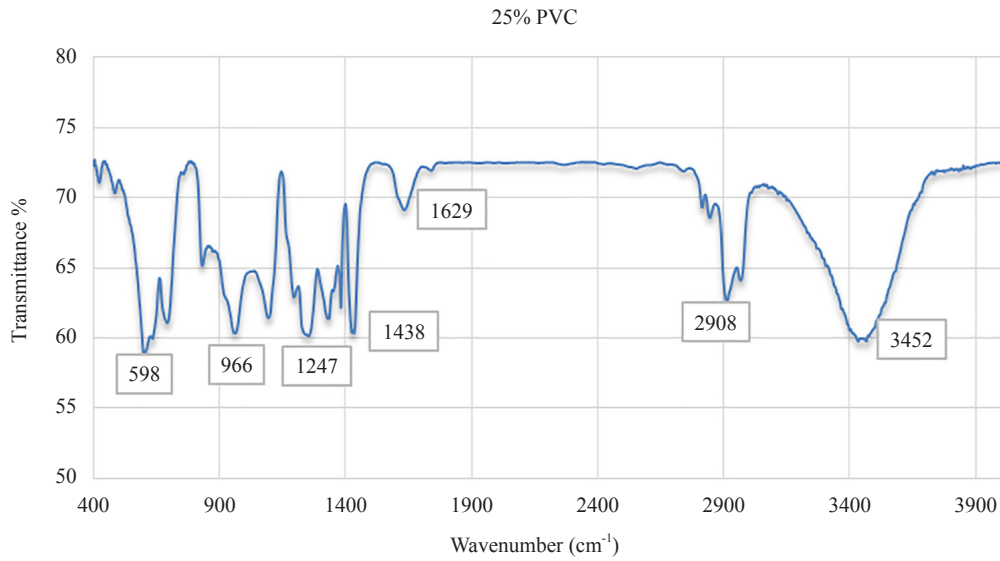


Figure 11. FTIR spectra of PVC

In Figure 11, the absorption peak of polyvinyl chloride (PVC) was found at the wave numbers corresponding to 1438 cm⁻¹ and 3452 cm⁻¹ associated with the expansion mode of O-H vibration and 598 cm⁻¹ is associated with the expansion mode of C-Cl vibration, and 2908 cm⁻¹ is associated with the expansion of C-H. The absorption peak of Ca(OH)₂ is caused by the stretching vibration of O-H (3641-3644 cm⁻¹)

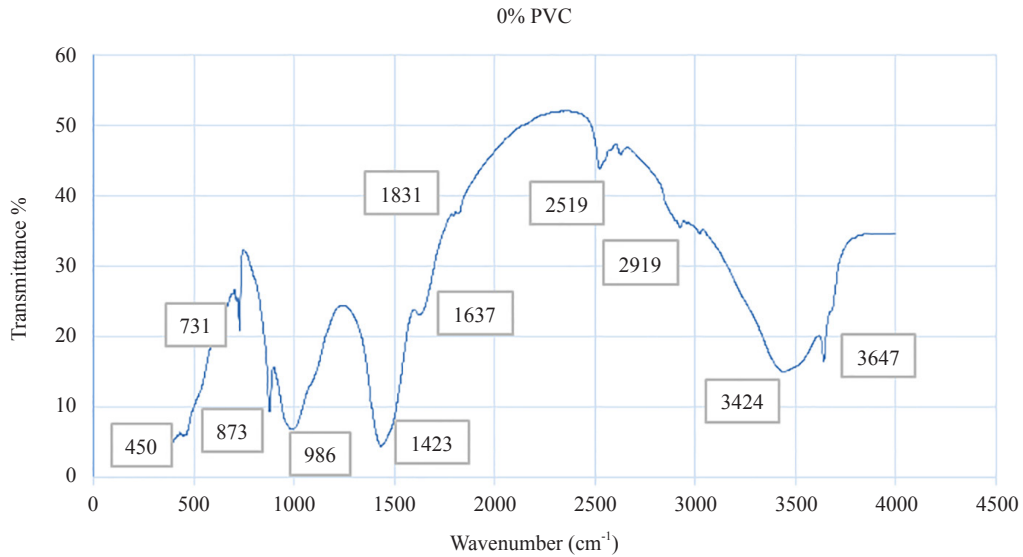


Figure 12. FTIR spectra of concrete mix 0% PVC

In Figure 12 the absorption peak of polyvinyl chloride (PVC) in the 0% mix was established at a wave number corresponding to 1423 cm⁻¹ and at 3424 cm⁻¹ associated with the expansion mode of O-H and 986 cm⁻¹ is associated with the expansion mode of C = C. The bands at 3390-3408 cm⁻¹ and 1640-1650 cm⁻¹ are due to the stretching vibrations and bending vibration of H₂O, respectively. The bands in the 1400-1500 cm⁻¹ range correspond to the asymmetric stretching of CO₃²⁻.

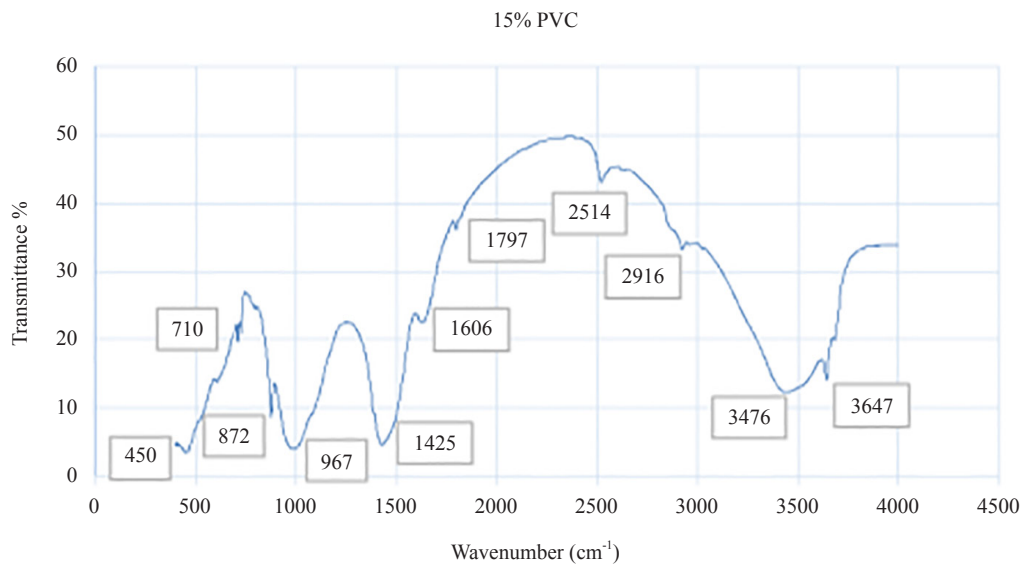


Figure 13. FTIR spectra of concrete mix with 15% PVC

In Figure 13 the absorption peak of polyvinyl chloride (PVC) in the 15% mix was observed at a wave number corresponding to 1425 cm^{-1} and another peak at 3476 cm^{-1} associated with the expansion mode of O-H, and 967 cm^{-1} is associated with the expansion mode of C = C.

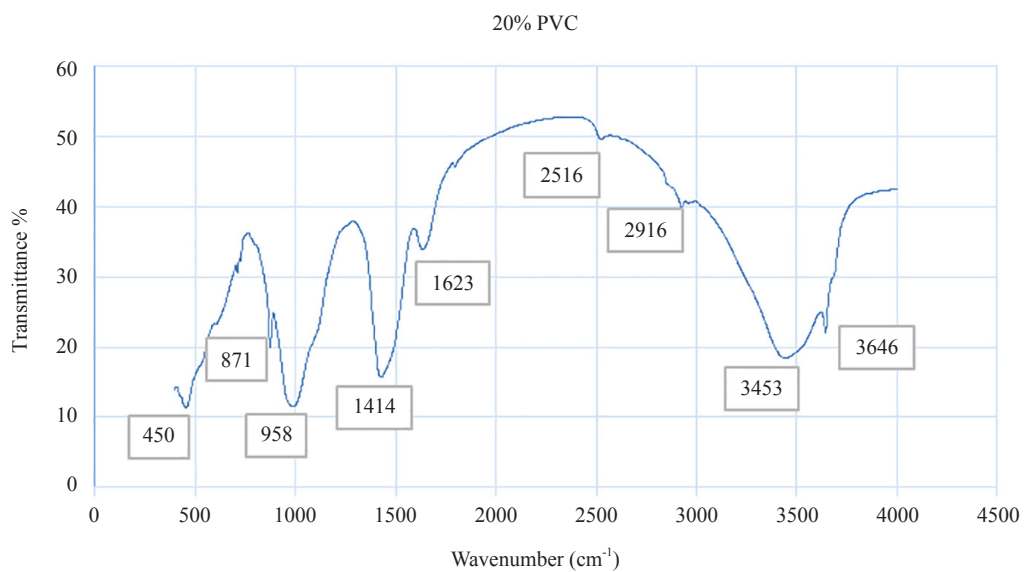


Figure 14. FTIR spectra of concrete mix with 20% PVC

Figure 14 showed the absorption peak of polyvinyl chloride (PVC) for the 20% mix was found at a wavenumber of 1414 cm^{-1} and the second peak at 3453 cm^{-1} associated with the expansion mode of O-H and 871 cm^{-1} is associated with the expansion mode of C-H.

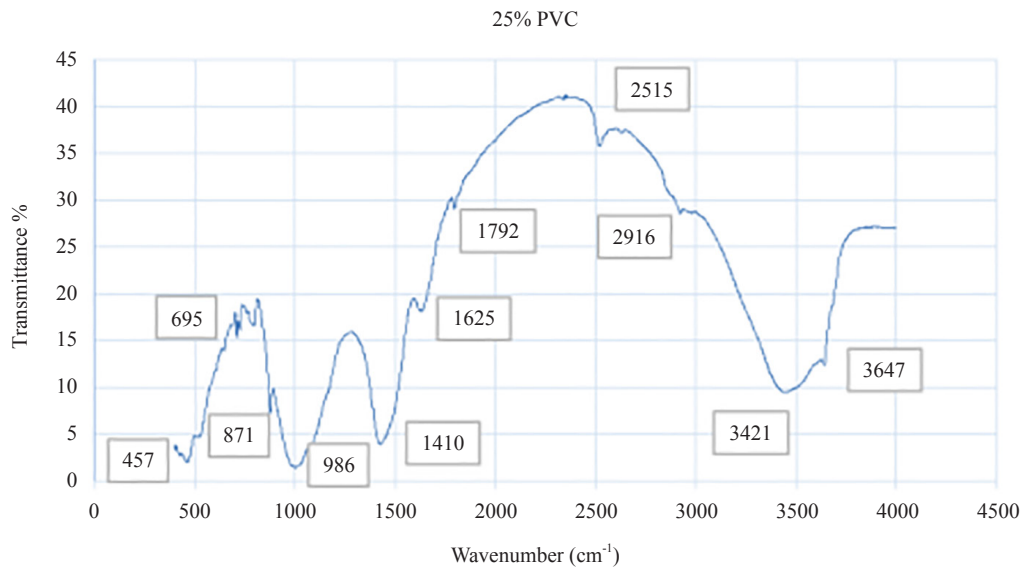


Figure 15. FTIR spectra of concrete mix with 25% PVC

In Figure 15 above the absorption peak of polyvinyl chloride (PVC) in the 25% mix is founded in the wavenumber 1410 cm^{-1} and 3421 cm^{-1} associated with the expansion mode of O-H and 986 cm^{-1} is associated with the expansion mode of C = C.

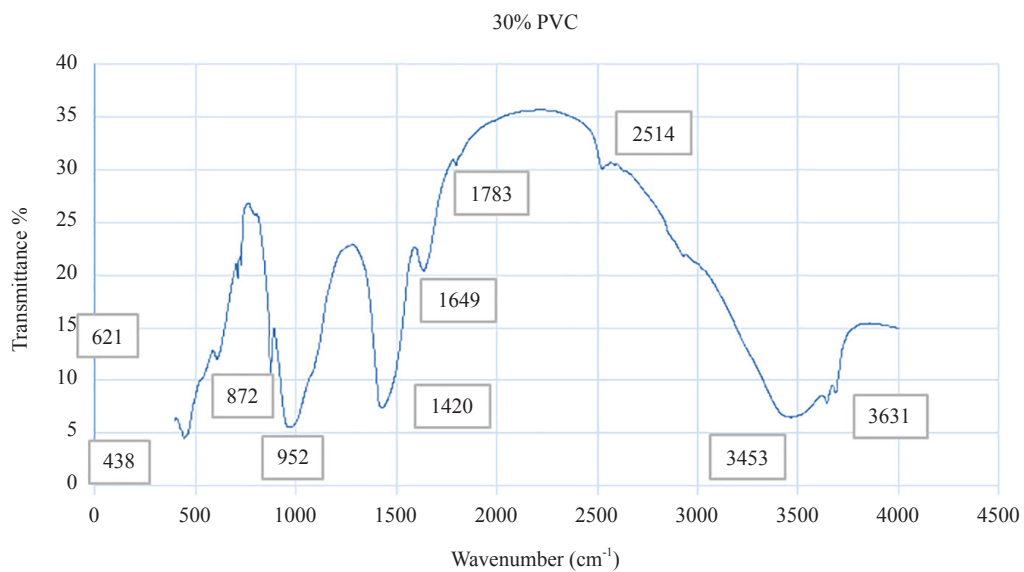


Figure 16. FTIR spectra of concrete mix with 30% PVC

The peak observed in Figure 16 indicates the absorption peak of polyvinyl chloride (PVC) in the 30% mix at a wavenumber of 1420 cm^{-1} and 3453 cm^{-1} associated with the expansion mode of O-H and 1649 cm^{-1} is associated with the expansion mode of C = C.

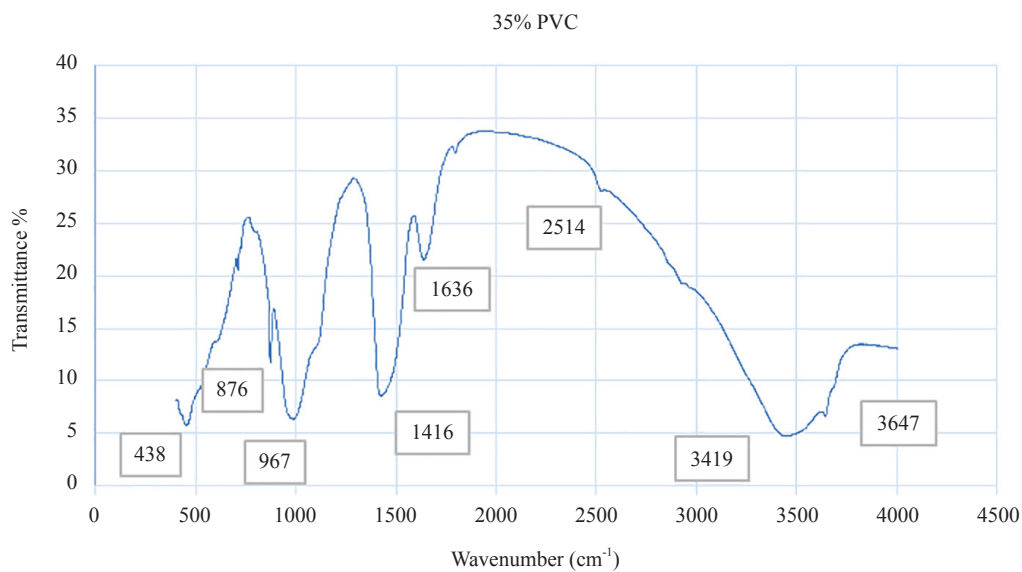


Figure 17. FTIR spectra of concrete mix with 35% PVC

In Figure 17, the absorption peak of polyvinyl chloride (PVC) in the 35% mix was found at wavenumbers corresponding to 1416 cm^{-1} and 3419 cm^{-1} , which are associated with the stretching vibration of O-H, 967 cm^{-1} is associated with the expansion of C = C and 876 cm^{-1} is associated with the expansion mode of C-H. Fourier transforms infrared spectroscopy analysis indicates that the PVC powder has a physical effect (i.e., nucleation effect and dilution effect) on cement hydration and also it contributes a chemical effect (i.e., chemical reaction).

3.6 Statistical analysis

Statistical analysis was carried out for compressive strength tests. Error bar shows the minimum and maximum values in a ranged dataset. For the statistical analysis, 95% confidence levels are considered for control mix and concrete with various percentages of plastic wastes. Table 6 shows the mean, variance, standard deviation and standard error of the mean values for compressive strength tests for all the mixes. The 'z' score for 95% confidence level is 1.96. Figure 18 shows the compressive strength test results of all the cube specimens with error bars.

Table 6. Descriptive statistics of compressive strength test results

Descriptive Statistics	Compressive Strength in MPa					
	0%	15%	20%	25%	30%	35%
Mean	21.64	19.25	15.18	16.77	12.4	12.22
Variance	4.839	0.696	18.699	13.106	1.151	1.854
Standard Deviation	2.199	0.834	4.324	3.62	1.073	1.362
Standard Error of the Mean	1.270	0.590	2.496	2.090	0.619	0.786
Margin of Error (95% CF)	± 2.488	± 1.156	± 4.893	± 4.096	± 1.214	± 1.541

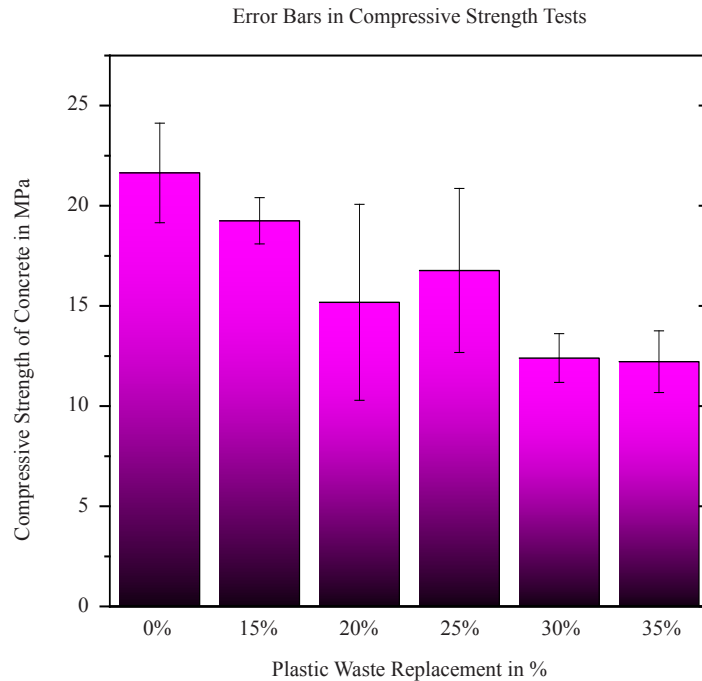


Figure 18. Compressive strength test results with error bars

4. Conclusion

Plastic processing industry is one of the major pollution-causing industries in the country. This research attempted to assess the application of polyvinyl chloride discarded from the plastic-pipe manufacturing industry for producing plastic cement in an environmental-friendly and economical method. The partial replacement of the OPC by polyvinyl chloride offers an eco-friendly way to produce plastic cement. The experimental results indicate that Portland cement could partially be replaced with waste polyvinyl chloride in the varying percentages of 15%, 20%, 25%, 30% and 35% respectively. The results show that the density of the mixes increases with an increase in PVC composition up to 25% mix and then decreased. The maximum density of 2.051 g/cm^3 is observed at 25% concrete mix. The water absorption capacity is maximum (5.86%) at a concrete mix percentage of 35%. The optimum compressive strength of the concrete mix is established at 15% concrete mix by 19.25 MPa. The results demonstrate that polyvinyl chloride has the capability to replace cement by 15% (weight) slightly less than that of control mix. Moreover, the results are confirmed through Fourier Transform Infra-Red Spectroscopy and X-ray Diffraction analyses. The study recommends the prospects of using waste polyvinyl chloride as an alternative to partial replacement of OPC with eco-friendly binding material in normal environmental conditions. The seven-day compressive strength of concrete is normally 60% of the 28-day strength and for C30 grade concrete it should be more than 18 MPa. Based on the experimental results, the seven-day compressive strength of concrete with 15% plastic waste used as partial replacement of cement is, 19.25. Hence, the concrete with plastic waste up to 15% replacement of cement can be used for the construction of structural members. Concrete with 15% plastic waste replacement as partial replacement of cement may be used for structural applications. The utilization of waste plastic materials in concrete as a partial aggregate replacement has an obvious effect on the material properties. Reduction in the compressive strength was between 34% and 67% for concrete containing 10%-50% recycled plastic. Test results of present study prove that the reduction in the compressive strength is between 11.04% and 43.53% for concrete containing 15%-35% PVC waste.

Conflict of interest

The authors declare that they have no conflicts of interest.

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