# The Effect of Fillers on the Chemical, Mechanical and Dielectric Properties of Polyvinyl Chloride Composites

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## Abstract:

The compounding of polyvinyl chloride (PVC) with two types of fillers and some additives were studied for the manufacturing of acid resistant tile. Various concentrations of two types of fillers namely; calcium carbonate and recycled glass powder were used along with different additives generally categorized as plasticizers, stabilizers, and lubricants were mixed in the standard concentration unit parts per hundred resins (phr) with the PVC as base polymer. The effects of filler materials on acid resistant towered different acids like sulphuric, nitric and hydrochloric at different concentration were studied. Samples which passed the test were further checked for dielectric strength and mechanical properties. It was found that the recycled glass powder is very suitable filler for preparing PVC composites materials for flooring tile, where most samples undergo negligible change in weight and maintained its shape and flexibility during the acid resistant test.

**Key words:** PVC, mechanical properties, acid resistant, dielectric strength, breakdown voltage, fillers

## Introduction

Polyvinyl chloride (PVC) has been studied and used widely in industrial fields for many years. It is one of the most common thermoplastic materials employed today, with applications ranging from packaging to healthcare devices, toys, electrical wire insulation, clothes, furniture, packaging, interior decoration, building materials and the car industry [1-6]. However, due to its inherent disadvantages, such as low thermal stability and brittleness, PVC and its composites are subject to some limitations in certain applications [7, 8].

Unmodified PVC polymer is a brittle, inflexible material with rather limited commercial possibilities. Several attempts have been made to enhance the properties of PVC in recent years [9-12]. With the addition of additives and copolymerization with other monomers, the poor properties of PVC can be improved [13- 17]. Commercially, compounding PVC contains sufficient modifying components to the raw polymer to produce a homogeneous mixture suitable for processing and requiring performance at the lowest possible price [18,19]. The proper compounding and processing PVC resin using suitable additives produces a complex material whose behavior and properties are quite different from the PVC resin by itself [20-24]. The selection of particular additive is dependent on the end use of the PVC product like PVC-resin is not plasticized for the use in making rigid products such as water pipe, plumbing fittings, and phonograph records. The modification of rigid poly (vinyl chloride) (PVC) having relatively low toughness carried out by incorporation of a rubbery phase [25, 26]. Therefore, it is necessary to develop new PVC products with high quality and good properties in order to yield high added values and broaden PVC applications.

The additives used in PVC formulations are mainly plasticizers, stabilizers, lubricants and fillers. Fillers have important roles in modifying the properties of various polymers and lowering the cost of their composites. The effect of fillers on properties of composites depends on their level of loading, shape and particle size, aggregate size, surface characteristics and degree of dispersion [27-31].

The recycling of waste glass is a major issue in urban areas of developed countries which has resulted in significant interest of late in utilizing it in different applications [32-36]. Thermoplastics and elastomers have outstanding resistance to a wide range of chemical reagents. Such resistance however, is a function both of temperatures and concentration.

PVC flooring tiles may be subject to a number of aggressive chemical exposures, accidental or otherwise [32]. Calcium carbonate is the most widely used low-cost filler that is added to extend and cheapen the application of PVC [27, 9], but to the best of our knowledge recycled glass powder has never been used as a filler for the manufacture of PVC acid resistant flooring material.

In this study, vary concentrations of two fillers namely; calcium carbonate and recycled glass powder have been studied for the manufacturing of PVC acid resistant flooring materials. The effects of filler materials on acid resistant toward different acids at different concentration were studied. Dielectric strength and mechanical properties of PVC samples have been investigated.

## Materials and Methods:

### 1. Materials

The general-purpose polyvinyl chloride (PVC) resin used was a white powder made by suspension polymerization with k value of 70. It was supplied by Sabic Company (Saudi Basic Industries Corporation). Dioctyl phthalate (DOP), dibasic lead sulphate (DLS), calcium stearate (CS), stearic acid (SA), and calcium carbonate powder (CC), were of technical grade. Sulfuric, nitric and hydrochloric acids were obtained from Merck (Germany). Recycled waste glass powder (RGP) was derived from recycled glass bottles and dry comminuted in a laboratory shaking mill to obtain fine powder.

### 2. Compound mixing

A high speed laboratory mixer (Fielder 8L, USA) was used to mix PVC and the additives. To produce moulded flat sheet, the dry compounds of PVC and additives were first sheeted on a two roll-mill before being compression moulded at the set temperature of 160 $^{o}C$. The concentration of the base polymer is referred as 100 parts in the mixture; whereas the concentration of rest of the additives used is referred as parts per 100 resins i.e., .phr. Tables (1and 2) show the different formulations for two types of fillers which were used in the preparation of PVC based compounds. Three samples of each compound were taken and were analyzed for determining the acid resistant, mechanical, and electrical properties.

**3. Acid resistant test**

The chemical resistance of the prepared samples has been studied according to ASTM D–543 method [37]. The acids used for the study were $H_2SO_4$, HCl, and $HNO_3$. For this purpose, the specimen of each PVC sample (2 cm x 2 cm) was placed in the reagents for four days at room temperature, specimens which pass the test were further immersed in acids for fourteen days according to the Iraqi specification 109/1992. After fourteen days the specimens were removed and were dried. They were then examined for the percentage weight change.

**4. Dielectric breakdown strength**

High voltage supplier with a range (0-60 kV) and frequency 50 Hz, model BAUR-PGO-S-3, Germany was used for the measurement of dielectric strength of the specimens. The dielectric strength of a material can be defined as the voltage gradient or dielectric stress through the material at which electrical failure or breakdown occurs. The total breakdown voltage is determined by placing electrodes on opposite surfaces of a specimen disc, and increasing the potential difference between the electrodes until the material can no longer resist the flow of current. Test specimens should be in the form of a sphere of 40 mm in diameter and their standard thickness is 2 mm. Insulating oil was used as embedding medium for the measurement at room temperature. Imposed voltage is AC 50 Hz with increasing rate of 2 kV/s .

**5. Mechanical measurements**

The tensile measurements were carried out according to the ASTM D638 [38] using Universal Testing Machine LR 50K from Lloyd Instruments Ltd., U.K. In this analysis, tensile strength and elongation at break were carried out.

Specimens were processed through compression molded and brought in standard shape with 0.13 to 0.28 inch thickness. The shore hardness of the samples was measured using a Durometer device, Shore D hardness instrument (Italy) according to the ASTM (D 2240) [39].

## Results and Discussion:

This study was carried out to investigate the effect of two types of fillers namely; calcium carbonate and recycled waste glass powder on PVC compound acid resistant toward different acids at different concentration. Dielectric strength and mechanical properties of PVC compounds were also investigated. Tables (1and 2) show the different formulations for two types of PVC based compounds which were prepared.

**Table (1) PVC formulation using calcium carbonate (CC) as filler**

| Sample No. | Concentration (phr) | | | | | |
|---|---|---|---|---|---|---|
| | PVC | DOP | CC | DLS | SA | CS |
| CC-1 | 100 | 11.2 | 52.3 | 0.8 | - | 0.8 |
| CC-2 | 100 | 24.5 | 33.6 | 3.2 | 0.4 | - |
| CC-3 | 100 | - | 30.0 | 1.1 | 0.4 | 0.4 |
| CC-4 | 100 | 6 | 20.2 | 1.1 | 0.4 | 0.4 |
| CC-5 | 100 | 8.5 | 10.8 | 1.8 | 0.4 | 0.4 |
| CC-6 | 100 | 7.0 | 8.8 | 2.0 | 0.4 | 0.4 |

**Table (2) PVC formulation using recycled glass powder (RGP) as filler**

| Sample No. | Concentration ( phr ) | | | | | |
|---|---|---|---|---|---|---|
| | PVC | DOP | RG | DLS | SA | CS |
| RGP-1 | 100 | 8.7 | 9.3 | 1.1 | - | 0.4 |
| RGP -2 | 100 | 15.1 | 9.2 | 1.1 | - | 0.4 |
| RGP -3 | 100 | 20.2 | 9.5 | 1.1 | 0.4 | 0.4 |
| RGP -4 | 100 | 7 | 8.8 | 2 | 0.4 | 0.4 |
| RGP -5 | 100 | 7 | 13.9 | 2 | 0.35 | 0.35 |
| RGP -6 | 100 | 10 | 15.5 | 2 | 0.35 | 0.35 |

**i**. Acid resistant of 12 PVC flooring samples in three concentrations of three types of acids (sulphuric, nitric and hydrochloric acids) were investigated. All results are shown in tables (3 and 4).A detailed observations about the immersed samples are shown in tables ( 5 and 6) .Samples which undergo a change in weight , deformation in shape , and loss of flexibility in one of the acids or in certain concentration within the same acid were considered as failed samples . From the above tables, samples RGP-1, RGP-2, RGP-4, RGP-5, RGP-6, CC-5 and CC-6 were succeeded in all acids due to their negligible change in weight and they maintained their shape and flexibility. For this reason these seven formulations were further tested for acid resistant by immersing them for two weeks in the three acids as shown in Table 7 , 8 and 9 .It was observed that all the selected samples passed the acid resistant test, there was no change in shape, flexibility and weight.

PVC composites samples filled with (CC) failed in the acid test when the filler content exceed 15 %. While all PVC composites samples filled with (RGP) pass the test except RGP-3 due to its high plasticizer content [20].

**Table (3) Acid resistance of PVC samples with CC filler toward sulfuric, nitric and hydrochloric acids**

| Sample No | Acid concentration % v/v | $H_2SO_4$ | | | | $HNO_3$ | | | | HCl | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | % Wt. change | | | | % Wt. change | | | | % Wt. change | | | |
| | | 24 h | 48 h | 72 h | 96 h | 24 h | 48 h | 72 h | 96 h | 24 h | 48 h | 72 h | 96 h |
| CC-1 | concentrated | 18 | 27 | 27 | 2.13 | -2.1 | -1.03 | -1.5 | -1.5 | 13.6 | 11.8 | 7.5 | 7.5 |
| | 50 | 1.9 | 1.4 | 3.4 | 5.8 | 1.3 | 1.9 | 3.7 | 4.4 | -1.07 | -0.03 | -0.01 | -0.6 |
| | 25 | 2 | 4.1 | 5.3 | 4.3 | 0.2 | 1.3 | 3.9 | 2.9 | 0.4 | 0.22 | 0.75 | 0.87 |
| CC-2 | concentrated | 48 | 47 | 39 | 47 | 3.8 | 3.7 | 2.3 | 1.4 | 15.2 | 6.7 | 4.6 | 7.8 |
| | 50 | 11 | 8.9 | 7 | 10 | 1.2 | 2.4 | 2.4 | 2.4 | 13.1 | 10.1 | 3.5 | 6.5 |
| | 25 | 8.2 | 9.0 | 4.4 | 8.0 | 1.2 | 2.3 | 2.1 | 2.1 | 9.2 | 7.55 | 4.1 | 4.2 |
| CC-3 | concentrated | 2.4 | 1.4 | 1.1 | 0.7 | -0.2 | -0.2 | -0.2 | -0.2 | 0.9 | 1.2 | 2 | 0.6 |
| | 50 | 0.6 | 0.8 | 0.7 | 0.8 | 0.01 | 0.04 | 0.04 | 0.04 | 0.8 | 0.8 | 0.6 | 0.7 |
| | 25 | 1.4 | 1.2 | 1.0 | 0.7 | -0.2 | -0.2 | -0.2 | -0.2 | 1.3 | 0.78 | 0.9 | 0.1 |
| CC-4 | concentrated | 1.5 | 1.2 | 1.1 | 0.9 | -0.2 | -0.2 | -0.2 | -0.2 | 0.9 | 0.9 | 1.7 | 0.3 |
| | 50 | 0.5 | 0.7 | 0.6 | 0.7 | 0.01 | 0.04 | 0.04 | 0.04 | 0.7 | 0.7 | 0.5 | 0.6 |
| | 25 | 1.3 | 1.2 | 1.0 | 0.7 | -0.2 | -0.2 | -0.2 | -0.2 | 1.3 | 0.78 | 0.9 | 0.1 |
| CC-5 | concentrated | 0.1 | 0.1 | 0.1 | 0.1 | -0.2 | Zero | Zero | Zero | 0.02 | 0.02 | 0.01 | 0.01 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | -0.1 | -0.2 | -0.2 | -0.2 | 0.08 | Zero | Zero | Zero |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | -0.1 | -0.1 | -0.1 | -0.1 | Zero | Zero | 0.01 | 0.01 |
| CC-6 | concentrated | 0.1 | 0.1 | 0.1 | 0.1 | -0.2 | Zero | Zero | Zero | 0.02 | 0.02 | 0.01 | 0.01 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | -0.1 | -0.2 | -0.2 | -0.2 | 0.08 | Zero | Zero | Zero |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | -0.1 | -0.1 | -0.1 | -0.1 | Zero | Zero | Zero | 0.01 |

**Table (4) Acid resistance of PVC samples with recycled glass (RGP) filler toward sulfuric, nitric and hydrochloric acids**

| Sample No | Acid concentration % v/v | $H_2SO_4$ % Wt. change 24 h | 48 h | 72 h | 96 h | $HNO_3$ % Wt. change 24 h | 48 h | 72 h | 96 h | HCl % Wt. change 24 h | 48h | 72 h | 96 h |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RGP-1 | concentrated | 0.3 | 0.3 | 0.4 | 0.4 | 0.5 | 0.5 | 0.6 | 0.6 | 0.4 | 0.2 | 0.2 | 0.2 |
| | 50 | 0.09 | 0.09 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | Zero | Zero |
| | 25 | Zero | Zero | Zero | Zero | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.01 | Zero | Zero |
| RGP -2 | concentrated | 0.5 | 0.07 | 0.07 | 0.07 | 1.4 | 1.9 | 1.8 | 1.5 | 1.0 | 1.0 | 1.0 | 0.9 |
| | 50 | 0.3 | 0. 5 | 0. 4 | 0. 4 | 0.5 | 0.9 | 0.7 | 0.4 | 0.9 | 0.9 | Zero | Zero |
| | 25 | 0.2 | 0.2 | 0.3 | 0.4 | 0.2 | 0.2 | 0.3 | 0.3 | 1.0 | 1.0 | Zero | Zero |
| RGP -3 | concentrated | 1.4 | 1.3 | 1.5 | 1.5 | 1.6 | 2.1 | 3.2 | 3.9 | 2.0 | 2.0 | 2.0 | 2.0 |
| | 50 | 0. 7 | 0.3 | 1.0 | 1.0 | 0.9 | 0.9 | 1.8 | 1.9 | 1.9 | 1.7 | 1.7 | 2.0 |
| | 25 | 0.5 | 0.4 | 0.4 | 0.5 | 0.3 | 0.7 | 0.9 | 0.9 | 2.0 | 1.0 | 1.0 | 1.0 |
| RGP -4 | concentrated | 0.07 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.06 | 0.1 | 0.1 | 0.1 |
| | 50 | Zero | 0.1 | 0.1 | 0.1 | Zero | Zero | Zero | Zero | 0.02 | 0.02 | 0.02 | Zero |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | Zero | Zero | Zero | Zero | 0.1 | 0.1 | Zero | Zero |
| RGP -5 | concentrated | 0.1 | 0.2 | 0.3 | 0.5 | 0.6 | 0.7 | 0.9 | 0.9 | 0.2 | 0.2 | 0.5 | Zero |
| | 50 | 0.2 | 0.1 | Zero | Zero | 0.25 | 0.15 | Zero | Zero | 0.01 | 0.08 | Zero | Zero |
| | 25 | Zero | 0.05 | 0.06 | 0.1 | 0.7 | 0.3 | 0.4 | 0.1 | 0.04 | 0.04 | Zero | Zero |
| RGP -6 | concentrated | 0.6 | 0.7 | 0.7 | 0.7 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.05 | 0.05 |
| | 50 | 0.4 | 0.5 | 0.5 | 0.5 | 0.8 | 0.6 | 0.6 | 0.6 | Zero | Zero | 0.03 | 0.03 |
| | 25 | 0.2 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | Zero | Zero | Zero | 0.05 |

**Table (5) results of acid resistance of PVC samples with CC filler toward sulfuric, nitric and hydrochloric acids**

| Sample No. | Observations | Result |
|---|---|---|
| **CC-1** | An increase in the weight of the sample with little deformation in shape, acid discoloration occurred | Failed |
| **CC-2** | An increase in the weight of the sample, the specimen maintained its flexibility but deformation in shape occurred | Failed |
| **CC-3** | An increase in the weight of the sample, with the loss of flexibility | Failed |
| **CC-4** | An increase in the weight of the sample, with the loss of flexibility | Failed |
| **CC-5** | Negligible change in weight and the sample maintained its shape and flexibility | Succeeded In all acids |
| **CC-6** | Negligible change in weight and the sample maintained its shape and flexibility | Succeeded In all acids |

**Table (6) results of acid resistance of PVC samples with Recycled glass (RGP) filler toward sulfuric, nitric and hydrochloric acids**

| Sample No. | Observations | Result |
|---|---|---|
| **RGP -1** | Slight change in weight and the sample maintained its shape and flexibility | Succeeded In all acids |
| **RGP -2** | Slight change in weight and the sample maintained its shape and flexibility, but very slight change in color occurred. | Succeeded In all acids |
| **RGP -3** | An increase in the sample weight with deformation in shape and slight change in color occurred. | Failed |
| **RGP -4** | Slight or negligible change in the weight and the sample maintained its shape and flexibility | Succeeded In all acids |
| **RGP -5** | Negligible change in the weight and the sample maintained its shape and flexibility | Succeeded In all acids |
| **RGP -6** | Negligible change in the weight and the sample maintained its shape and flexibility | Succeeded In all acids |

**Table (7) Acid resistance of selected PVC samples toward sulfuric acid for two weeks**

| Sample No | Acid concentration % v/v | $H_2SO_4$ % Wt. change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 120 h | 144 h | 186 h | 192 h | 216 h | 240 h | 264 h | 288 h | 312 h | 336 h |
| RGP -1 | concentrated | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RGP -2 | concentrated | 0.6 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | 50 | 0.4 | 0.4 | 0.4 | 04 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 25 | 0.5 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| RGP -4 | concentrated | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 | 0.07 |
| | 50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RGP -5 | concentrated | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| RGP -6 | concentrated | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 | 0.9 |
| | 50 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| | 25 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| CC-5 | concentrated | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 50 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| CC-6 | concentrated | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

**Table (8) Acid resistance of selected PVC samples toward hydrochloric acid for two weeks**

| Sample No | Acid concentration % v/v | HCl % Wt. change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 120 h | 144 h | 186 h | 192 h | 216 h | 240 h | 264 h | 288 h | 312 h | 336 h |
| RGP-1 | concentrated | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RGP -2 | concentrated | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 50 | 0.1 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| RGP -4 | concentrated | 0.05 | 0.05 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 | 0.04 |
| | 50 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 25 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| RGP -5 | concentrated | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 |
| | 50 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | 25 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| RGP -6 | concentrated | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | 50 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 25 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| CC-5 | concentrated | 0.06 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 | 0.05 |
| | 50 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| | 25 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| CC-6 | concentrated | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| | 50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

**Table (9) Acid resistance of selected PVC samples toward nitric acid for two weeks**

| Sample No | Acid concentration % v/v | $HNO_3$ % Wt. change | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 120 h | 144 h | 186 h | 192 h | 216 h | 240 h | 264 h | 288 h | 312 h | 336 h |
| RGP - 1 | concentrated | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 | 0.6 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| RGP - 2 | concentrated | 0.9 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 | 0.8 |
| | 50 | 0.5 | 0.5 | 0.5 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 | 0.4 |
| | 25 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| RGP - 4 | concentrated | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 | 0.7 |
| | 50 | 0.4 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 25 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| RGP - 5 | concentrated | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 50 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| | 25 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| RGP - 6 | concentrated | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 50 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| | 25 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| CC-5 | concentrated | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 | 0.3 |
| | 50 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| CC-6 | concentrated | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 50 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| | 25 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |

### ii. Dielectric Strength Test Result

The dielectric breakdown strength for the selected samples was measured at room temperature by applying alternating current stress to a sample sheet with a sphere shape of of 40 mm in diameter and their standard thickness is 2 mm. The sample is then inserted between rod-plane electrodes. Three different specimens were sampled from each composite and have been tested. The three test results were averaged and taken as the breakdown voltage. Table 10 shows the breakdown voltage of PVC/calcium carbonate and, PVC/ recycled waste glass powder blends.

Results from the breakdown tests clearly reveal that fillers content have an important effect on the breakdown voltage of PVC/ recycled glass and, PVC/ calcium carbonate samples [27]. Between both types of fillers, PVC/ recycled glass samples exhibit considerable improvement in dielectric strength test compared to PVC/calcium carbonate.

**Table 10 -Result of Dielectric Strength Test**

| Sample No. | Breakdown Voltage(kV/mm) |
|---|---|
| RGP-1 | 9.11 |
| RGP -2 | 8.6 |
| RGP -4 | 9.04 |
| RGP -5 | 9.36 |
| RGP -6 | 9. 95 |
| CC-5 | 6. 96 |
| CC-6 | 6.71 |

### iii- Mechanical properties

Table 11 shows the correlation between filler concentration and tensile strength, elongation and hardness of the compounded PVC product. It can be seen that as the concentration of filler increases, the hardness of the PVC products is increased while tensile strength and elongation values decreased. The gradual decrease of the tensile strength may be because that at higher filler content the interaction between fillers and polymer matrix was impeded, resulting in lower strength of the respective composites [23, 28].

**Table 11 Mechanical properties of PVC compounds**

| Sample No. | Tensile Strength ($Kg/cm^2$) | Elongation at break (%) | Hardness (Shore D) |
|---|---|---|---|
| **RGP-1** | 160 | 259 | 84 |
| **RGP -2** | 131 | 240 | 66 |
| **RGP -4** | 172 | 271 | 72 |
| **RGP -5** | 153 | 252 | 86 |
| **RGP -6** | 149 | 249 | 89 |
| **CC-5** | 148 | 245 | 82 |
| **CC-6** | 151 | 250 | 78 |

## Conclusion:

The following conclusions can be drawn from the present investigation.

1- The recycled glass powder is very suitable filler for preparing PVC composites materials for flooring tile, where most samples undergo negligible change in weight and maintained its shape and flexibility during the acid resistant test.

2- PVC composites samples filled with (CC) failed in the acid resistant test when the filler content exceed 15 %.

3- Filler content has an important effect on the breakdown voltage of PVC/ recycled glass and, PVC/ calcium carbonate samples. Where the former exhibited considerable improvement in dielectric strength test.

4- It was observed that as the concentration of filler increases, the hardness of the PVC products is increased while tensile strength and elongation values decreased.

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# تاثير المالئات على الخواص الكيمياوية، الميكانيكية، والكهربائية لمتراكبات البولي فينايل كلورايد

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**الخلاصة:**

تم تحضير متراكبات البولي فينيل كلورايد المستخدمة في الارضيات البلاستيكية المقاومة للحوامض باستخدام نوعين من المالئات وبعض المضافات . حيث تم في هذا العمل خلط نسب قياسية مختلفة من نوعين من المالئات وهما كربونات الكالسيوم ومسحوق الزجاج المعاد مع مواد ملدنة ،مثبتة ومواد مزيتة ومع البولي فينايل كلورايد كبوليمر اساس. ايضا تم دراسة تاثير المود المالئة على قابلية النماذج البلاستيكية المحضرة في مقاومة الحوامض المختلفة مثل الكبريتيك ،النتريك ، والهدروكلوريك وبتراكيز مختلفة. خضعت العينات التي اجتازت اختبارات فحص مقاومة الحوامض الى فحوصات العازلية الكهربائية والفحوصات الميكانيكية . وجد ان مسحوق الزجاج المعاد ملائم جدا للاستخدام كمادة مالئة لتصنيع متراكبات البولي فينيل كلورايد المقاومة للحوامض، حيث ان معظم النماذج المحضرة ابدت تغير ضئيل في الوزن وحافظت على شكلها ومرونتها خلال الفحص.

**الكلمات المفتاحية:** بولي فينيل كلورايد، الخواص الميكانيكية، المقاومة الحامضية، قوة العزل الكهربائي، جهد الانهيار، المالئات.