Porcelain Reinforced Polyester Resin Composites: Preparation and Characterization

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Porcelain reinforced polyester resin composites containing 10-60% porcelain with respect to the weight of unsaturated polyester resin were prepared by compression molding. Synergistic improvements in the composite properties were achieved and are superior to those of the individual components. The effects of porcelain content on some important physical and mechanical properties such as water absorption, compressive strength and hardness of the composites were investigated in detail. It is evident from the XRD spectra of the composites that porcelain has been incorporated into polyester resin of the composites resulting in better mechanical properties.

Keywords: Composites, Porcelain, Polyester Resin, Compressive Strength, Hardness

Introduction

Composites have been of interest because of their adaptability to different situations and the relative ease of combination with other materials to serve specific purposes and desirable properties¹-². They are widely used in many fields such as civil, industrial, military, spacecraft and biomedical applications mainly because of their excellent thermo-mechanical properties³-⁴. By permutation and combination of various fibers and polymers, a wide range of composites having unique properties for versatile applications as alternative to conventional materials like metals, wood etc. have been prepared⁵. Composites comprise strong load carrying material known as reinforcement embedded in weaker material known as matrix⁶. Polymers are used as a matrix in these types of composites, and clay minerals act as reinforcement material. By combining these two different structures, new materials can be synthesized that have better physical and mechanical properties according to their component⁷. Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. Polyester resin with suitable fillers and reinforcements were the first applications of composites in road transportation. Using a variety of reinforcements, polyester has continued to be used in improving the system and other applications. Polymer matrices are most commonly used because of cost efficiency, ease of fabricating complex parts with less tooling cost and also have excellent room temperature properties when compared to other matrices. Thermoset matrices are formed due to an irreversible chemical transformation of a resin into an amorphous crosslinked polymer matrix⁸-¹⁰. Moreover, unsaturated polyester resin is one of the most commonly used polymer matrix for the preparation of advanced composite materials because of its low cost, ease of handling and processing, flexibility, rigidity and weather resistant properties¹¹-¹². The presence of unsaturation in polyester resin helps in cross-linking. The susceptibility of a polymer to degradation depends on its structure. Polymers are susceptible to degradation by hydrolysis, while polymers containing an unsaturated backbone are especially susceptible to ozone cracking. The resins are pretty resistant to both water and UV rays. Porcelain is a ceramic material that serves to control viscosity, promotes flow, and improves resistance to cracking in molded parts and to reduce the resin cost and/or improve its physical properties such as hardness, stiffness and impact strength¹³-¹⁴. Ismail et al. have studied sand/clay...

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unsaturated polyester composite materials\textsuperscript{15}. The effect of a radiation-initiated on the physico-mechanical properties of a sand/clay-polyester composite has been investigated. The unsaturated polyester resins containing various styrene contents were used at different sand/clay composites from 10 to 70wt % with respect to the weight of sand and clay together; polymerization was conducted using gamma-radiation at 50 kGy. They observed that compressive strength decreases with an increase in sand/clay, as well as the styrene content in the unsaturated polyester resin, whereas the apparent porosity and water absorption of the composite samples were found to increase. In this study porcelain reinforced polyester resin composites were prepared by compression molding and the physical and mechanical properties of the composites were studied in detail.

**Experimental**

The chief raw materials used for the specimen preparation are porcelain and polyester resin. Porcelain is collected from USA and polyester is collected from the local market. At first porcelain was dried at 100°C for 24 hours in a preheated oven. Four samples of porcelain and polyester composites in the ratio of 10:90, 30:70, 40:60, 60:40 were prepared and were termed as PPC-1, PPC-2, PPC-3 and PPC-4, respectively. Required amounts of porcelain and polyester resin were taken in a bowl and were mixed very carefully with a stirrer for about half an hour. Methyl ethyl ketone peroxide at an amount of 1.5 wt% of polyester resin was used as a hardener. The mixture was then poured into the closed mould and kept it 4-5 hours for drying. After drying the composite is released from the mould with Karl Kolb Press Machine by applying pressure. Polyethylene sheet was used to smoothen the sides of the composite. Photograph of a PPC sample is shown in Figure 1.

**Results and Discussion**

**Determination of Water Absorption of PPCs**

Water intake specimen was prepared according to ASTM Designation: C 67-91. The test specimen was 26-29 mm Length, 23.5-25.5 mm width, and 7-8 mm height. Water absorption depends on time and amount of materials. Effects of immersion time and amount of porcelain content on water absorption of PPCs are shown in Figure 2. Results show that water absorption of PPCs decreased with an increase in porcelain content and increased with immersion time. The rate of water absorption was very low. This is due to the fact that reduction in the cured polyester and the degree of cross-linking reaction which diminishes the void spaces. Consequently, with an increase in molding load, the composite becomes denser or reinforced materials are distributed properly eliminating all voids.

**Determination of Compressive Strength of PPCs**

Figure 3 shows compressive strengths of PPCs as a function of porcelain content. Compressive strengths of PPCs increased with an increase in amount of porcelain. Variation of compressive strength of PPCs depends on the size of particles. Ismail et al. reported that the compressive strength increases with an increase in clay ratio with a particle size <0.5mm as a result of the catalytic effect of clay constituents\textsuperscript{15}.

![Photograph of a PPC sample made by compression moulding](image)

![Effect of immersion time on water absorption of PPCs](image)
This was attributed to a reduction in the cured polyester and the degree of cross-linking reaction, which diminishes the void spaces between porcelain and clay particles. Compressive strengths of PPCs are found to be very high, four times higher than brick. The very fine powder of porcelain contributes to the high compressive strength of PPCs. The increase in porcelain ratio in PPCs has a catalytic effect on copolymerization rate of the unsaturated polyester resin mixture in which a large number of cross-linking occurs. Consequently, compressive strength of PPCs increased with an increase in amount of porcelain.

**Determination of Hardness of PPCs**

Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex. Hardness is dependent on ductility, elastic stiffness, plasticity, strain, strength, toughness, viscoelasticity and viscosity. In this study, we studied the Vickers hardness of PPCs. The test samples were prepared to have very smooth surface and were held perpendicular to the indenter. All things being equal, a lighter indenter load will require a smoother surface for a satisfactory test. Samples are usually mounted in plastic to fix them during preparation and testing. Vickers hardness (HV) is calculated according to the following equation:

\[ HV = 1854.4 \times \frac{L}{d^2} \]  \( \ldots (1) \)

Where L is the load in gm force and d is the mean of two diagonals in millimeters. Table 1 illustrates that Vickers Hardness for PPCs as a function of the addition of different wt% of porcelain. It can be seen that hardness increased with an increase of porcelain and maximum hardness was found for the composite with 60% porcelain which may be due to the filler content or reinforced particles (dense particle).

**X-Ray Diffraction Analysis of PPCs**

The crystalline nature of PPCs was observed by X-ray diffraction. Figure 4 shows the XRD pattern of porcelain, polyester resin and PPC2. The XRD spectra reveal that polyester resin shows a broad peak while porcelain exhibits sharp peaks and light broad peak which reveal its crystalline and amorphous nature. PPC-2 shows sharp peaks which are almost superimposed on XRD pattern of porcelain at 2θ values of 16°, 26°, 31°, 33°, 35°, 37°, 39°, 41° and 43° that reveal their crystalline nature and incorporation of porcelain with polyester resin. According to Kato et al the polar groups in the polymers will interact with the polar group in the nano clay and the interaction decreases the d-spacing in the composite producing stronger denser composite. Similar result has been observed by Supri et al in which they studied the effect of poly acrylic acid on the LDPE-nanoclay composites. It is evident from the XRD studies of PPCs that there are interactions between the porcelain and polyester resin resulting in strengthening the matrix.
Conclusion

In this study, porcelain reinforced polyester composites were prepared by compression molding. Porcelain contents of the composites were varied from 10-60% with respect to the weight of unsaturated polyester resin to investigate its effects on physical and mechanical properties of the PPCs. The following conclusions may be drawn from the work done so far. The porcelain contents and the size of porcelain were found to have a significant effect on the compressive strength of the composites. Compressive strength was found to increase with an increase in porcelain content. Hardness of PPCs was increased with an increase in amount of porcelain content. It is due to permanent plastic deformation. XRD studies of PPCs confirm the interaction between porcelain and polyester resin resulting in better strength of the matrix. Thus the porcelain reinforced polyester resin composites may be potential candidates for their applications as building construction materials.

References