# Mechanical Properties of Micro-size Glass Beads Filled Epoxy Composites

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*Abstract*— Solid glass microspheres of around 100 microns size were incorporated in epoxy matrix in present work. Composite were fabricated in six different sets using simple hand lay-up technique. The filler content varies in between 0 wt% i.e. neat epoxy and 25 wt % for fabricating the different sets of composites. The main emphasis of the present work is on the general trends observed in their mechanical properties i.e. micro-hardness, tensile strength, flexural strength and impact energy. In the analysis it was found that, solid glass microsphere invariably increases the micro-hardness and impact energy of the composite and this increase is a function of filler content. On the other hand it was found that flexural strength increases but the rate of increase of this strength is very less whereas a surprising output of this analysis was that the tensile strength decreases with increase in filler content though the decrement is marginal.

***Key words:*** Polymer Matrix Composites, Epoxy, Solid Glass Micro-Sphere, Filled Polymers, Mechanical Properties

## I. INTRODUCTION

Glass beads are considered as the prominent filler material with thermoplastic as well as thermoset polymer to improve the physical and mechanical properties of the composites. Glass beads are preferred as filler material in polymers mainly when isotropy of material is of prime importance which does not create a source of stress concentration in the matrix unlike other long fibers or irregular shape fillers which have sharp edges leading to stress generation in the matrix and in turn early failure of the composites. Also, with the spherical shape, incorporation of glass beads results in reduction in the orientation effect associated with molding. In addition, because of good flow properties of such composites, the power consumption in processing can be reduced to improve wearing of the equipment, which is beneficial to raise the production efficiency [1].

In 60s and 70s, numbers of researchers have investigated the relationship between the morphology, structure and properties of glass bead filled polymer composites [2-4]. Ramsteiner and Theysohn [5] studied the effect of shape and content of the glass beads on the tensile property of polymer composites and derived a model for the same. Liang and Li [6] found the effect of content and surface treatment of glass microsphere on the impact properties of the glass beads-polypropylene composites and found that with increase in filler impact energy increases and reported that there is no effect of surface treatment on such properties. Liang and Li [7] studied the effect of SGM content and size on mechanical properties such as Young's modulus, tensile strength, yield strength, impact strength and toughness of PP resin. In another work, Liang and Li [8] treated the surface of glass bead with silane coupling agent and found that Young's modulus and tensile stress at break of PP composite are somewhat higher as compared to those in case of untreated fillers. Their study was too rigorous and caught the attention of many researcher around the world.

Agrawal and Satapathy [9] used solid glass microsphere as filler in combination with ceramic fillers in polymer and studied its properties so that it can be used for microelectronic applications. They found improvement in the dielectric constant of the polymer matrix reinforced with hybrid filler. Against this background, an attempt has been made in this research work to develop solid glass microsphere (SGM) based epoxy composites using simple hand lay-up technique and to study their physical, mechanical and sliding wear behavior under controlled laboratory conditions.

## II. MATERIALS & METHODS

### A. *Material Considered*

Matrix materials are the base of composite fabrication. The presently used matrix is a thermoset polymer epoxy. The epoxy resin Lapox-12 is used in the present work which belongs to the epoxide family. Bisphenol-A-Diglycidyl-Ether (commonly abbreviated to DGEBA or BADGE) is the common name of the presently used epoxy resin. It provides a solvent free room temperature curing system when it is combined with the hardener tri-ethylene-tetramine (TETA) which is an aliphatic primary amine with commercial designation HY 951. The various physical and mechanical properties of epoxy resin are presented in Table I.

| Characteristic Property | Values | Units |
|---|---|---|
| Density | 1.1 | g/cm$^3$ |
| Tensile strength | 50 | MPa |
| Cross breaking strength | 130 | Mpa |
| Impact strength/Energy | 17 | kJ/m$^2$ |
| Thermal conductivity | 0.363 | W/m-K |
| Coefficient of thermal expansion | $5.80\times10^{-6}$ | /ºC |

Table 1: Important Properties of Epoxy Resin

Solid glass microsphere (SGM) of average size of 100 m is the primary filler materials used in the present research work. It is procured from Scientific Ltd, Bhopal. The glass used in present investigation is soda-lime glass, composed of around 75% silicon dioxide (SiO2), sodium oxide (Na2O) from sodium carbonate (Na2CO3), calcium oxide, also called lime (CaO), and several minor additives. In present investigation, this soda-lime glass is used in the form of microspheres and known as solid glass microsphere. The SGM used in present investigation possesses density of 2.23 g/cm3, tensile strength of 70 MPa, flexural strength of 248 MPa and hardness of 16.84 GPa.

### B. *Composite Fabrication*

Particulate filled polymer composite is fabricated using simple hand lay-up technique. The fabrication of composite using hand lay-up method involves following steps:

 

1) The epoxy resin (LY556) and the corresponding hardener (HY 951) are mixed in a ratio 10:1 by weight as recommended.
2) Solid glass micro-sphere will then added to the epoxy-hardener combination.
3) Before pouring the epoxy/filler mixture in the mould, a silicon spray is done over the mold so that it will easy to remove the composite after curing. The uniformly mixed dough is then slowly poured into the mould of 200×200 in area and thickness 3 mm.
4) The cast is than cured for 24 hours before it was removed from the mould.
5) The specimens of different sizes according to the ASTM standards for different tests were then cut from the fabricated rectangular sheet.

Composites were fabricated with different weight fraction of filler ranging from 0 to25 wt. %. The list of fabricated composite in present work is presented in table 2.

| S.No. | Set | Composition |
|---|---|---|
| 1 | Set 1 | Neat Epoxy |
| 2 | Set 2 | Epoxy + 5 % by weight SGM |
| 3 | Set 3 | Epoxy + 10 % by weight SGM |
| 4 | Set 4 | Epoxy + 15 % by weight SGM |
| 5 | Set 5 | Epoxy + 20 % by weight SGM |
| 6 | Set 6 | Epoxy + 25 % by weight SGM |

Table 2: Epoxy Composites Filled With Micro-Sized Solid Glass Microsphere

### C. *Mechanical Characterization*

The tensile strength of the composite specimen is measured using universal testing machine (UTM) INSTRON H10KS. ASTM D3039 tensile testing is used to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point. The three point bend test was carried out in Universal Testing Machine (UTM) in accordance with ASTM D790 to measure the flexural strength of the composites. Leitz micro-hardness tester is used to determine the micro-hardness of the fabricated composite. The tests are in accordance with ASTM E384. In order to determine the impact energy of the test specimen in present analysis, Izod impact test is performed following ASTM D256 standard.

## III. RESULTS & DISCUSSION

### A. *Micro-Hardness*

The micro-hardness of the fabricated composites is measured using Leitz micro-hardness tester. The presently used equipment works on the principle of Vicker's hardness testing method. The results obtained during the experimentation of are shown in figure 1.

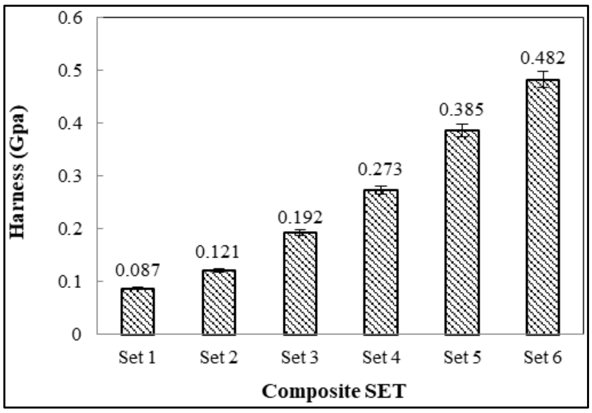


Fig. 1: Micro-Hardness of Epoxy/SGM Composites

From the figure it is clear that, with the increase in the content of solid glass microsphere in matrix, hardness of the composites increases and reaches its maximum value of 0.482 GPa for 25 wt. % of filler loading. It is evident that with addition of SGM particles, micro-hardness of the composites is improved and this improvement is a function of the filler content. This increment is attributed to around 450 %.

### B. *Tensile Strength*

The tensile strength of all the fabricated samples is measured by universal testing machine and is shown in figure 2. From the figure it is observed that the tensile strength of composite decreases slightly with increase in filler content. The minimum tensile strength among the various fabricated samples was of sample with 25 wt. % of SGM. Its values were reported to be of 44.2 MPa which was a decrement of around 11.2 %. Comparison of values obtained from different methods

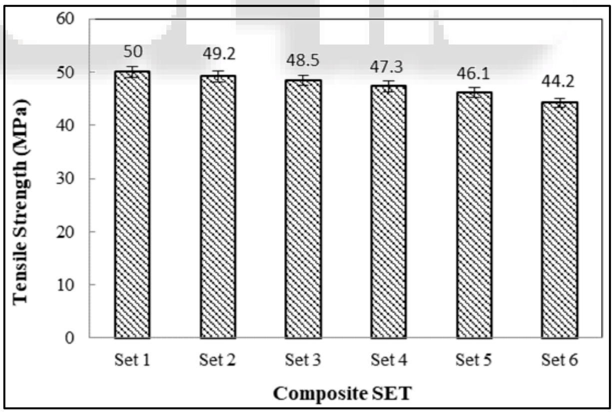


Fig. 2: Tensile Strength of Epoxy/SGM Composites

### C. *Flexural Strength*

Composite materials used in structures are prone to fail in bending and therefore development of new composites with improved flexural characteristics is essential. In the present work, the variation of flexural strength of epoxy based composites with SGM content is shown in figure 3. It is observed from the figure that there is a gradual increase in the value of flexural strength with increase in filler content. The maximum value of flexural strength for composite under study is reported to be 144.5 MPa which is an increment of around 11.1 %.

 

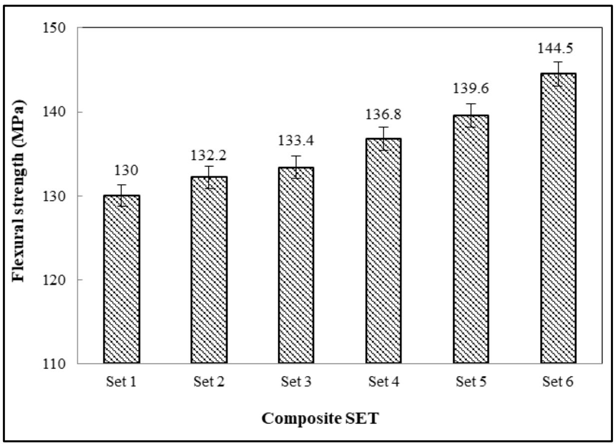


Fig. 3: Flexural Strength of Epoxy/SGM Composites

### *D. Impact Energy*

The effect of filler content on the impact energy of the fabricated composites is shown in figure 4.

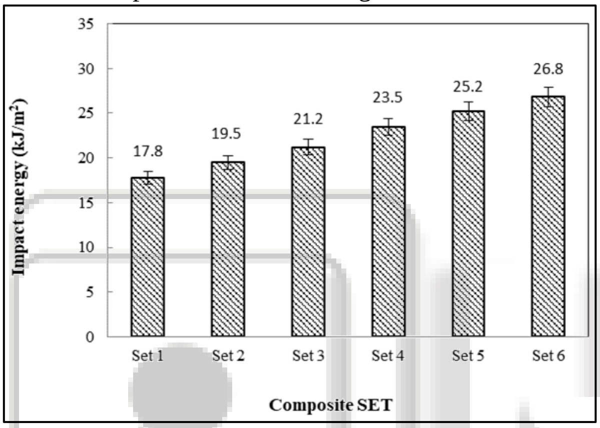


Fig. 4: Impact Energy of Epoxy/SGM Composites

It is seen from this figure that impact strength is gradually increasing with addition of SGM in epoxy composites. An increase of 50.5 % in impact strength is recorded for epoxy based composites when filled with 25 wt% SGM only. This indicates that the toughening effect of glass bead incorporation in epoxy composites is significant. The gradually increasing trend in impact strength is due to the increase of filler contents and also due to compression pressure which eliminates voids contents.

## IV. CONCLUSIONS

This experimental investigation on solid glass microsphere filled epoxy composites has led to the following specific conclusions:

1) With increase in filler content an improved value of micro-hardness is reported. This increment is reported to around 450% when compared to the hardness of neat epoxy.
2) With increase in filler content, flexural and impact strength increases as well and maximum improvement is reported of around 11 % in flexural strength and around 50 % in impact strength.
3) With increase in filler content, there is a marginal decrement in the value of tensile strength, which is mainly because of the generation of voids.

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