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Effect of silica and calcium carbonate fillers on the properties of woven glass fibre composites

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The effect of silica and calcium carbonate fillers on the properties of woven glass fibre composite has been studied with an attempt to observe the amount of property loss due to replacement of expensive resin by cheap fillers. The silica and calcium carbonate fillers of the amount 25% and 50% respectively of the weight of the resin have been used and the properties, namely tensile strength, flexural strength and impact strength, studied. It is observed that the impact and tensile strength slightly reduce but the flexural strength significantly increases.

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Composites straddle the textile with plastic industries and can be regarded as a macroscopic combination of two or more materials to produce special properties, which are not present in the separate components. The composite materials are advantageous when the modulus per unit weight and strength per unit weight are adjusted with the criteria of weight reduction, greater efficiency and energy saving, especially in all forms of transportations.[1] Besides, fibre and matrix should be put in correct volume to suit the end-use at a minimum cost.

By using various materials, changing the reinforcement fibre content and orientation in material layers, and combining fibres with different elasticity and strength, one can obtain materials with desired properties.[2] Several glass compositions and their variants have been formulated to produce specific properties.[3] The developments in composite material after meeting the challenges of aerospace sector and space sector have cascaded down for catering to domestic and industrial applications. High cost of polymers is sometimes a limiting factor in their use for commercial applications. Use of low-cost easily available fillers may be useful to bring the cost of component down. The study on such economical filler is necessary to ensure that the mechanical properties of the product are not affected adversely by their addition. A large number of materials has been studied for their use as fillers in polymers but only a few of them are found to deal with the material systems containing fibres and fillers simultaneously.[4,5] The purpose of use of fillers can be divided into two basic categories (i) to improve the properties of the material and (ii) to reduce the cost of component. Common fillers used for thermoplastics include mineral fillers, such as calcium carbonate, talc and wollastonite. Filler materials are also used extensively with polyester resins for a variety of reasons, such as cost reduction of the moulding, facilitation of the moulding process and imparting specific properties to the moulding. Fillers are often added in quantities up to 50% of the resin weight although such an amount affects the flexural and tensile strengths of the laminates.[6] The use of fillers can be beneficial in laminating or casting of thick components where otherwise considerable exothermic heating can occur. Addition of certain fillers can also contribute to increase the heat resistance of the laminate.[7] Fillers also affect processing by increasing the viscosity of resin mixes. The viscosity rise is related to the particle size distribution. Increased viscosity may be beneficial or detrimental, depending on the composite manufacturing applications.[8] In the present work, the effect of silica and calcium carbonate fillers in presence of glass fibre reinforcement on tensile strength, impact strength and flexural strength of woven glass fibre composites has been studied. The glass fibre volume has been kept minimal so that the effect of fillers is not subdued.

E-glass fabric (200 GSM) of plain weave construction, procured from Shri Premolite Industry, Sakinaka Mumbai, was used for the study. Orthophthalic polyester resin matrix with methyl ethyl ketone peroxide catalyst and cobalt octet accelerator were used. The fillers used were silica and

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calcium carbonate. Woven glass fabric was layered seven times so as to get the GSM of 1400 (200 × 7). Five types of samples were made as per the specifications shown in Table 1. Hand lay-up process was carried out at room temperature using inexpensive mould of wood. A release agent (wax) was used to clean the mould to prevent the resin from sticking. One or two coats of gel containing polyester resin, fillers, catalyst and accelerator were applied to achieve the desired surface finish. Then one layer of fibre reinforcement was put on the coat given. Thereafter, with the help of a brush the resin and fillers were coated again so that the reinforcement is properly being impregnated with resin. A roller was used to remove the air bubbles and to make the woven fabric saturated with resin. In this way, required numbers of fabric layers were put to obtain the laminate of required fibre volume fraction. Then, with the help of wood the pressure was given to the laminate which was then dried for 6 h.

All the samples produced were tested as per the ASTM standards. The tensile strength was tested as per ASTM standard D-638 with sample size of 200mm × 20mm on Universal testing machine of the capacity of 30 tons. The flexural strength was tested as per ASTM standard D-790 with sample size of 50mm × 10 mm with the supporting length 25 mm and rate of loading 0.8 mm/min on a universal testing machine of the capacity 50 kg. The impact strength was tested as per ASTM standard D-256. The sample size for the impact test was 60mm × 10mm, length projecting outward was 32mm and the point of impact was 22 mm. The impact test was conducted on the impact tester for plastic of the capacity 10 J.

It is observed that the silica fillers pose greater processing difficulties than the calcium carbonate fillers for composite manufacturing. However, the silica fillers are approximately 20% more cheaper than the calcium carbonate fillers. The properties of the individual constituents are given in Table 2.

Table 3 shows the tensile, flexural and impact strengths of composites. It is found that the control sample (without silica or calcium carbonate) shows higher tensile and impact strengths. However, the flexural strength of the filler contained composites is much higher than that of the control sample. Figure 1 shows the comparison with respect to percentage-wise difference in the properties of the filler contained composites with reference to control sample. It is very clear from the trends that as the filler concentration increases the tensile strength and impact strength decrease for both the types of fillers. This may be due to the higher filler loading; the interstitial volume must have been occupied by filler and there might be less matrix available to contribute for the tensile and impact strengths. The impact strength decreases with increasing concentration of filler in the case of both

Table 1 — Constitution of filler, fibre and resin

Sample No.	Laminate thickness mm	Fibre volume fraction	Filler type	Filler amount %
1	3.20	0.1708	Nil (control)	0
2	3.30	0.1657	Silica	25
3	3.33	0.1642	Silica	50
4	3.28	0.1667	Calcium carbonate	25
5	3.34	0.1637	Calcium carbonate	50

Table 2 — Properties of composites

Sample. No.	Tensile strength MPa	Flexural strength MPa	Impact strength × 10^{-3} J/mm²
1	116.68	19.03	4.10
2	112.85	27.52	3.98
3	110.06	28.72	3.78
4	113.00	29.50	3.70
5	98.61	30.21	3.62

Table 3 — Properties of composite constituents

Material	Density, g/cc	Tensile strength, MPa
Polyester resin	1.36	20.0
Glass	2.6	3400
Calcium carbonate	1.03	26
Silica	2.2	110

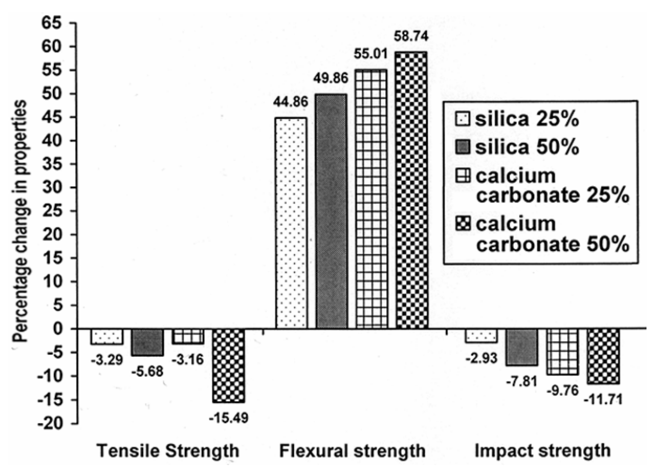

Fig. 1 — Percentage difference in properties in comparison to without filler sample

calcium carbonate and silica. This indicates the agglomeration of the fillers, thereby generating the increase in void space, which is responsible for stress propagation. It is also observed that the increase in filler concentration reduces the deformability of matrix, which, in turn, reduces the ductility in the skin area so that the composite tends to form a weak structure. The flexural strength for all the filler samples increases with increasing filler concentrations. The fillers particles act as the barriers to the propagation of microcracks, and impart higher flexural strength. These fillers are stiffer than the matrix and deform less, causing an overall reduction in the matrix strain, especially in the vicinity of the particle as a result of the particle/matrix interface. The trend shown by the silica and calcium carbonate fillers is similar but differs in quantity. This difference in quantity can be attributed to immiscibility of silica with the polyester matrix and therefore improper interface adhesion as well as formation of voids.

Addition of silica as well as the calcium carbonate filler in the matrix affects the properties of composites. The tensile strength reduces in the range of 3-15% for 25-50% fillers. The impact strength also reduces by 2-12% but the flexural strength increases considerably to the range of 44-58% for different contents of fillers. The study gives an idea about the extent to which the properties of the composites can be scarified to reduce the composite cost.

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