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Experimental Investigation on Mechanical Characterization, Ranking and Water Absorption Behavior of RHA/WDA/RHAWDA Filled Epoxy Based Glass Fiber Reinforced Hybrid Composites

Vidya Sagar Battula[1,*], K Venkata Subbaiah[1]

[1] Department of Mechanical Engineering, Andhra University (AU) College of Engineering, Andhra University (AU), Vishakhapatnam, Andhra Pradesh (AP), India

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ABSTRACT

In the present research work, a novel class of epoxy built hybrid combinations strengthened with E-Glass woven rowed mat and occupied with rice husk ash (RHA), wood dust ash (WDA) and a mixture of RHA & WDA has been developed and structural mechanical properties were determined and the results were matched with the non-filled composites. The studies on these composites reveal that the tensile strength (TS) of the composites is decreased by the escalation in weight percentage of the filler material and the rest of the mechanical properties were increased with the increase in weightiness proportion of RHA, WDA and RHAWDA. TOPSIS and VIKOR'S ranking methods are applied to know the best composite from 16 alternative composites having 6 attributes. From the results, the composite filled with RHA at 5 wt% is selected as the best composite based on mechanical characteristics. Water absorption behavior of the composites at various time intervals for RHA, WDA and RHAWDA filled hybrid composites has been studied and it is concluded that the composites occupied with RHA at 12.5 wt% have given the minimum water absorption rate (WA) compared to other filled composites immersed in distilled and mineral waters and the composite filled with WDA at 2.5 wt% has exhibited the minimum water absorption rate (WA) when it is immersed in ground water for 144 hours of a time interval. Based on the results of water absorption rate (WA) and mechanical characteristics (impact strength and Vickers hardness) the composites filled with RHA at 5 wt% and RHA at 12.5 wt% can be used for the manufacturing of roof sheets and water tanks.

1. Introduction

Nowadays the use of composite materials reinforced with the fibers of synthetic materials and filled with industrial wastes and agro wastes in the form of fillers is increasing in various manufacturing, construction and structural applications due to their high strengths to weight ratio (S/W), stiffness (S) and high durability (D) properties [1-3]. Many researchers in India and from abroad

* *Corresponding author.*
E-mail address: vidyasagarb@gmail.com

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have done so much of work on polymer matrix composites (PMC's) to improve the properties and to reduce the built-up or fabrication cost.

The researchers are using various industrial waste materials like dust from coal transportation, cement bypass dust, fly ash, ashes produced from burning agro wastes in industries etc., as polymer modifiers or fillers [4-9]. The usage of these fillers on large scales can decrease ecological contamination and also discard problems along with the enhancement in mechanical properties of the composites [10-12]. Some of the researchers performed the water absorption tests and concluded that the industrial waste filled hybrid composites can be the best suitable materials for the manufacturing of the components used in the water environment [13-15]. The works on applications of various MCDM techniques for decision making based on various attributes of alternatives have been carried out [16-17] and the methods of TOPSIS and VIKOR's ranking are of great use in the selection of composite materials based on their mechanical characteristics. With reference to the above problems and previous research findings, the objectives are set as follows for the present research investigation as shown in Figure 1.

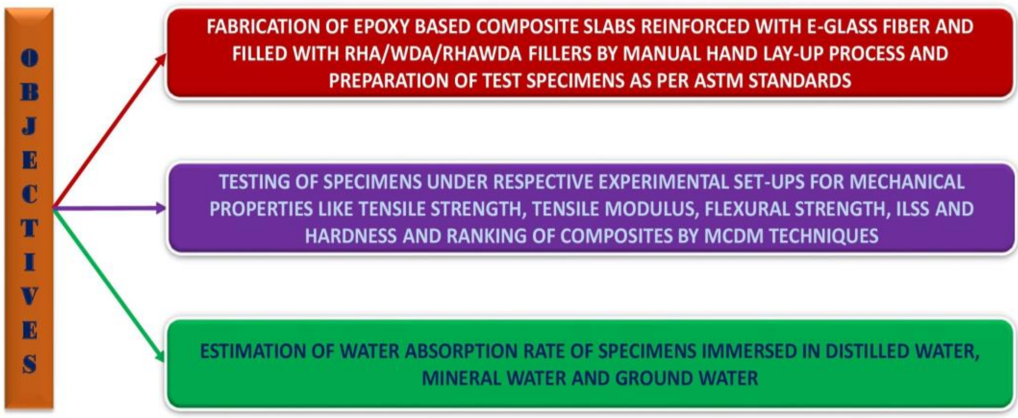

Fig. 1. Objectives of research work

2. Materials and Methods

In Figure 2, the required materials and methods used to prepare each composite are shown. Epoxy resin (Araldite LY256 & Aradur HY951), 8 layers of E-Glass fiber mat of Woven Rowing type of size: 250mm x 250mm and industrial wastes like RHA/WDA/RHAWDA as fillers in given proportions as shown in Table 1 are used to fabricate the composites by physical hand lay-up process presented in Figure 3.

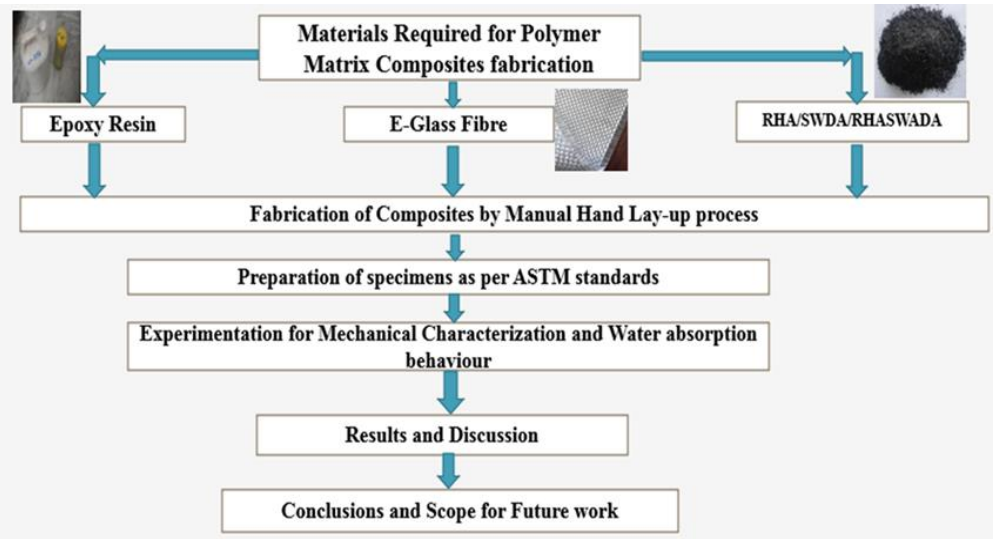

Fig. 2. Flow chart

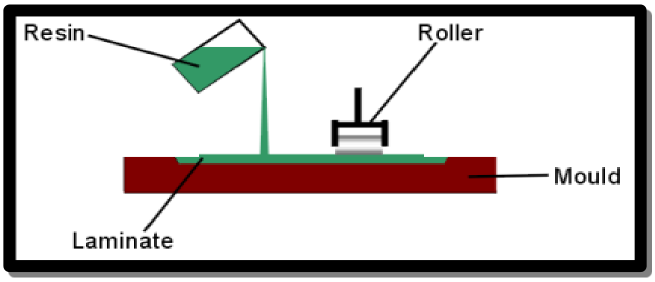

Fig. 3. Physical hand lay-up process

Table 1
Designation of composites (DoF) and compositions

Composite designation	Composition
GE	50 wt% of glass fibre ('GF') + 50 wt% of epoxy resin ('ER')
GERHA2.5	47.5 wt% of 'ER'+ 2.5 wt% of rice husk ash (RHA) +50 wt% of 'GF'
GERHA5	45 wt% of 'ER'+ 5 wt% of rice husk ash (RHA)+ 50 wt% of 'GF'
GERHA7.5	42.5 wt% of 'ER'+ 7.5 wt% of rice husk ash (RHA) + 50 wt% of 'GF'
GERHA10	40 wt% of 'ER'+ 10 wt% of rice husk ash (RHA) + 50 wt% of 'GF'
GERHA12.5	37.5 wt% of 'ER'+ 12.5 wt% of rice husk ash (RHA) + 50 wt% of 'GF'
GEWDA2.5	47.5 wt% of 'ER'+ 2.5 wt% of wood dust ash (WDA)+ 50 wt% of 'GF'
GEWDA5	45 wt% of 'ER'+ 5 wt% of wood dust ash (WDA)+ 50 wt% of 'GF'
GEWDA7.5	42.5 wt% of 'ER'+ 7.5 wt% of wood dust ash (WDA)+ 50 wt% of 'GF'
GEWDA10	40 wt% of 'ER'+ 10 wt% of wood dust ash (WDA)+ 50 wt% of 'GF'
GEWDA12.5	37.5 wt% of 'ER'+ 12.5 wt% of wood dust ash (WDA)+ 50 wt% of 'GF'
GERHAWDA2.5	47.5 wt% of 'ER'+ 2.5 wt% of RHAWDA+ 50 wt% of 'GF'
GERHAWDA5	45 wt% of 'ER'+ 5 wt% of RHAWDA+ 50 wt% of 'GF'
GERHAWDA7.5	42.5 wt% of 'ER'+ 7.5 wt% of RHAWDA+ 50 wt% of 'GF'
GERHAWDA10	40 wt% of 'ER'+ 10 wt% of RHAWDA+ 50 wt% of 'GF'
GERHAWDA12.5	37.5 wt% of 'ER'+ 12.5 wt% of RHAWDA+ 50 wt% of 'GF'

The specimens are made from the composite slab as per standards of ASTM shown in Figure 4a-4d for mechanical characterization (MC). The tests are conducted to evaluate the mechanical properties and water absorption rate (WA). TOPSIS and Vikor's ranking methods are implemented to select the best composite and the results are compared with each other. Finally, the causes for the increase or decrease of the values of properties are discussed. Conclusions and scope for future work are listed.

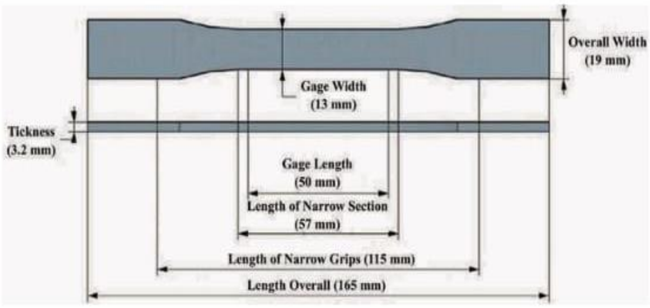

Fig.4a: Tensile Test Specimen Size as per ASTM D-638-III

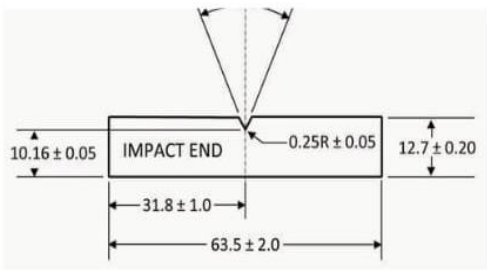

Fig.4c: Impact Test Specimen Size as per ASTM D-256

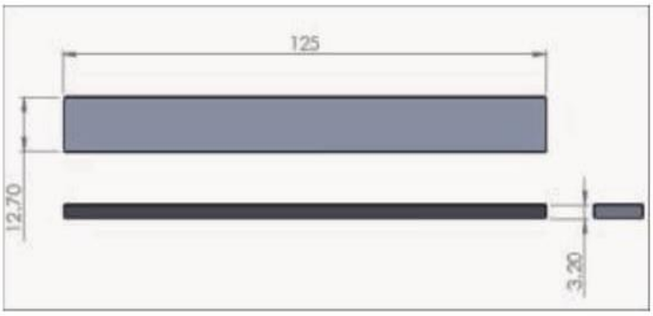

Fig.4b: Flexural Test Specimen Size as per ASTM D-790

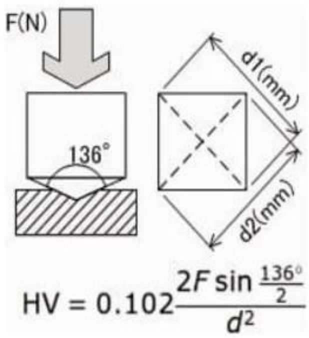

Fig.4d: Vickers microhardness Test Specimen Size as per ASTM E-384

Fig. 4. Specimen sizes and standards of ASTM for mechanical characterization (MC)

3. Results and Discussion

3.1 Mechanical Characterization (MC)

3.1.1 Tensile strength ('TS')

From Figure 5, it is detected that the 'TS' of the composite without the filler material is 246.32 MPa and it is reduced with the addition of the filler ingredients and the increase in the weightiness percentage of the filler material of the composites leads to a reduction in the 'TS'. Maximum 'TS' is observed in the composites filled with the filler RHAWDA at 2.5 wt% and the minimum tensile strength is perceived in the composite occupied with the filler WDA at 12.5 wt%. The decrease in 'TS' may be due to i) weak bonding present between the matrix and reinforcement and ii) non uniform size and shape of the filler materials and non-uniform distribution of the fillers.

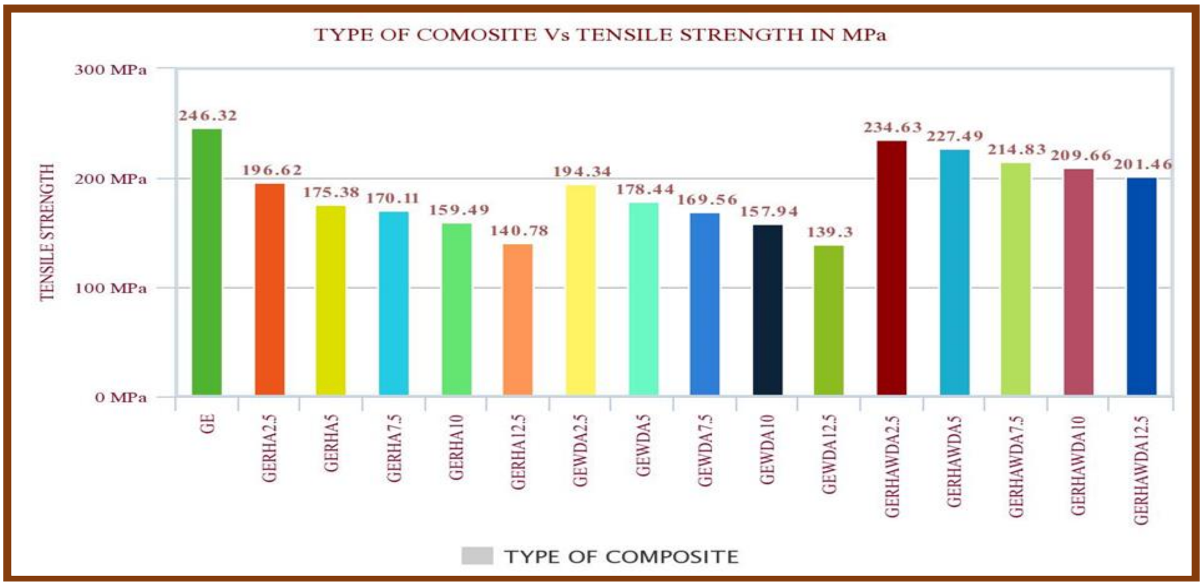

Fig. 5. Chart for type/nature of composite vs tensile strength ('TS')

3.1.2 Tensile modulus ('TM')

From Figure 6, it is observed/seen that the maximum 'TM' is 7.742 GPa for the composite packed with RHA at 5 wt% and the minimum tensile modulus is for the composite filled with WDA at 12.5 wt%. In the case of RHA & WDA filled composites with the rise in addition of filler up to 5 wt% the 'TM' is increased and with further addition of filler material 'TM' values show decreasing trend but in the case of the composites filled with RHAWDA with the rise in adding of filler the 'TM' values are decreased.

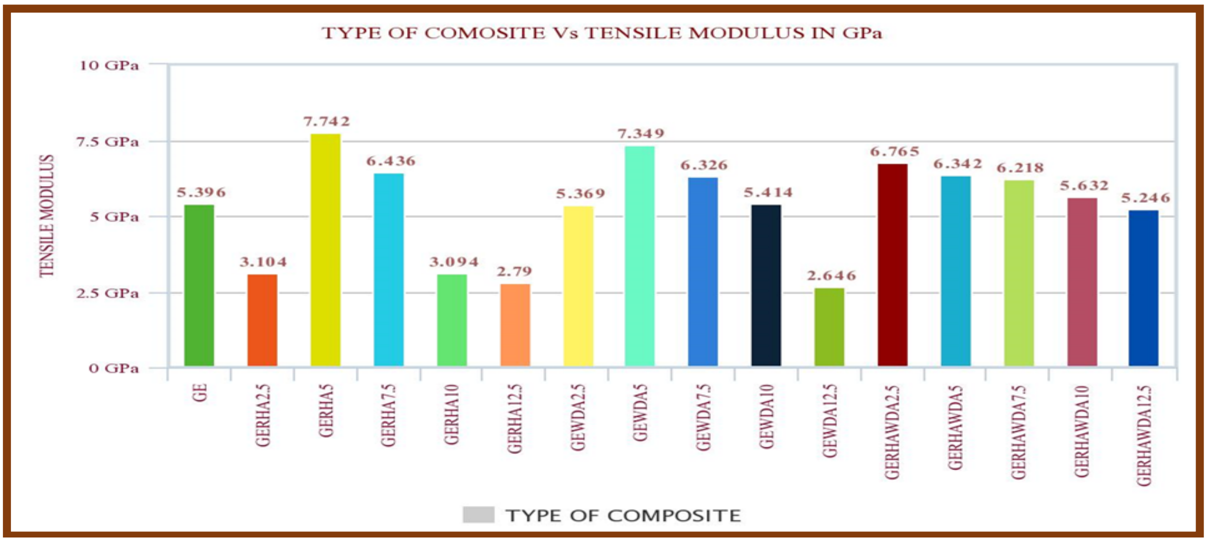

Fig. 6. Chart for type/nature of composite vs tensile modulus ('TM')

3.1.3 Flexural strength ('FS')

From Figure 7, the extreme 'FS' of 618.63 MPa is seen in the composite occupied with RHAWDA at 10 wt% and minimum 'FS' is observed in unfilled and RHA2.5 filled composites. With the rise in the weighting proportion of fillers, the increasing trend of flexural strength is observed up to 10 wt% of the filler. The reason for the rise in 'FS' might be due to the strong adhesion between matrix and reinforcement. It is suggested that the composite filled RHAWDA filler can be utilized for structural applications.

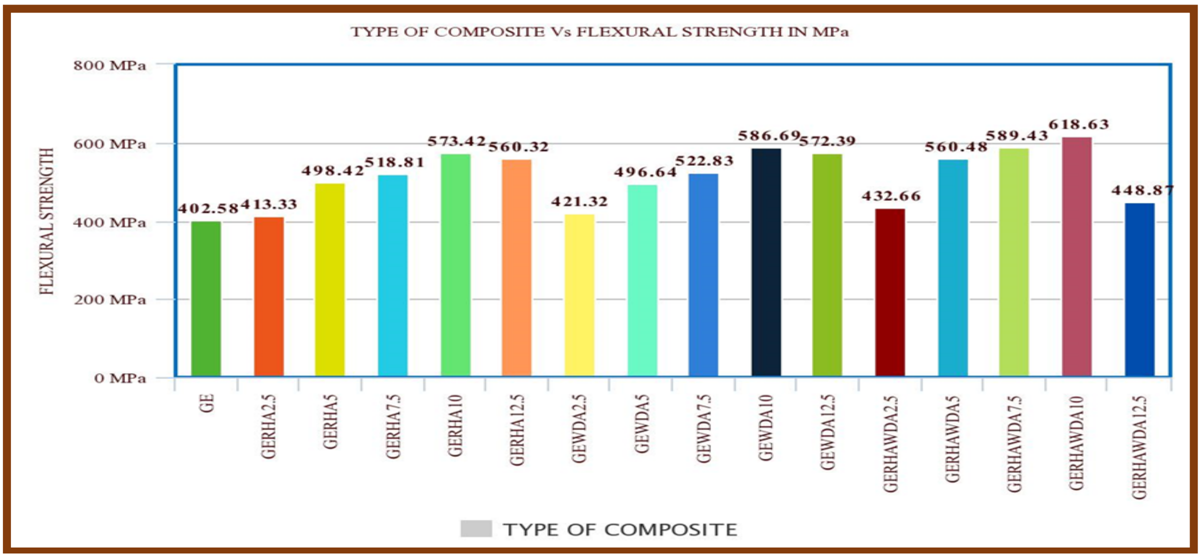

Fig. 7. Chart for type/nature of composite vs flexural strength ('FS')

3.1.4 Inter-laminar shear strength ('ILSS')

From Figure 8, the high 'ILSS' of 20.841 MPa is seen in the composite occupied with RHAWDA at 10 wt% and minimum 'ILSS' is perceived in RHA2.5 filled composites. With the growth in the weightiness proportion of fillers the increasing trend of 'ILSS' is observed up to 10 wt% of the filler and at 12.5 wt% of filler addition, the value has been decreased for the composites. The presence of voids in the inter-laminar region of the matrix material may be the reason for the decrease in 'ILSS'.

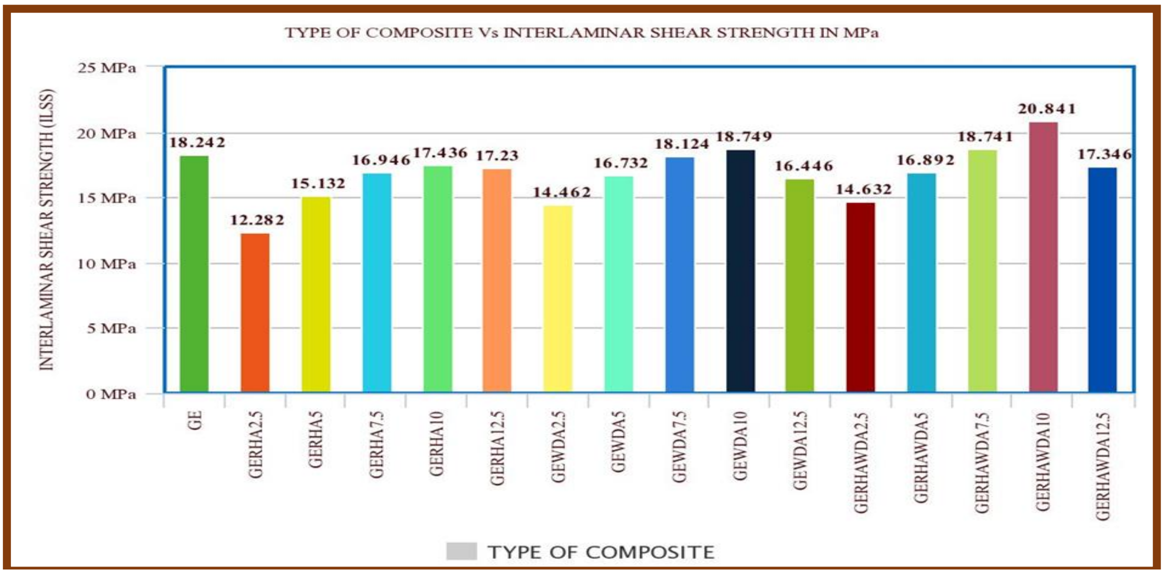

Fig. 8. Chart for type/nature of composite vs inter-laminar shear strength ('ILSS')

3.1.5 Impact strength ('IS')

From Figure 9, the extreme 'IS' of 278.9 J/m is seen in the composite filled through RHA at 10 wt% and minimum 'IS' is observed in unfilled and WDA2.5 filled composites. Through the rise in the weight ratio of fillers the increasing trend of 'IS' is observed up to 10 wt% of the filler. From the values of 'IS' it is recommended that the composite occupied with RHA10 is a prospective material for structural material for the components to be used in an erosive environment.

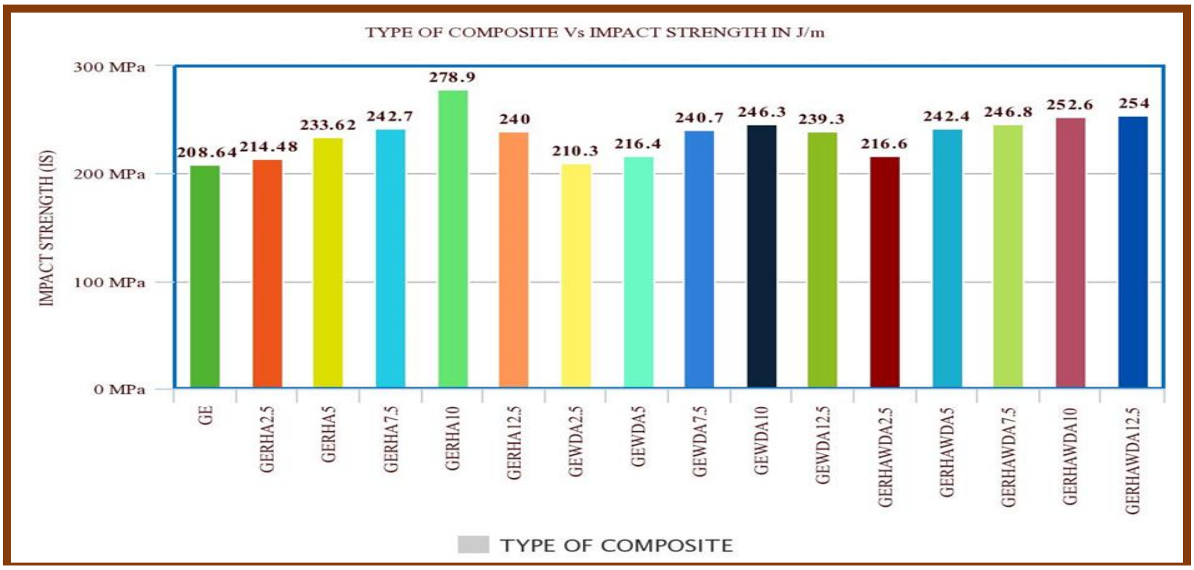

Fig. 9. Chart for type/nature of composite vs impact strength ('IS')

3.1.6 Vickers micro hardness ('Hv')

From Figure 10 the peak value of 'Hv' of 49 is seen in the composite occupied with RHA at 12.5 wt% and a low 'Hv' value is observed in WDA2.5 filled composites. Through the increase in weight fraction of fillers, the growing trend of hardness value is detected up to 12.5 wt% of the filler addition to the composites. The existence of pores and voids may lead to a decrease in the hardness of the composites.

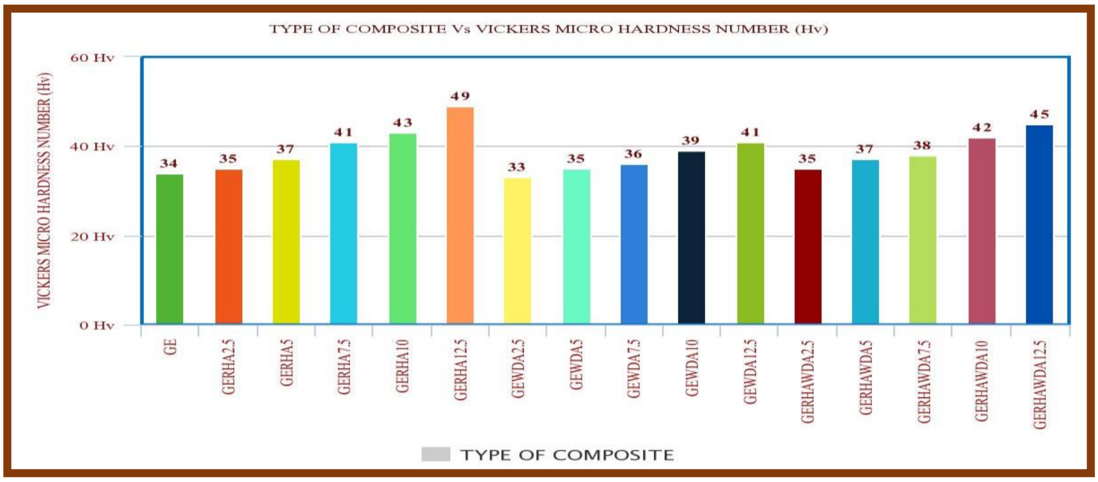

Fig. 10. Chart for type/nature of composite vs Vickers micro hardness ('Hv')

3.2 TOPSIS and VIKOR's Ranking

The systematic procedure is followed to find the best suitable composite from 16 alternatives for 6 attributes by TOPSIS and VIKORS ranking methods.

From the results revealed in Table 2, it is witnessed that the composite occupied with RHA at 5 wt% got the 1st rank and the composite occupied with WDA at 12.5 wt% got the 16th rank in both methods. The ranking results obtained by the TOPSIS ranking are nearly equal to the ranking results obtained by the VIKORS ranking method at the VIKORS Index of 0.25.

Table 2
Utility measures index (Q_{si}), indivisible regret measure (Q_{ri}), Vikor's index (Q_v), Vikor's ranking (R_v) and Topsis ranking (R_t) of the composites (C)

Designation of composites (C)	Q_{si}	Q_{ri}	Q_v at v=0.25	Q_v at v=0.5	Q_v at v=0.75	R_v at v=0.25	R_v at v=0.5	R_v at v=0.75	Topsis ranking R_t
GE	0.332	0.333	0.333	0.333	0.332	10	10	10	9
GERHA2.5	1.000	0.890	0.918	0.945	0.973	14	15	16	13
GERHA5	0.001	0.027	0.021	0.014	0.008	1	1	1	1
GERHA7.5	0.169	0.078	0.101	0.124	0.146	6	6	7	5
GERHA10	0.727	0.893	0.851	0.810	0.769	13	13	13	14
GERHA12.5	0.843	0.966	0.935	0.904	0.873	15	14	14	15
GEWDA2.5	0.546	0.338	0.390	0.442	0.494	12	12	12	11
GEWDA5	0.074	0.016	0.030	0.045	0.059	2	2	4	2
GEWDA7.5	0.212	0.105	0.132	0.159	0.186	7	8	8	7
GEWDA10	0.317	0.328	0.326	0.323	0.320	9	9	9	10
GEWDA12.5	0.946	1.000	0.987	0.973	0.960	16	16	15	16
GERHAWDA2.5	0.123	0.000	0.031	0.061	0.092	3	5	6	3
GERHAWDA5	0.014	0.102	0.080	0.058	0.036	4	4	3	4
GERHAWDA7.5	0.000	0.131	0.098	0.066	0.033	5	3	2	6
GERHAWDA10	0.021	0.275	0.211	0.148	0.084	8	7	5	8
GERHAWDA12.5	0.321	0.367	0.356	0.344	0.333	11	11	11	12

3.3 Water Absorption Behavior of Composites (C)

The sixteen composites are initially weighed and then immersed in 'ground water', 'mineral water' and 'distilled water', for the time interval of 144 hours. After the time interval, the specimens are again weighed and the difference of the final weight and initial weight are tabulated. The equation to calculate the water absorption rate (WA) is as follows

$$(\mathrm{WA})(\%) = \frac{\mathrm{Wf}-\mathrm{Wo}}{\mathrm{Wo}} \times 100\ \% \qquad (1)$$

Wf = Final weight of specimen after immersion in water for x time interval
Wo = Initial weight of specimen before immersion in water

From Figure 11, the chart for water absorption behavior of the composite specimens immersed in 'mineral water', 'distilled water' and 'ground water' for the time interval of 144 hours, it is perceived that the composite occupied with RHAWDA has more water absorption rate (WA) when they are immersed in 'mineral water' and less absorption rate when immersed in 'distilled water'. RHA filled composite at 12.5 wt% has shown minimum water absorption rate (WA) when immersed in ‘mineral water’ and ‘distilled water’. WDA2.5 filled composite has given the minimum water absorption rate (WA) when it is immersed in ‘ground water’.

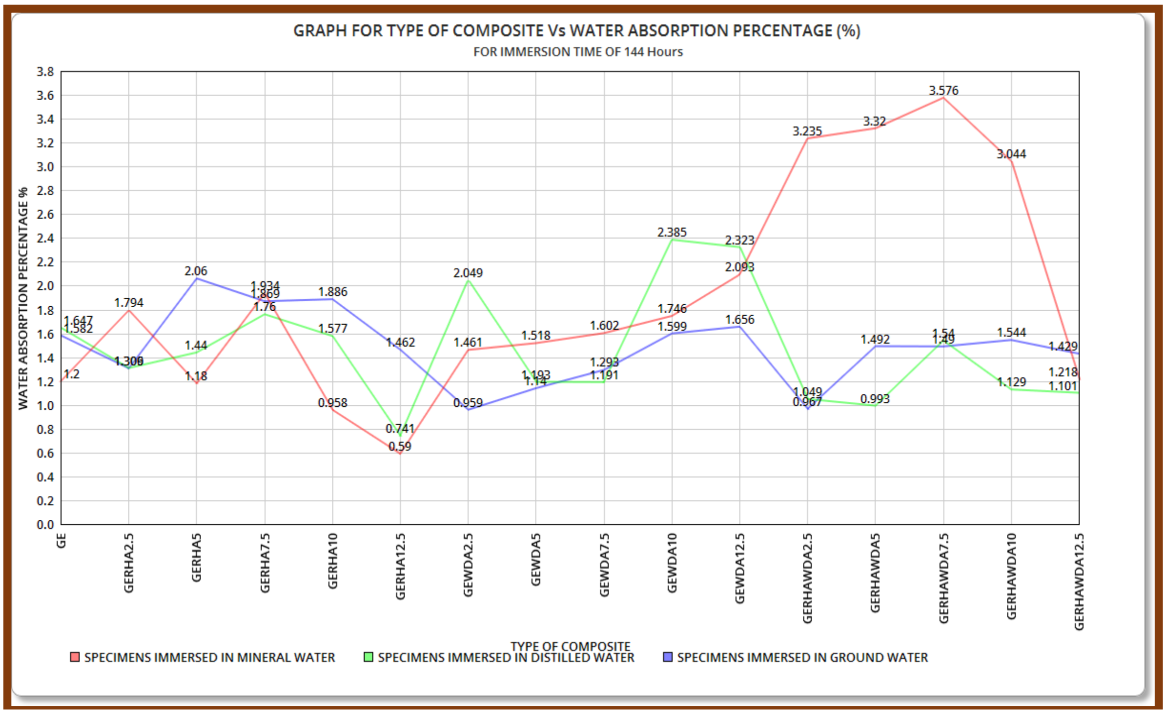

Fig. 11. Chart for water absorption behavior of the composite specimens immersed in ‘mineral, distilled and ground waters’ for the time interval of 144 hours

4. Conclusions and Opportunities for Future Work

The conclusions and opportunities for future work as below.

i. From the graphs of mechanical characterization (MC), it is observed that except ‘TS’ other mechanical properties of the composites were improved with the rise in the amount of filler addition.
ii. With the addition of industrial wastes (RHA/WDA/RHAWDA) to the epoxy composites embedded with E-glass fiber, the manufacturing/development cost is reduced compared to un-filled composites.
iii. Topsis and Vikor’s rankings were successfully applied to know the best suitable structural composite i.e., EGRHA5, for the manufacturing of the water tank.
iv. From the water immersion behavior of the composites, immersed in ‘distilled water’, ‘mineral water’ and ‘ground water’, it is seen/identified that the composites occupied with RHA at 12.5 wt% have given the minimum water absorption rate (WA) in ‘distilled and mineral waters’ and has given the maximum ‘IS’ and ‘Hv’. So, the composite occupied with RHA at 12.5 wt% can be used to manufacture the roof sheets.
v. With the accumulation of other industrial trashes, resins and fiber materials with varying compositions the composites can be manufactured/ prepared successfully.
vi. The erosion wear behavior of the composites can be studied.
vii. Thermal, electrical and dielectric properties can be determined.

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