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INFLUENCE OF REDMUD FILLER ON PALMYRA FRUIT AND PALMYRA FIBER WASTE REINFORCED POLYESTER COMPOSITE: HARDNESS, TENSILE AND IMPACT STUDIES

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Abstract. The enhancement of composite strength by addition of fillers especially industrial waste attracts more attention. In this article, the effect of redmud (aluminium industry waste) as a secondary reinforcement on Palmyra fruit fiber and Palmyra fiber waste as primary reinforcement along with unsaturated polyester has been analyzed. Hardness, Tensile and Impact property of the Palmyra fibers with and without redmud have been reported. Palmyra fiber (both fruit and waste type) of length 30 mm and weight percentage of 50 % has been taken for this study. Also redmud of different varying weight percentages 10 %, 20 %, 30 %, and 40 % respectively taken to study its effect. It is noted that the Impact strength increases with more and more addition of redmud in both cases of fibers. The Tensile strength increases for 10 %wt addition of redmud in the case of Palmyra fruit fiber and 20 %wt addition of redmud for Palmyra fiber waste. The failure mechanism of the composites has also been discussed by microscopic studies.

1. Introduction

The growing trend in the utilization of composite materials instead of conventional materials in various industrial applications creates much interest among the researchers. One of such research is the usage of Palmyra fibers which is available by nature itself along with the industrial waste redmud as a filler material for making potential new composites. The composite consists of two phases in general, the matrix and reinforcement phase. The reinforcement play vital role in the composite final strength. The addition of fillers as secondary reinforcement along with fiber proved to be a strength enhancing factor. The usage of Palmyra fiber along with polyester was first investigated by Manikandan and Velmurugan, it is observed that the Palmyra fruit fiber with varying weight percentage show an enhanced mechanical performance. They continued their studies on Glass and Palmyra fiber waste/polyester sandwich composite and reported that the waste of 48 %wt and addition of glass fiber of 10 %wt has high strength [1]. Further Manikandan and Velmurugan carried out studies on use of fillers such as sawdust/coir pith as reinforcement along with Palmyra fiber by varying weight percentage and reported an increase in the mechanical properties [2].

Thiruchitrambalam and Shanmugam [3] carried out studies on the palm leaf stalk fiber reinforced polyester composites with a special reference to treatments of fiber by using various chemicals, for the purpose of increasing matrix adhesion and reported considerable hike in the mechanical properties. Adavi Balakrishna et al. [4] performed studies on Asian Palmyra composite with importance to variables such as treatment time, fiber volume and

fiber weight percentage and all the variables can be validated by mathematical modeling. Furthermore studies on Palmyra Fiber with different matrix and manufacturing technique have been done by Budrun Neher et al. [5, 6]. In their work, Palm fiber in the Bangladesh region reinforced with Acryonitrile Butadiene Styrene (ABS) matrix prepared by injection moulding technique. Palm fiber of different weight percentages 5 %, 10 %, and 20 %wt has been taken and observed that the tensile and flexural strength decreases beyond 10 %wt. Also they analyzed the fracture mechanisms by performing characterization studies for the same.

Jawaid et al. [7] performed mechanical performance studies on oil palm empty fruit bunch fiber and jute fiber along with epoxy matrix composite prepared by hand layup technique. They reported that the treatment of fibers improve the mechanical properties, also which is evident from the scanning electron microscopy studies. The thermal and mechanical studies on Palmyra bract fiber composite reinforced with polyester have been done by Mahesh et al. [8]. The effect of filler (chalk powder) also was analyzed in detail in their work. The same studies have been done by Padmavathi et al. [9] in which only the filler can be replaced by copper powder. The effect of redmud as a potential filler for making composites has already evident from the extensive studies done by Arumuga Prabu et al. [10-12] in which banana, sisal and pineapple fiber used as a reinforcement along with the polyester matrix. It is noted that considerable increase in mechanical strength in all cases observed. From the thorough literature survey, the authors come to know that no work carried out by using Palmyra fiber along with redmud as a filler, also comparison of the Palmyra fruit and Palmyra waste fiber with and without redmud effect is reported in this work.

2. Materials

The raw materials used for the composite preparation are as follows:

- Palmyra fruit fiber and Palmyra fiber waste.
- Red mud.
- Polyester resin.
- Catalyst (Methyl Ethyl Ketone Peroxide).
- Accelerator (Cobalt Naphtha late).

2.1. Palmyra fruit fiber and Palmyra fiber waste. Palmyra fruit fibers are obtained from the fruit husk of Palmyra trees. The fibers are extracted and used as shown in Fig. 1.

Palmyra fiber waste also extracted from the same palm trees but the difference is its waste obtained during the fruit extraction which is shown in Fig. 2.

Fig. 1. Extracted Palmyra fruit fiber.

Fig. 2. Extracted Palmyra fiber waste.

2.2. Redmud. Redmud or red sludge is a waste product generated in the aluminium production industry in an enormous quantity. The discharge of redmud is hazardous environmentally because of its disposal problem and alkalinity. The redmud in porous form is shown in Fig. 3 and the chemical composition is shown in Fig. 4.

Fig. 3. Redmud.

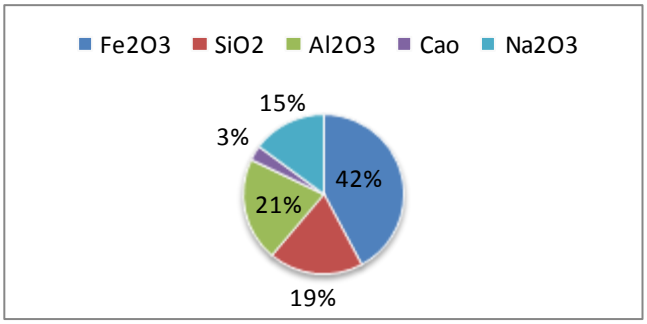


Fig. 4. Chemical composition of redmud.

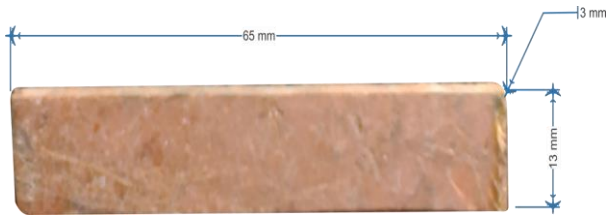
2.3. Polyester resin. The unsaturated polyester resin of grade VBR4503 is used as a matrix material. To initiate the curing reaction with the resin accelerator and catalyst are added. Cobalt Napthalate used as accelerator and Methyl Ethyl Ketone Peroxide used as catalyst. All are purchased from Vasavibala Resins Ltd., Chennai.

3. Experimental details

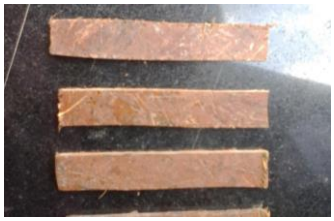
The Compression Molding Technique is used for preparing the specimen. Palmyra fruit fibers and Palmyra fiber waste are reinforced with unsaturated polyester resin filled with and without red mud used to prepare the composites through compression molding machine. Cobalt naphtha late as accelerator and Methyl ethyl ketone peroxide as catalyst are mixed with resin about 1.5 ml for 100ml of resin into the reinforcement. Before the fibers are being arranged into the mold, the mold is coated with wax in order to avoid fibers sticking to the mold. Then the molds are closed and loaded into the molding machine. The specimens are kept under load for about 5 hours for proper curing at room temperature. After specimen is cured it is taken out carefully and removed from the mold. Red mud is added in varying weight percentage to the resin before adding catalyst and accelerator. It is mixed in 10 %, 20 %, 30 %, and 40 %wt, respectively. Typical specimen is shown in Fig. 5.

Fig. 5. Specimen of red mud filled Palmyra fruit fiber and Palmyra waste fiber.

3.1. Impact test. The Charpy impact test has been carried out on the prepared specimens as per ASTM D256 as shown in Fig. 6(a, b). Five specimens are tested and the average value is reported.



(a)



(b)

Fig. 6. Impact test specimens.

3.2. Tensile test. The test process involves placing the test specimen in the universal testing machine and slowly extending it until it fractures.

Fig.7. Tensile test specimen.

The specimen used for tensile test as per ASTM D3039 is shown in Fig. 7 and 8.

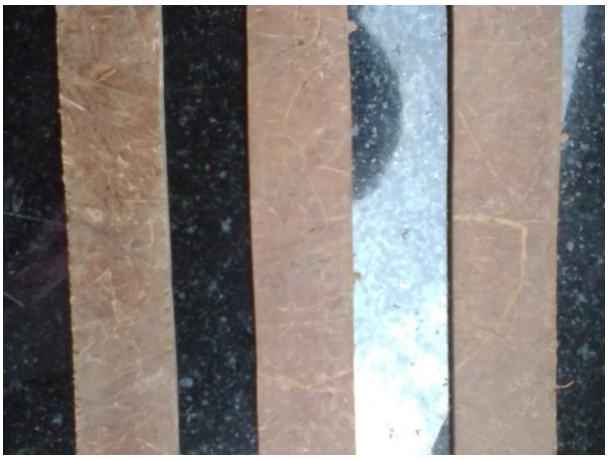


Fig. 8. Tensile test specimen in varying redmud ratios.

3.3. Hardness test. Hardness test has been performed using Shore-D hardness tester as shown in Fig. 9. The test has been carried out by pressing the surface of the indenter pin against the specimen and the readings are displayed in the digital screen.

Fig. 9. Shore-D tester.

4. Result and discussion

4.1. Tensile test result of redmud filled Palmyra fruit fiber composite. The tensile strength, results of Palmyra fruit fiber with and without red mud filler is shown in Fig. 10. It is observed that the addition of 10 % and 40 % with red mud along with Palmyra fruit show enhanced increase in the tensile strength. This shows the potential usage of redmud that enhance the tensile strength. The tensile value for pure Palmyra fruit reinforced polyester is 26.66 MPa, whereas the addition of redmud except 30 % weight shows potential increase in

strength. This is due to the more pulling load withstand capability of the redmud as shown in Fig. 11(a). Also the bonding between fiber and matrix give enhanced strength by the addition of more and more redmud as shown in Fig. 11(b).

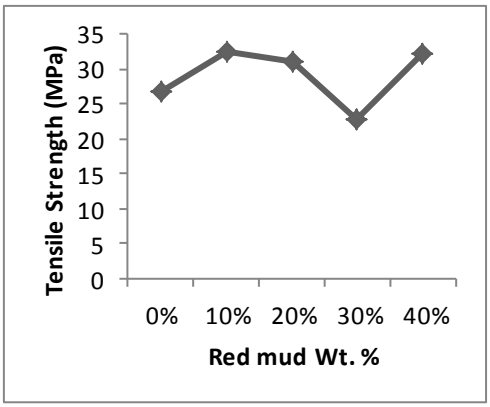


Fig. 10. Tensile values of redmud filled Palmyra fruit fiber composites.

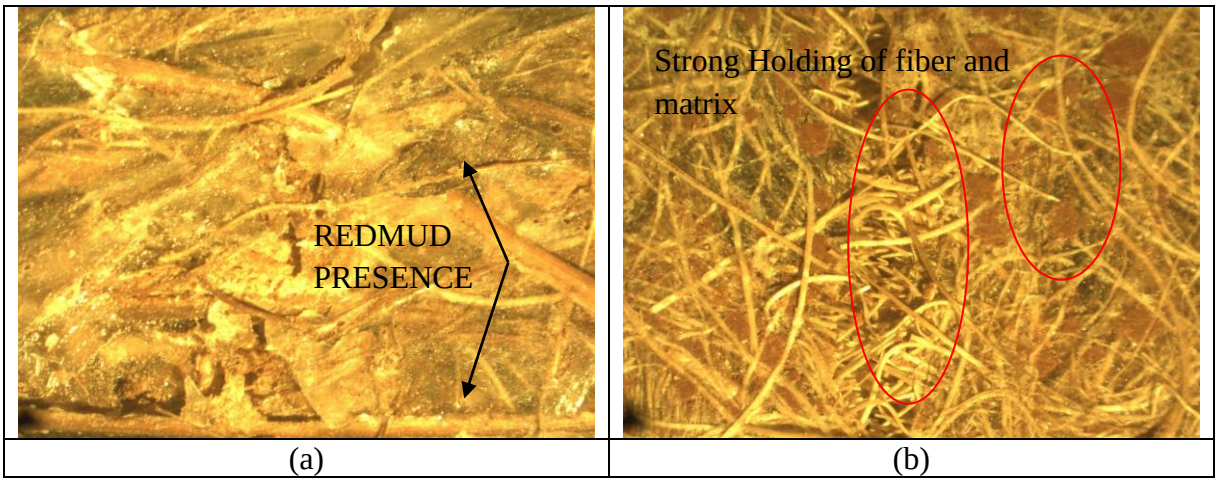


Fig. 11. Tensile strength microscopic images for Redmud filled Palmyra fruit fiber composites.

4.2. Tensile test result of redmud filled Palmyra fiber waste composite. From the tensile strength results of Palmyra fiber waste reinforced polyester composite shown in Fig. 12, it is evident that the addition of redmud of varying percentage (10-40 %wt) shown up and down trend in the tensile value.

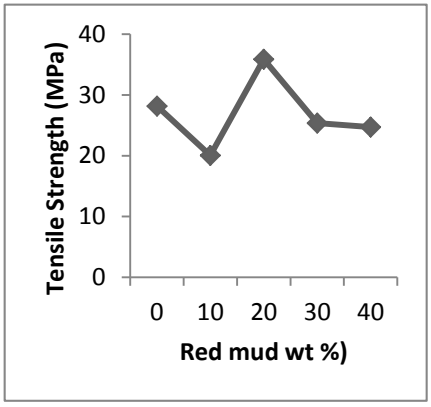


Fig. 12. Tensile values of redmud filled Palmyra fiber waste composites.

Among all addition of 20 %wt redmud show an increased strength value compare to pure Palmyra waste fiber, in the same time the other weight percentages show variation in value but all lesser than the pure Palmyra waste fiber. This may be due to poor distribution of redmud filler observed from the tested specimen as shown in Fig. 13(a, b). Also random orientation of Palmyra waste fiber which occupies the space here and there with more quantity in a particular area and less in other area result in poor tensile strength.

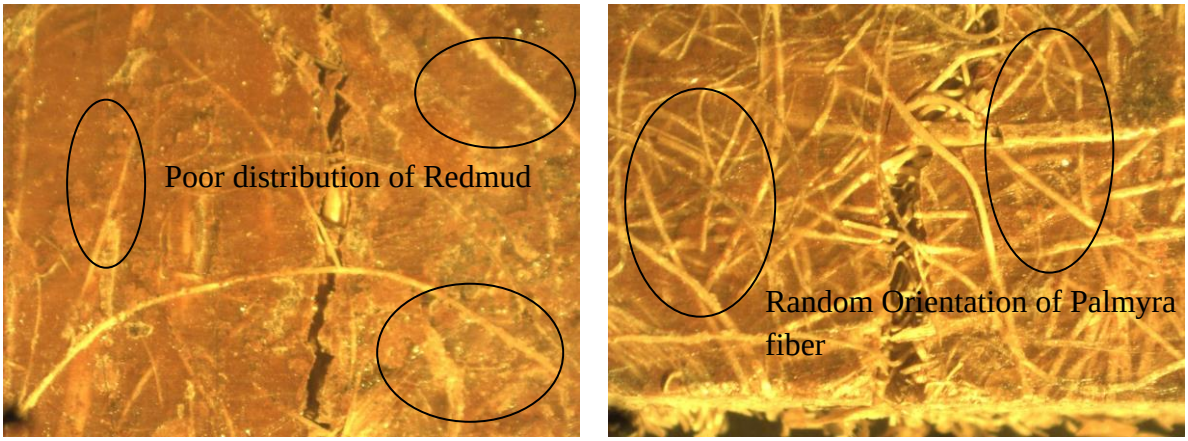


Fig. 13. Tensile strength microscopic images for redmud filled Palmyra fiber waste composites.

4.3. Impact test result of redmud filled Palmyra fruit fiber composite. The impact strength result of Palmyra fruit fiber with and without redmud is shown in Fig. 14. From the results, it is clearly noted that the addition of redmud increases the impact strength due to more energy absorption. The impact strength increases linearly from 10 % to 40 % wt of redmud. It is observed that the impact strength value of Palmyra composite is 1.616 J/cm^2, at the same time the addition of 10 %, 20 %, 30 %, and 40 % weight of redmud with Palmyra has higher values. Finally it is evident that the addition of redmud increases the impact strength when compared with Palmyra/polyester composites.

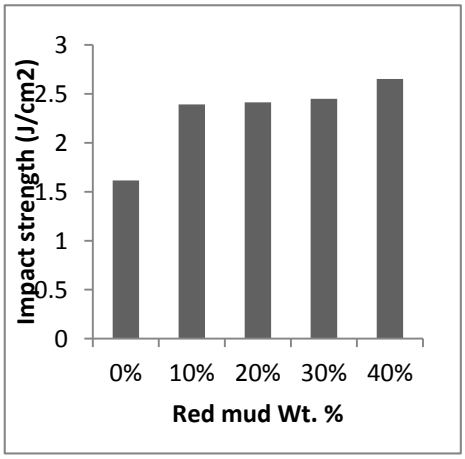
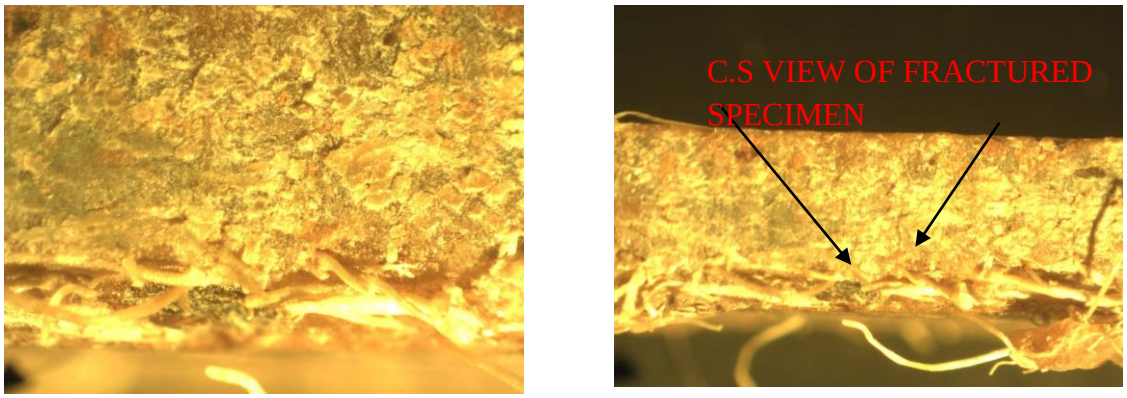


Fig. 14. Impact values of redmud filled Palmyra fruit fiber composites.

In general natural fiber like Palmyra has high energy absorbing capacity. The incorporation of redmud along with natural fiber increases the impact strength to a greater extent because of high load bearing capacity. The redmud filler occupies the vacuum space in the matrix that creates damage which in term holds the fiber strongly result in high strength as shown in Fig. 15(a, b).



(a) (b)

Fig. 15. Impact strength microscopic images for Redmud filled palmyra fiber waste composites.

4.4. Impact test result of redmud filled Palmyra fiber waste composite. The impact values of redmud reinforced Palmyra fiber Waste composites are shown in Fig. 16. From the results it is clearly noted that the addition of redmud increases the impact strength due to the more energy absorption. The impact strength increases linearly from 10 % to 40 %wt of redmud. It is observed that the impact strength value of pure Palmyra composite is 5.69 J/cm^2 at the same time the additions of 10 %, 20 %, 30 %, and 40 % weight of redmud with Palmyra has value of 6.15 J/cm^2, 6.33 J/cm^2, 10.05 J/cm^2, and 11.74 J/cm^2 respectively. Among all composite combination, the composite with 40 %wt redmud show enhanced strength value. It is also clearly noted that there is no broken pieces of fiber as shown in Fig. 17(a, b). This resembles strong bonding of fiber and matrix by addition of fillers.

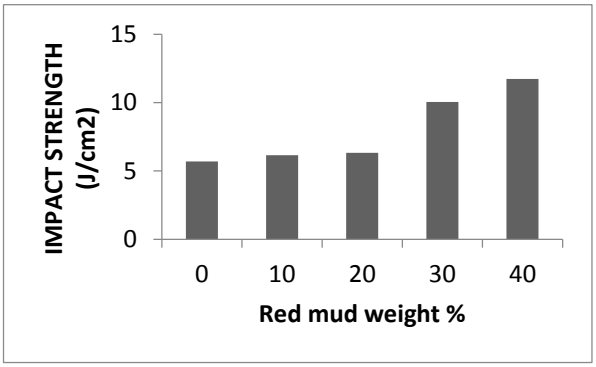
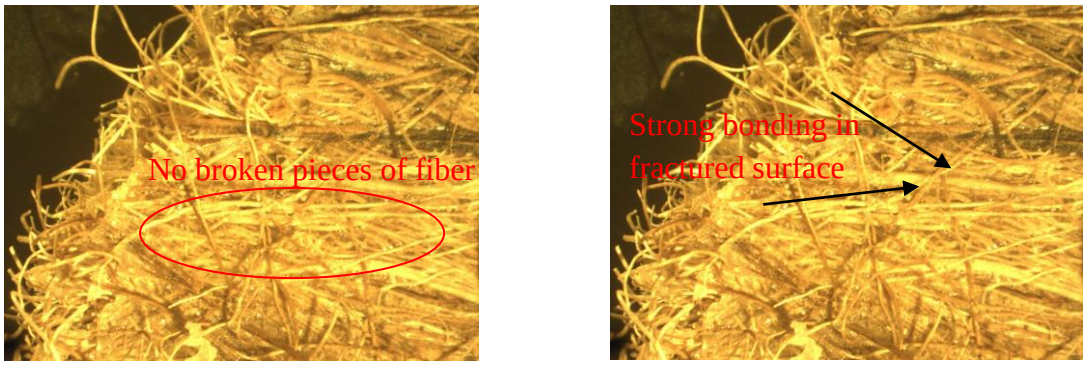


Fig. 16. Impact values of redmud filled Palmyra fiber waste composites.



(a) (b)

Fig. 17. Microscopic images for redmud filled Palmyra fiber waste composites.

4.5. Hardness values of redmud filled Palmyra fruit fiber and Palmyra fiber waste composite. The hardness test results of Palmyra fruit fiber and Palmyra fiber waste is shown in Fig. 18. It is inferred from the results that the addition of redmud decreases the hardness values in both cases. From the variation in the hardness values the different weight percentage of redmud dispersion with the matrix and fiber is justified.

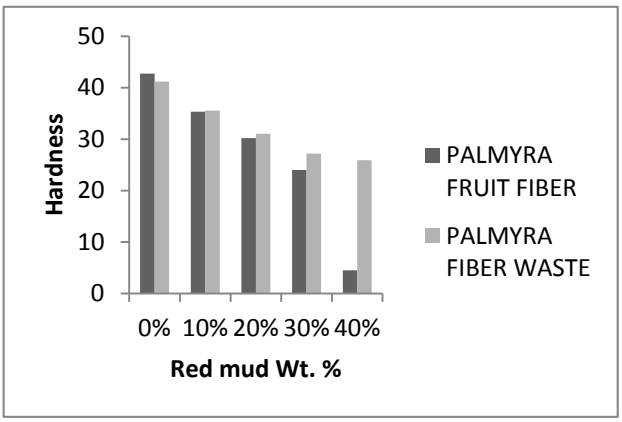


Fig. 18. Hardness values of redmud filled Palmyra fruit fiber and Palmyra fiber waste composites.

4.6. Comparative study. From the comparison the mechanical performance of Palmyra fiber waste filled with redmud show better strength than Palmyra fruit fiber filled with redmud. But it is noted that in both cases addition of redmud filler increase the tensile and impact strength. In the case of Palmyra fiber waste addition of redmud increases the tensile and impact strength by 22 % and 52 % respectively compared with Palmyra/polyester composites. For Palmyra fruit fiber addition of redmud increases the tensile and impact strength by 17 % and 39 % respectively. But for hardness the phenomenon gets reversed where Palmyra fruit fiber has the highest value. Also the addition of redmud decreases hardness in both cases compared with Palmyra/polyester composites.

5. Conclusions

- Palmyra fruit fiber and Palmyra fiber waste filled with redmud has been successfully fabricated.
- Impact strength of Palmyra fruit fiber and Palmyra fiber waste filled redmud increases by 39 % and 52 % compared to Palmyra/polyester composite.
- Tensile strength of Palmyra fruit fiber and Palmyra fiber waste filled redmud increases by 17 % and 22 % compared to Palmyra/polyester composite.
- Mechanical performance of the composites increases by the addition of redmud is justified from the results obtained. It is also evident from the microscopic studies.
- Hardness values of the composites decreases by the addition of redmud due to the dispersion of different weight percentage redmud with the matrix.
- By means of getting better results, the potential environmental hazards caused by redmud reduced drastically by reusing the same.
- The newly developed composites can be used for making helmets, skating boards, clutch plate etc.

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