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Experimental Investigations on Flexural Properties of Coconut Shell and Granite Particles Reinforced Epoxy Matrix Based Hybrid Bio-Composites

Girimurugan R[1]*, Manickavasagam P[2], Anandhu K[3] ,Thirumaran J [4]

[1,2,3]Assistant Professor, Professor , Department of Mechanical Engineering, Nandha College of Technology, Perundurai, Tamilnadu, India.

[4]Associate Professor, Department of Pharmaceutics, Nandha College of Pharmacy, Perundurai, Tamilnadu, India.

Abstract

Integrating diverse natural resources as reinforcement and filler materials to hybrid bio-composites has risen dramatically in contemporary times to improve the needed qualities of the composites. Experimentation was used to determine the impacts on the epoxy resin matrix's flexural and impact characteristics by adding fine granite powder and coconut shell powder particles. Reinforcement materials include fine granite powder and coconut shell powder. To create hybrid bio-composite specimens, researchers varied the reinforcing material weight percentages while maintaining the epoxy resin weight percentage as-fixed. The traditional hand layup process was used to manufacture hybrid bio-composite boards. With the use of a water jet machining technique, hybrid bio-composite specimens for flexural and impact testing are cut away from the hybrid bio-composite boards. The flexural characteristics of the hybrid bio-composites are greatly improved by adding a little amount of fine granite powder and coconut shell powder to the epoxy resin matrix, according to the findings of the experiments.

Keywords: Coconut shell powder, granite powder, hybrid composites, flexural behavior, experimental study.

1. Introduction

There is no doubt that the current and future engineering trends have been drawn to the usage of natural fibre composites for waste reuse and cost reduction [1]. Natural fiber-reinforced polymer composite materials are becoming increasingly popular, both in terms of industrial applications and basic research. The structure and mechanical characteristics of carbonized coconut shell nanoparticles reinforced epoxy composite have been studied to establish the viability of employing the composite as a novel material for vehicle bumper application [3]. Palm-epoxy hybrid composites (PEHC) may be made by introducing granite powder (0, 5, 10, and 15 wt percent) into the mixture [4]. "Cordia otoma" natural fibres and "granite powder" filler have been used to create a hybrid composite in this study. According to the results, granite powder might be used as a filler material to improve the mechanical characteristics of composites. The epoxy matrix was reinforced with shell particles (sized between 200-800m) at weight percentages of 20, 25, 30 and 35 to create coconut particle reinforced composites [6]. This investigation focuses on the source, volume, and environmental impact of this trash. To create a new composite material, marble and granite dust will be disseminated in high-density polyethylene. The mechanical characteristics of the composite were examined in relation to the proportion of marble and granite dust and particle size [7]. [8] looked at the mechanical properties of epoxy resin matrix bio composites reinforced with banana fibre and filled with groundnut shell powder. The mechanical characteristics of epoxy resin/banana fibre composites were dramatically improved by adding groundnut shell powder. [9] looked at the mechanical properties of epoxy resin matrix bio composites reinforced with jute fibre and filled with egg shell powder. The mechanical characteristics of epoxy resin/jute fibre composites were dramatically improved when egg shell powder was added to the mixture. [10] Banana fibre reinforced, camellia sinensis particles filled epoxy resin matrix bio composites were experimentally studied for impact and hardness behaviour. The mechanical characteristics of epoxy resin/banana fibre composites are greatly improved when camellia sinensis particles are added. Experiments were conducted to determine how well treated and untreated hybrid bio-composites absorbed water. Hybrid polymer composites' tensile behaviour was examined experimentally. The flexural performance of epoxy matrix composites reinforced with chemically modified and unmodified banana fiber/used camellia sinensis particles was experimentally studied [13]. [14-20] Examined the impact of polymer Nano-composites coated with double hydroxide. Research into the mechanical characteristics of epoxy resin matrix bio-composites filled with jute fibre reinforced coconut shell particles was carried out experimentally. In the literature review, the use of granite powder with coconut shell ash and epoxy resin composites appears to be rare. It has been attempted to prepare and evaluate the flexural characteristics of epoxy resin composites reinforced with granite powder particles and coconut shell powder.

2. Materials and Methods

Matrix materials were obtained from the local polymer market using epoxy resin and hardener. With a mechanical stirring machine, epoxy resin and hardener were combined to achieve excellent bonding with filler materials at a ratio of

15:02. Marble businesses in the area have supplied us with the necessary granite powder. Filler materials made from coconut shells have been obtained from oil mills in the Erode district of Tamil Nadu, India. It rinsed twice with hot water to eliminate any remaining dust particles from the collected trash coconut shells. After washing, it was left to air dry for seven hours at room temperature. The well-dried coconut shell has been placed in a flourmill to get coconut shell powder particles after the drying process. Using a flourmill, coconut shells of all shapes and sizes were ground into a fine powder. Using a manual sifting technique, the powdered form of coconut shell has been separated into 95 micron-sized pieces. The composition details for all the six composites were given in table 1.

Table 1. Composition details of the composites

Sl.No.	Composite Description	Matrix wt. %	Granite Powder wt. %	Coconut Shell Powder wt. %
1	Composite - 1	65	35	0
2	Composite - 2	65	0	35
3	Composite - 3	65	17.5	17.5
4	Composite - 4	65	20	15
5	Composite - 5	65	22.5	12.5
6	Composite - 6	65	25	10

This method has yielded the required quantity of tiny coconut shell particles. To make the composites plates using granite powders, epoxy resin, and tiny coconut shell particles, a compression moulding machine was employed. The compression-molding machine arranges granite powder particles as the first step in the creation of composite plates. On the surface table of the compression moulding machine, granite powder has been spread. After this arrangement, the granite powder plates' surface has been fully disseminated with the appropriate number of coconut shell powders. To achieve a certain layer thickness, an epoxy resin/hardener solution was sprayed on top of the distributed surface of coconut shell particles. Granite powder has been sprinkled over the same coconut shell powder distributed surface after the epoxy resin/hardener solution had been applied. Using a compression-molding machine with a specified hydraulic pressure, a blend of granite power, epoxy resin hardener, and coconut shell allowed temperatures to reach 110°C for 90 minutes. After 90 minutes of processing, the requisite composite plates were obtained, allowing for room-temperature cooling. Upon completion of the chilling process, waterjet cutting has been used to remove the necessary composite specimens from the composite plate in accordance with the ASTM criteria. For the remaining five compositions, the same method was followed. Figure 1 (a) and (b) show the well-prepared composite specimens as per ASTM requirements for flexural testing (before and after). Tests on the flexural properties of composites have been possible thanks to well-prepared specimens. The flexural test (ASTM D790-10) of composites was performed using a computerized universal testing equipment with a 400 KN capacity and a loading rate of 2 mm/min.

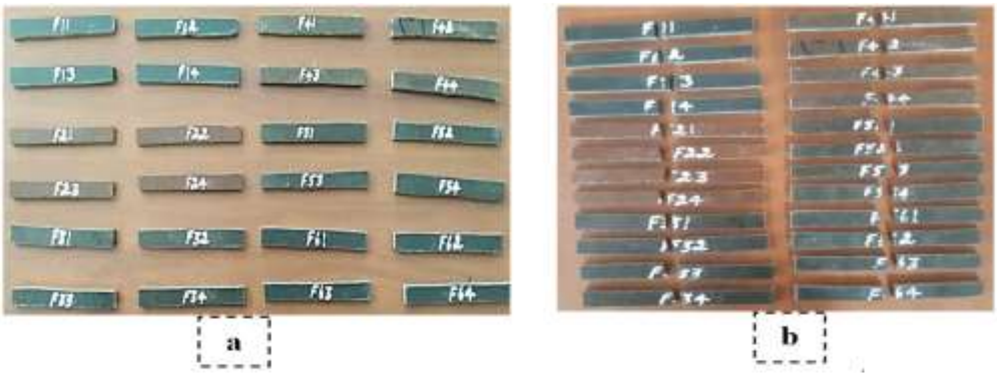

Figure 1 Flexural Test Specimens (A) Before Test (B) After Test

3. Results and Discussions

3.1 Peak Flexural Load for C1 Composite Specimens

The variation on peak flexural load for C11, C12, C13 and C14 bio-composite specimens were demonstrated in figure 2. The peak flexural load of 216, 211, 237 and 250 N were observed during the flexural test on the C11, C12, C13 and C14 bio-composite specimens respectively. An average peak flexural load of 228 N was noticed in C1 bio-composite specimens.

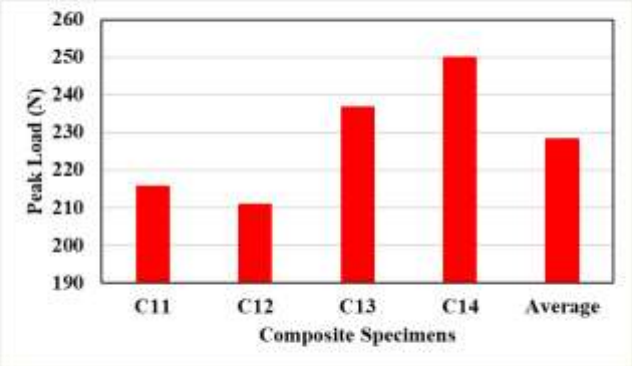

Figure 2 Variation on peak flexural load for composite specimen-01

3.2 Flexural Strength for C1 Composite Specimens

The variation on flexural strength for C11, C12, C13 and C14 bio-composite specimens were demonstrated in figure 3. The flexural strength of 35, 34, 38 and 40 MPa were observed during the flexural test on the C11, C12, C13 and C14 bio-composite specimens respectively. An average flexural strength of 37 MPa was noticed in C1 bio-composite specimens.

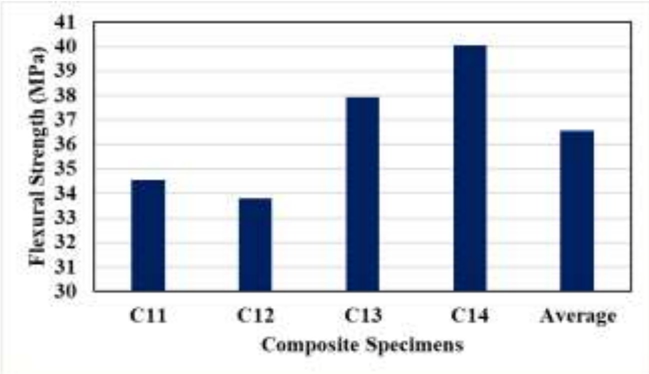

Figure 3 Variation on flexural strength for composite specimen-01

3.3 Flexural Modulus for C1 Composite Specimens

The variation on flexural modulus for C11, C12, C13 and C14 bio-composite specimens were demonstrated in figure 4. The flexural modulus of 5016, 4875, 4810 and 5402 GPa were observed during the flexural test on the C11, C12, C13 and C14 bio-composite specimens respectively. An average flexural modulus of 5026 GPa was noticed in C1 bio-composite specimens.

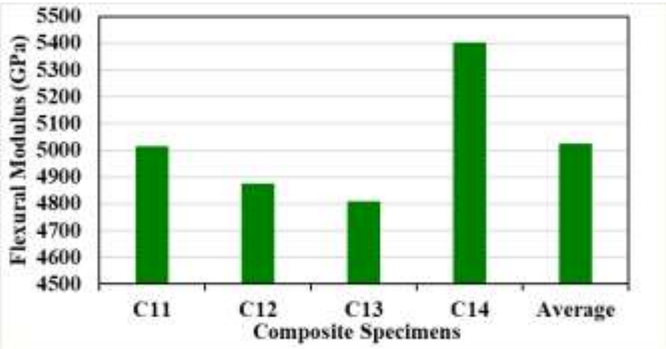

Figure 4 Variation on Flexural Modulus for Composite Specimen-01

3.4 Peak Flexural Load for C2 Composite Specimens

The variation on peak flexural load for C21, C22, C23 and C24 bio-composite specimens were illustrated in figure 5. The peak flexural load of 159, 181, 207 and 173 N were observed during the flexural test on the C21, C22, C23 and C24 bio-composite specimens respectively. An average peak flexural load of 180 N was noticed in C2 bio-composite specimens.

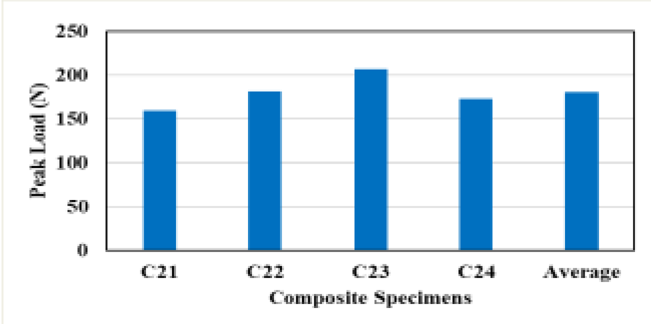

Figure 5 Variation on Peak Flexural Load for Composite Specimen-02

3.5 Flexural Strength for C2 Composite Specimens

The variation on flexural strength for C21, C22, C23 and C24 bio-composite specimens were demonstrated in figure 6. The flexural strength of 26, 29, 33 and 28 MPa were observed during the flexural test on the C21, C22, C23 and C24 bio-composite specimens respectively. An average flexural strength of 29 MPa was noticed in C2 bio-composite specimens.

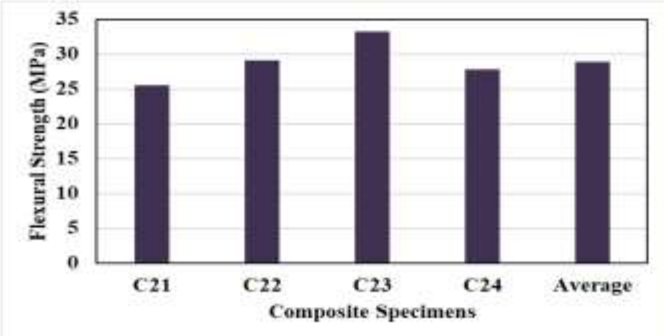

Figure 6 Variation on flexural strength for composite specimen-02

3.6 Flexural Modulus for C2 Composite Specimens

The variation on flexural modulus for C21, C22, C23 and C24 bio-composite specimens were demonstrated in figure 7. The flexural modulus of 2757, 3406, 4001 and 3346 GPa were observed during the flexural test on the C21, C22, C23 and C24 bio-composite specimens respectively. An average flexural modulus of 3377 GPa was noticed in C2 bio-composite specimens.

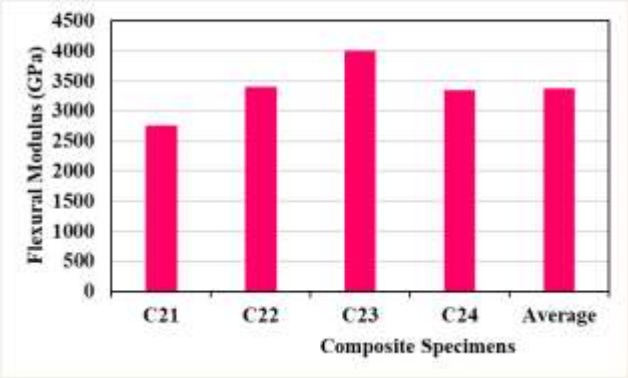

Figure 7 Variation on flexural modulus for composite specimen-02

3.7 Peak Flexural Load for C3 Composite Specimens

The variation on peak flexural load for C31, C32, C33 and C34 hybrid-bio-composite specimens were illustrated in figure 8. The peak flexural load of 208, 208, 205 and 186 N were observed during the flexural test on the C31, C32, C33 and C34 hybrid bio-composite specimens respectively. An average peak flexural load of 201 N was noticed in C3 hybrid bio-composite specimens.

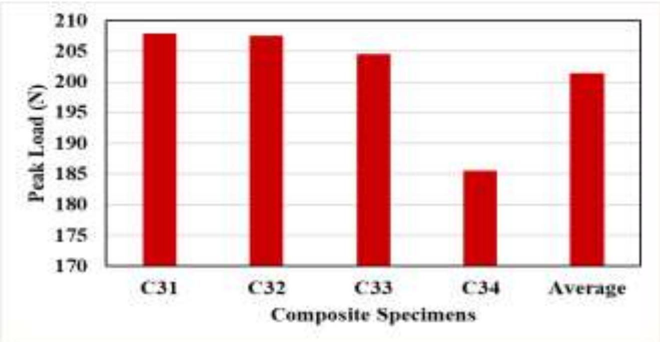

Figure 8 Variation on peak flexural load for composite specimen-03

3.8 Flexural Strength for C3 Composite Specimens

The variation on flexural strength for C31, C32, C33 and C34 hybrid-bio-composite specimens were demonstrated in figure 9. The flexural strength of 33, 33, 33 and 30 MPa were observed during the flexural test on the C31, C32, C33 and C34 hybrid bio-composite specimens respectively. An average flexural strength of 32 MPa was noticed in C3 hybrid bio-composite specimens.

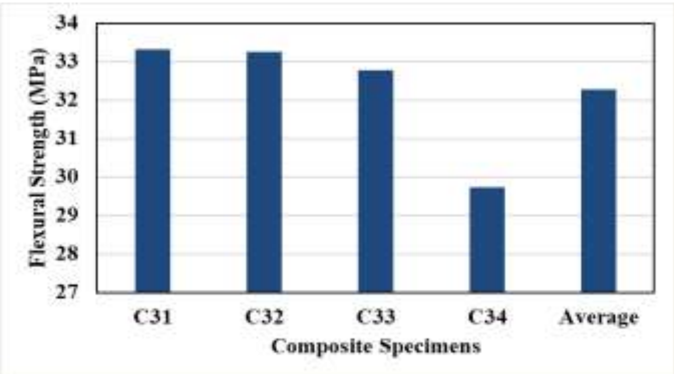

Figure 9 Variation on flexural strength for composite specimen-03

3.9 Flexural Modulus for C3 Composite Specimens

The variation on flexural modulus for C31, C32, C33 and C34 hybrid-bio-composite specimens were demonstrated in figure 10. The flexural modulus of 4217, 4159, 3860 and 3917 GPa were observed during the flexural test on the C31, C32, C23 and C34 hybrid bio-composite specimens respectively. An average flexural modulus of 4038 GPa was noticed in C3 hybrid bio-composite specimens.

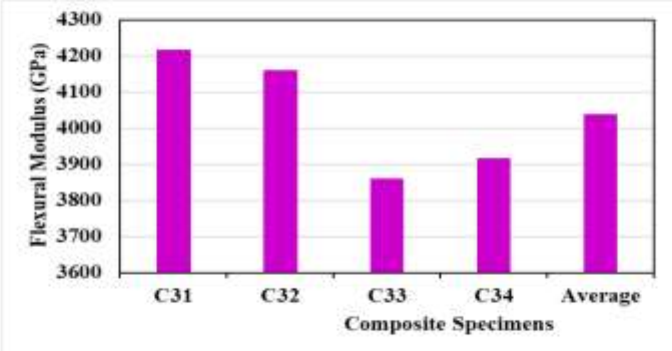

Figure 10 Variation on flexural modulus for composite specimen-03

3.10 Peak Flexural Load for C4 Composite Specimens

The variation on peak flexural load for C41, C42, C43 and C44 hybrid-bio-composite specimens were illustrated in figure 11. The peak flexural load of 228, 210, 216 and 258 N were observed during the flexural test on the C41, C42, C43 and C44 hybrid bio-composite specimens respectively. An average peak flexural load of 228 N was noticed in C4 hybrid bio-composite specimens.

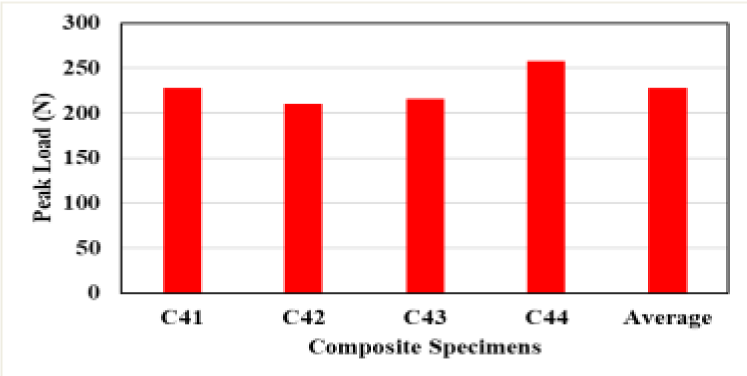

Figure 11 Variation on peak flexural load for composite specimen-04

3.11 Flexural Strength for C4 Composite Specimens

The variation on flexural strength for C41, C42, C43 and C44 hybrid-bio-composite specimens were demonstrated in figure 12. The flexural strength of 36, 34, 35 and 41 MPa were observed during the flexural test on the C41, C42, C43 and C44 hybrid bio-composite specimens respectively. An average flexural strength of 37 MPa was noticed in C4 hybrid bio-composite specimens.

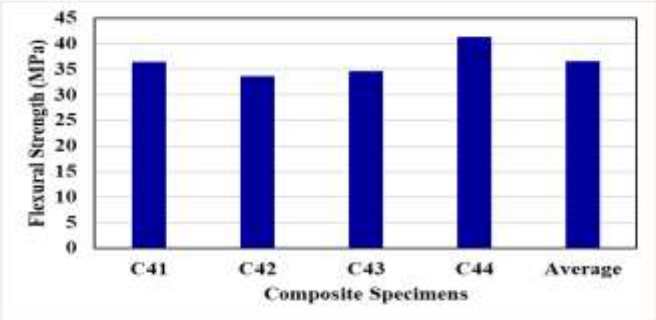

Figure 12 Variation on peak flexural load for composite specimen-04

3.12 Flexural Modulus for C4 Composite Specimens

The variation on flexural modulus for C41, C42, C43 and C44 hybrid-bio-composite specimens were demonstrated in figure 13. The flexural modulus of 3872, 3695, 3413 and 4017 GPa were observed during the flexural test on the C41, C42, C43 and C44 hybrid bio-composite specimens respectively. An average flexural modulus of 3749 GPa was noticed in C4 hybrid bio-composite specimens.

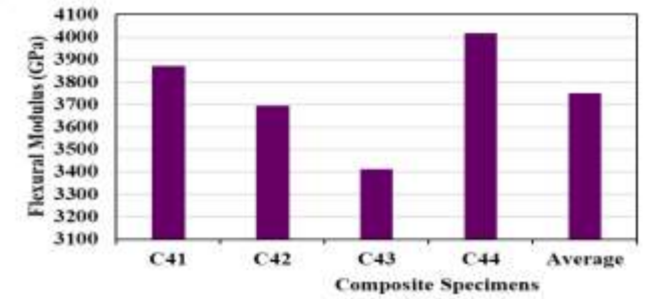

Figure 13 Variation on flexural modulus for composite specimen-04

3.13 Peak Flexural Load for C5 Composite Specimens

The variation on peak flexural load for C51, C52, C53 and C54 hybrid-bio-composite specimens were illustrated in figure 14. The peak flexural load of 147, 130, 175 and 174 N were observed during the flexural test on the C51, C52, C53 and C54 hybrid bio-composite specimens respectively. An average peak flexural load of 156 N was noticed in C5 hybrid bio-composite specimens.

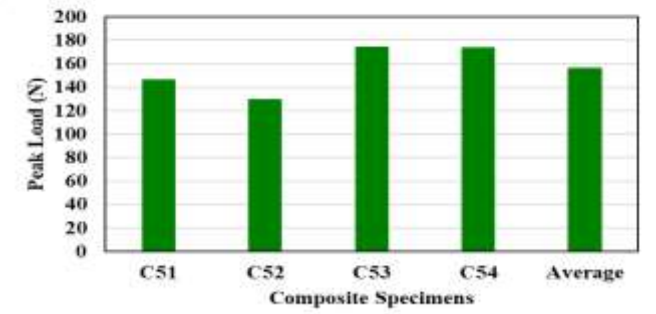

Figure 14 Variation on peak flexural load for composite specimen-05

3.14 Flexural Strength for C5 Composite Specimens

The variation on flexural strength for C51, C52, C53 and C54 hybrid-bio-composite specimens were demonstrated in figure 15. The flexural strength of 24, 21, 28 and 28 MPa were observed during the flexural test on the C51, C52, C53 and C54 hybrid bio-composite specimens respectively. An average flexural strength of 25 MPa was noticed in C5 hybrid bio-composite specimens.

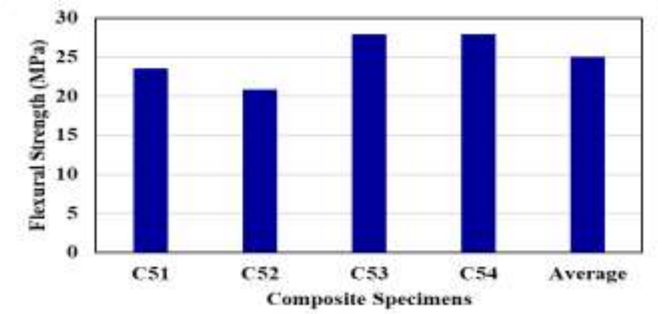

Figure 15 Variation on flexural strength for composite specimen-05

3.15 Flexural Modulus for C5 Composite Specimens

The variation on flexural modulus for C51, C52, C53 and C54 hybrid-bio-composite specimens were demonstrated in figure 16. The flexural modulus of 2486, 2425, 2141 and 2796 GPa were observed during the flexural test on the C51, C52, C53 and C54 hybrid bio-composite specimens respectively. An average flexural modulus of 2462 GPa was noticed in C5 hybrid bio-composite specimens.

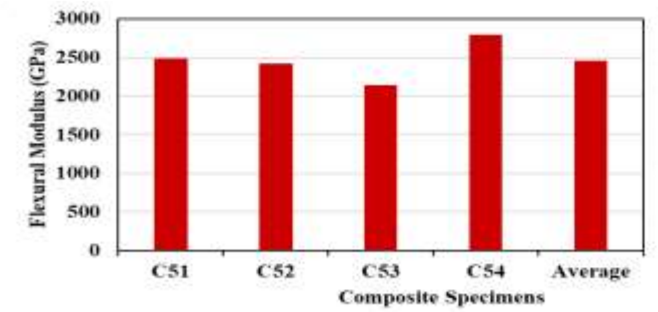

Figure 16 Variation on flexural modulus for composite specimen-05

3.16 Peak Flexural Load for C6 Composite Specimens

The variation on peak flexural load for C61, C62, C63 and C64 hybrid-bio-composite specimens were illustrated in figure 17. The peak flexural load of 212, 206, 219 and 219 N were observed during the flexural test on the C61, C62, C63 and C64 hybrid bio-composite specimens respectively. An average peak flexural load of 214 N was noticed in C6 hybrid bio-composite specimens.

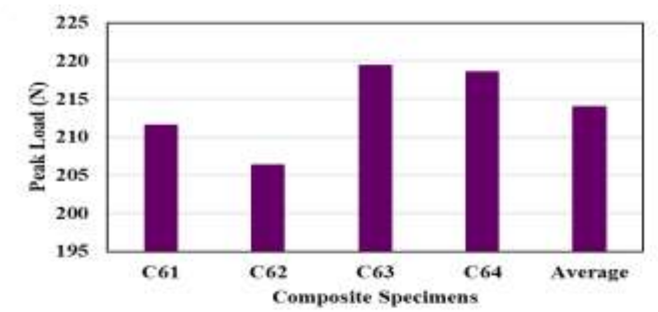

Figure 17 Variation on peak flexural load for composite specimen-06

3.17 Flexural Strength for C6 Composite Specimens

The variation on flexural strength for C61, C62, C63 and C64 hybrid-bio-composite specimens were demonstrated in figure 18. The flexural strength of 34, 33, 35 and 35 MPa were observed during the flexural test on the C61, C62, C63 and C64 hybrid bio-composite specimens respectively. An average flexural strength of 34 MPa was noticed in C6 hybrid bio-composite specimens.

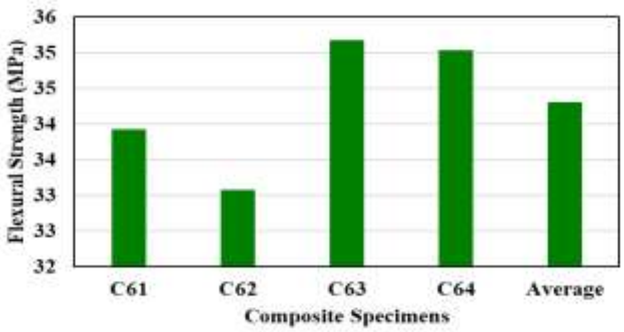

Figure 18 Variation on flexural strength for composite specimen-06

3.18 Flexural Modulus for C6 Composite Specimens

The variation on flexural modulus for C61, C62, C63 and C64 hybrid-bio-composite specimens were demonstrated in figure 19. The flexural modulus of 4117, 4048, 4069 and 3912 GPa were observed during the flexural test on the C61, C62, C63 and C64 hybrid bio-composite specimens respectively. An average flexural modulus of 4036 GPa was noticed in C6 hybrid bio-composite specimens.

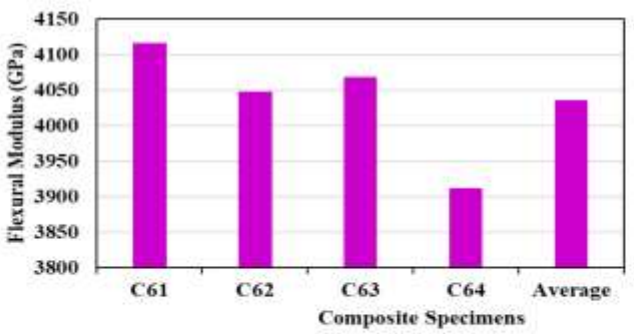

Figure 19 Variation on flexural modulus for composite specimen-06

3.19 Average Peak Flexural Load for All Composite Specimens

The variation on average peak flexural load for C1, C2, C3, C4, C5 and C6 bio-composite specimens were illustrated in figure 20. The average peak flexural load of 228.301, 180.286, 201.419, 228.031, 156.362 and 214.067 N were observed during the flexural test on the C1, C2, C3, C4, C5, and C6 bio-composite specimens respectively.

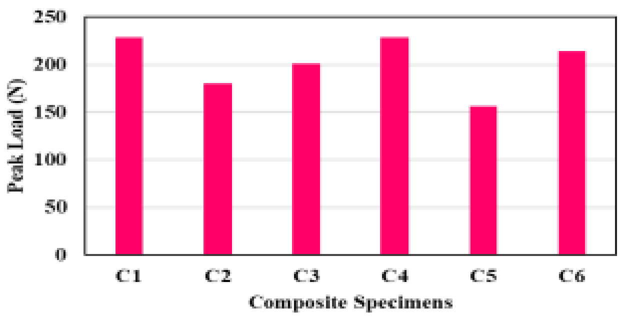

Figure 20 Variation on average peak flexural load for all composite specimens

3.20 Average Flexural Strength for All Composite Specimens

The variation on average flexural strength for C1, C2, C3, C4, C5 and C6 bio-composite specimens were demonstrated in figure 21. The average flexural strength of 36.587, 28.892, 32.279, 36.543, 25.058 and 34.306 MPa were observed during the flexural test on the C1, C2, C3, C4, C5 and C6 bio-composite specimens respectively.

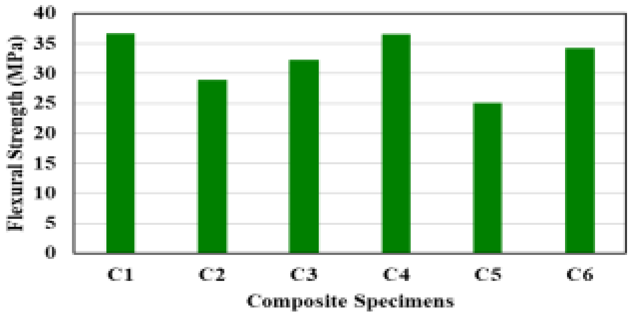

Figure 21 Variation on average flexural strength for all composite specimens

3.21 Average Flexural Modulus for All Composite Specimens

The variation on average flexural modulus for C1, C2, C3, C4, C5 and C6 bio-composite specimens were demonstrated in figure 22. The average flexural modulus of 5025.828, 3377.398, 4038.139, 3749.129, 2461.978 and 4036.336 GPa were observed during the flexural test on the C1, C2, C3, C4, C5 and C6 bio-composite specimens respectively.

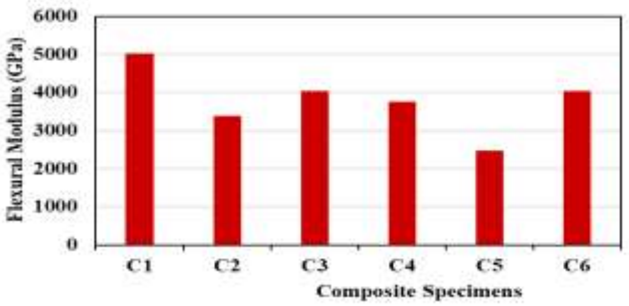

Figure 22 Variation on average flexural modulus for all composite specimens

4. Conclusions

Based on the experimental study, which was carried out on the coconut shell powder and granite powder particles reinforced epoxy matrix-based hybrid bio-composites, the following conclusions were made for its flexural characteristics. Theaverage peak flexural load of 228.301, 180.286, 201.419, 228.031, 156.362 and 214.067 N were observed during the flexural test on the C1, C2, C3, C4, C5, and C6 bio-composite specimens respectively. The maximum and minimum average peak flexural load of 228.301 and 156.362 N were noticed in C1 and C5 composite specimens correspondingly. The average flexural strength of 36.587, 28.892, 32.279, 36.543, 25.058 and 34.306 MPa were observed during the flexural test on the C1, C2, C3, C4, C5 and C6 bio-composite specimens respectively. The maximum and minimum average flexural strength of 25.058 and 36.587 MPa were noticed in C5 and C1 composite specimens correspondingly. The average flexural modulus of 5025.828, 3377.398, 4038.139, 3749.129, 2461.978 and 4036.336 GPa were observed during the flexural test on the C1, C2, C3, C4, C5 and C6 bio-composite specimens respectively. The maximum and minimum average flexural modulus of 5025.828 and 2461.978 GPa were noticed in C5 and C1 composite specimens correspondingly. It was noticed from the above experimental results, we have concluded that the hybrid bio-composites with 22.5 wt. % granite powder particles and 12.5 wt. % coconut shell powder particles exhibits the better flexural behavior than that of other five combinations, due to the optimum addition of granite powder and coconut shell powder particles into the epoxy resin matrix.

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