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Waviness Effect of Fiber on Buckling Behavior of Sisal/Carbon Nanotube Reinforced Composites Using Experimental Finite Element Method

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ABSTRACT

Sisal fiber-reinforced composites have huge potential applications in many industries. Different defects during the production process of the composite may decrease the performance of these composites. In this work, one of the important defects such as the waviness of thesisal fiber was studied under compressive loading. Two types of composite materials were considered for this study. One is sisal fiber-reinforced polymer matrix composite and another one is hybrid composite i.e sisal fiber and carbon nanotube reinforced polymer matrix composite. The sisal and hybrid sisal straight fiber composite specimens are prepared by using the hand lay-up technique. The buckling load of the sisal and sisal hybrid composites is estimated by conducting suitable experiments. Further, using the finite element method the effect of the waviness of sisal fiber on the buckling load is estimated. Two different wavy patterns such as Full Sine Waviness (FSW) and Half Sine Waviness (HSW) are considered for sisal fiber. The position effect of waviness of the fiber on the same property is also estimated by changing (A/λ) ratio from 0.1 to 0.35 and the amplitude of waviness from 5 to 17.5 mm (A) and maintaining the length of waviness (λ) to 100mm. The present study is used to design the buckling load of natural composite with waviness because the perfectly straight fibers are difficult to extract from plants.

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1. INTRODUCTION

The biodegradability, as well as environmental concerns in the view of plastic usage, has awakened many researchers to replace the conventional composite with natural fiber-reinforced composites. Sisal, hemp, jute, banana fibers are the most used fibers in the place of man-made fiber-reinforced composites. Two important aspects in the usage of the natural composite are needed to be addressed while replacing the commercial composite with natural composite. The first one is the type of natural resource we are using in the form of fiber and their characterization. The second aspect are how to enhance the already used natural fibers to make them as a better competitor in place of man-made fibers.

From these perspectives, the work performed so far on natural and hybrid composite has been reported. The buckling characteristics of natural fiber reinforced polymer composite beamsare studied experimentally [1]. In the view of lightweight structures, the compressive strength of flat plates and plain channel sections made with natural flax, jute and hemp have been studied [2-3]. The critical axial and lateral buckling loads of the composite material have been evaluated by conducting suitable experiments [4]. The extension in the buckling behavior was identified by preparing specimens with aluminium and polypropylene [5]. Woven flax–epoxy-laminated composite specimens are prepared and tested for in-plane and out-of-plane compressive behavior [6]. Rectangular and skew composite plates with embedded shape memory apply wire are tested for thermal buckling [7]. A thin-walled open cross-section profile made of fiber metal laminates were tested for buckling response [8]. Compared to straight fiber, the sinusoidal curved

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fiber showed high buckling strength than straight fiber reinfroced composite plate [9]. Composite I-beams are analyzed by adopting the refined beam theory supported by 3D Saint-Venant's solution [10]. Reinforcing the Carbon nanotubes with regular composite effects thebending and buckling properties because reinfrocement of CNT's enhances the stiffness of the resulting composite [11]. Compressive and tensile mechanical behavior along with the properties of Flax-fiber reinforced-Epoxy composite is examined [12]. The large deflection, post-buckling of graphene nano platelets-reinforced multi-scale composite beams is studied through a theoretical study [13]. Critical buckling strength of natural fiber fabric, polymer composite beam is analyzed experimentally. [14]. Using the Micromechanics methodology, the plate thickness influence by using functional graded graphene reinforced composites are reported [15]. Buckling loads and corresponding failure modes are also presented [16]. The global buckling and wrinkling behavior of sandwich plates with anisotropic face sheets are investigated [17]. The buckling behaviour of composites with cenosphere and sisal fabric epoxy is disussed y Wang and Wang [18]. The waviness effect of sisal fiber reinforced composite on elastic properties are explored by using experimental and micromechanics [19]. Using the micromechanics, moisture effect of fiber reinforced composites are explored [20]. The debond effet of fiber reinfroced nano based composite was addressed by Prasanthi et al. [21]. The waviness effect of fiber on the fatigue response is also explored [22]. Random waviness of fiber is also identifed [23-27]. Carbon nanotube curviness and waviness effect on the longitudinal modulus is reported by Matveeva et al. [26]. Using the multiwall carbon nanotube reinfrocement, buckling analysis performed on composite beams [28]. Using the buckling-restrained braces, the buckling failure load can be avoided [29]. From the above finding, the knowledge gap has been identified in relation to the natural fiber with waviness under compressive load.

The position effect of waviness of natural fiber with respect to the constrains (fixed and free end of the specimen) is not addressed so far. The buckling load of sisal fiber and carbon nanotube mixed epoxy composite is not performed yet. Considering the above factor, in this work, a complete study on buckling behavior of sisal fibers reinforced composite with waviness effect is reported using both experimental and analytical approaches. Two different waviness patterns such as Full Sine waviness (FSW) and Half Sine Wave (HSW) patterns are considered over a length of 100mm (λ) by varying the amplitude of waviness by changing (A/ λ) ratio to 0.1 to 0.35.

2. MATERIALS AND METHODS

The aim of the current proposal is to recognize the buckling load of natural sisal fiber composite and carbon nanotube reinforced sisal fiber (Hybrid) composite by using wavy fibers as reinforcement subjected to compressive load. The buckling load is estimated with experimental and Finite Element studies. Mostly faced problems in the natural fiber is waviness and the effect of waviness on the compressive strength and enhancement of buckling strength by nano reinforcement is also addressed in this work.

To conduct experimental studies, the testing samples are manufactured by using the hand lay-up technique. For that, the fibers were purchased from Vruksha composites, Tamilnadu. These fibers were treated with NaOH solution for 24 hours to promote better bonding between these fibers and the polymer matrix. These treated fibers are used as reinforcement in the polymer matrix and the weight of the matrix is selected in such a way that the fiber weight fraction is 0.1, 0.2, 0.3, 0.4 and 0.5%, respectively. The testing sample dimensions are fixed according to ASTM specified standards. To maintain the accuracy of the results, four testing samples are manufactured and tested.

To create hybrid composites, the Nano carbon tubes are used as reinforcement along with sisal fibers. In this work hybrid composite means sisal fiber reinfroced in CNT mixed epoxy matrix. The carbon tubes are mixed with polymer matrix using Ultra Sonication. The ultra sonicator ensures the uniform mixing of carbon tubes in the polymer matrix. The carbon nanotube-infused polymer matrix is used as a hosting medium to reinforce the sisal fibers. In this case, two types of reinforcements are using i.e sisal fiber and carbon nanotubes. The carbon nanotubes weight fraction is maintained at 0.1%. The sisal fiber weight fraction is the same fraction as considered for sisal composites. The specimens of sisal and hybrid composite are presented in Fig.1a-b.

Axial buckling samples were prepared according to the standards ASTM E2954 with a size of 200 mm length and 20 mm width and the thickness of the specimens is in the range of 2.5mm. Using a compression testing machine with 50KN loading capacity, the testing is performed by applying compressive load along the length of the fiber. The buckling load and corresponding elongation are estimated for sisal and hybrid composite. During the experiments, the specimens are fixed both from the bottom and top grips, the specimens are loaded in the axial direction (Fig. 1a). Four samples are tested at each weight fraction, and the average value is considered as the final buckling load (Fig.1b).

2. 1. Finite Element Method

To identify the waviness of sisal fiber composites on buckling load, the finite element method is used. The finite element models are created by using ANSYS. Using the mechanics of material method, the buckling load is estimated for sisal and hybrid composite. Applying the assumption of the micromechanics approach that is considering the uniform distribution of fibers in the hosting medium and selecting one unit cell from the total array and by analyzing one unit cell under compressive load, the buckling load can be obtained. (Fig. 2)

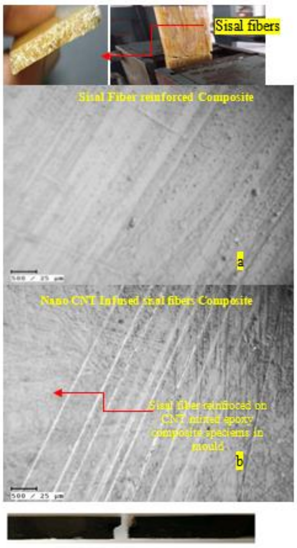

Figure 1. Sisal and hybrid composite and Microscopic view

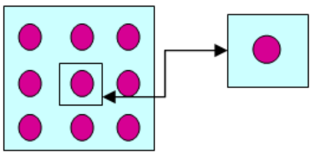

Figure 2. Micromechanics approach and unit cell

The unit cell dimensions are calculated based on the volume fraction of fiber. The volume fraction of fiber is changed from 10 to 50%. The Young's modulus of an epoxy matrix is 5.171 GPa, Poisson's ratio (ν) 0.35, sisal fiber modulus 190GPa, Poisson's ratio of sisal fiber 0.3 [20-21, 27]. The carbon nanotube mixed sisal fiber reinforced epoxycomposite elastic properties are obtained from our previous research work [28]. To compute the buckling load, one end of the FE model is fixed (Fig. 3a) and compressive elongation obtained from the experiments is applied at the opposite end of the FE model as shown in Fig. 3a. The eigen buckling load is estimated by performing analysis for strainght fibers. The finite element mesh on the FE model is presented in Fig. 3b.

The buckling load obtained from the finite element model and experimental results are presented along with the percentage of error in the results and discussion section. Further, the buckling load is estimated for the wavy fibers using finite element method ANSYS software. The fibers are modeled with waviness and the waviness is created at the center of the fiber. The length of the fiber (L) is 200mm, waviness length of the fiber (λ) and the amplitude (A) is changing according to the A/λ equal to 0.1, 0.2, 0.3 and 0.35. Fig. 4 shows the Full Sign Waviness (FSW) and Half Sign Waviness (HSW) of FE models.

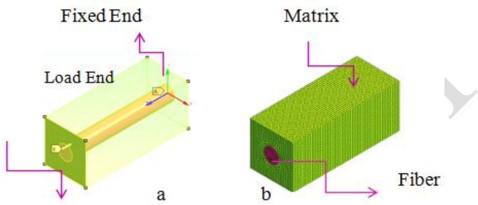

Figure 3. FE model and Finite element mesh

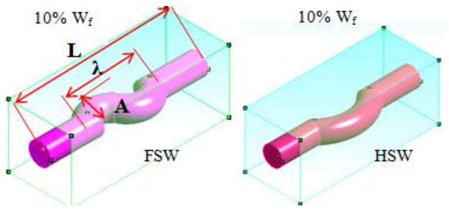

Figure 4. Finite Element models with fiber waviness

Further, the position of the waviness effect on the buckling load also studied by creating waviness at fixed end (Fig. 5) and load end of the fiber (Fig. 6). In all the cases, the waviness length in the fiber is fixed to 100 mm in the total length of 200 mm fiber and the amplitude of the waviness varies from 5 mm , 10mm, 15mm and 17.5mm. With these amplitude the (A/λ) becomes 0.1, 0.2, 0.3 and 0.35.

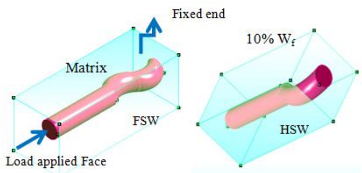

Figure 5.waviness at the fixed end of the fiber

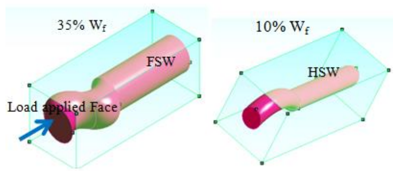

Figure 6.waviness at the Load end of the fiber

3. RESULTS AND DISCUSSIONS

Fig. 7 shows the buckling load of sisal and hybrid composites. The buckling load is increased with increasing the weight content of sisal fibers up to 40% [9]. Later the buckling load is slightly decreased in case of sisal fiber composites due to improper load transmission between the fibers and matrix under compressive loading. That 40% is the treshold limit for this case [4] .The hybrid composite buckling load is also increased with increasing the weight fraction of sisal fiber. The buckling strength is more for hybrid composites due to the additional carbon nanotubes in the polymer matrix. From this it is observed that, addition of nano CNT will enhance the buckling load of the sisal fiber reinforced composite [11]. Standard devaition of the results also presented in Table 2.

Fig. 8 shows the comparison of buckling load from experimental and FE results. To validate the finite element models, the buckling load of the composite plate is analysed, compared with the published results [25-26]. Table 2 presents the comparison of buckling loads of composite plate under uniaxial compression load with $[40^0/+40^0/90^0/0^0]_{2s}$ laminate lay-up and with two ends fixed support and two ends are simply supported. The results are obtained by performing the analysis with the same material properties, same geometrical data and same boundary conditions [25-26]. Good agreement is found between the present results and published results (Table 1).

TABLE 1. validation of buckling load with published results

Buckling load (KN/cm) [25]	Buckling load (KN/cm) [26]	Buckling load (KN/cm) Present work	% error
2.4	2.4	2.294	4.41%
3.3	3.2	3.1674	4.08%

At every volume fraction, the percentage of error between the experimental and analytical results is also presented. The correlation between the experimental and FE results are good at a lower weight fraction of sisal fiber. After validating the experimental and analytical results of buckling load, the waviness effect of sisal fiber on the buckling load is presented.

Fig. 9. shows the buckling load of sisal and hybrid composites by considering waviness in the fiber in the center of the fiber. The buckling load increasing with increasing the weight fraction of sisal fiber and hybrid composite buckling load is more than the sisal fiber composite. Increasing the waviness ratio (A/λ) from 0.1 to 0.35, increases the buckling load. Increasing the (A/λ) means the amplitude of the full sine wave increasing that means the deviation of the fiber from the straight shape is increasing and the resulting buckling load is also increasing. The reason for this behavior is that wavy pattern is created at the middle of the FE model and while transmitting a compressive force through the model, the fiber takes more loads. The penetrated fiber portions due to waviness receive more load than a pure matrix, as a result, the deformation due to compressive load is less and buckling strength is more. Similar trend in the results are found for fiber with sine waviness [9]

Fig. 10 shows the variation of buckling load with HSW of fiber at the center of its length. Compared to FSW of fiber, the buckling load is less for HSW of fiber. This is due to the reason that fiber penetration part into the matrix due to the waviness is less than FSW.

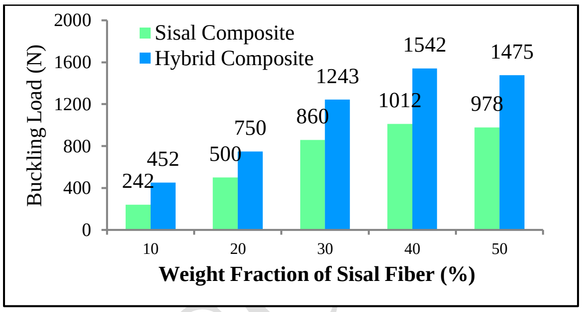

Figure 7. Buckling Load of sisal and Hybrid composites

TABLE 2. Standard deviation of experimental results

S1	S2	S3	S4	Avg.	SD
Sisal fiber reinforced composite					
220	254	239	255	242	16.39105
512	480	492	516	500	16.97056
850	840	860	890	860	21.60247
998	1015	1021	1014	1012	9.831921
960	954	995	1003	978	24.58997
Hybrid composite					
S1	S2	S3	S4	Avg.	SD
451	442	457	458	452	7.348469
740	745	750	765	750	10.80123
1226	1222	1256	1268	1243	22.53886
1558	1554	1542	1514	1542	19.86622
1468	1502	1476	1454	1475	20.16598

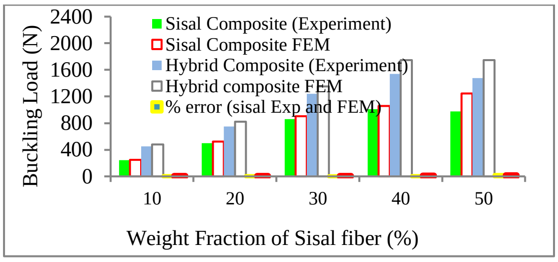

Figure 8. Buckling load from Experimental and FE results with percentage error

Figs. 11 and 12 show the response of buckling load of sisal and hybrid composite with the waviness at the fixed end of the fiber. In this case, the waviness effect of fiber is negligible on the buckling load. Because the waviness of the fiber is located nearer to the fixed end. The fixed end resricts the movement as a result the buckling load is not effected with the waviness of fiber.

Figs. 13 and 14 show the buckling load of sisal and hybrid composite with the waviness of fiber at the compressive load applied end. The buckling load is highly affected by waviness at load end in both cases (FSW and HSW). As the load applied on the composite is directly applied on the wavy part and later the load is passed through the straight part of the fiber.

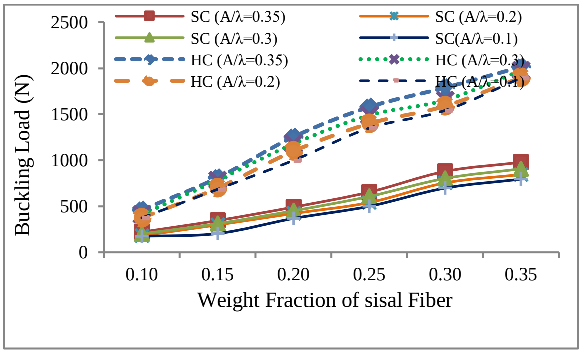

Figure 9. Buckling Load of FSW

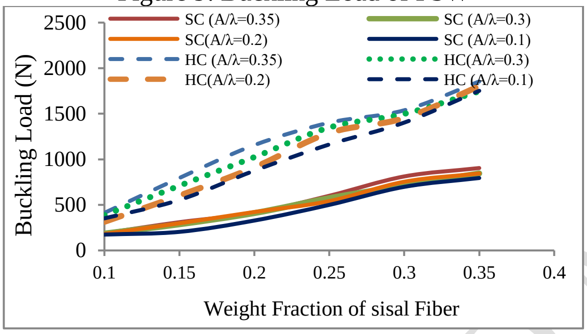

Figure.10. Buckling Load of HSW

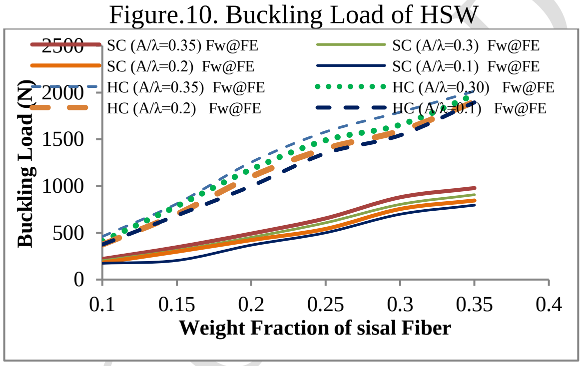

Figure 11. Buckling load ofFSW at the fixed end

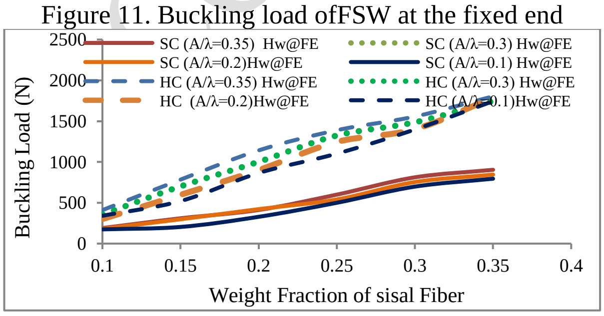

Figure 12. Buckling load of HSW at the fixed end

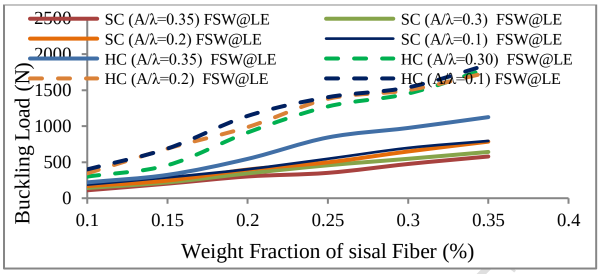

Figure 13. Buckling load of FSW at the Load end

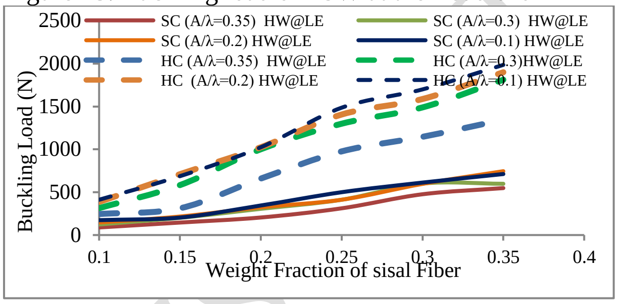

Figure 14. Buckling load of HSW at the Load end

3. CONCLUSIONS

As the fiber weight fraction increases, the buckling load increases up to 40% of weight fraction, later there is no improvement in the same property; but the hybrid composite buckling load increases even beyond 40% of fiber weight fraction due to the nano reinforcement.

Compared to FSW fiber reinforced composite, HSW fiber composite showed less buckling loads at all the waviness ratio (A/λ) considered for the study.

The waviness is located nearer to the fixed support will not influence the buckling load of wavy fiber reinforced composite. Whereas the waviness at the middle and nearer to the load ends, have a considerable influence on buckling load. In these cases, the waviness located at the load end having very high impact on buckling strength

6. REFERENCES

1. Sunil Waddar, Jeyaraj Pitchaimani, Mrityunjay Doddamani, Ever Barbero, “Buckling and vibration behaviour of syntactic foam core sandwich beam with natural fiber composite facings under axial compressive loads”, ***Composites Part B: Engineering***,175, (2019), 107-133, https://doi.org/10.1016/j.compositesb.2019.107133.

2. M.R. Bambach, “Compression strength of natural fibre composite plates and sections of flax, jute and hemp”, ***Thin-Walled Structures***,119, (2017), 103-113, https://doi.org/10.1016/j.tws.2017.05.034.

3. M.R. Bambach, ”Geometric optimisation and compression design of natural fibre composite structural channel sections, ***Composite Structures***, 185, (2018), 549-560, https://doi.org/10.1016/j.compstruct.2017.11.065.

4. Omer YavuzBozkurt, Mehmet Bulut, Ahmet Erklig, Waleed Ahmed Faydh, “Axial and lateral buckling analysis of fiber reinforced S-glass/epoxy composites containing nano-clay

particles", ***Composites Part B: Engineering***,158, (2019), 82-91,https://doi.org/10.1016/j.compositesb.2018.09.043.

5. Shunfeng Gong, Xipeng Wang, Tao Zhang, Chengbin Liu, "Buckle propagation of sandwich pipes under external pressure, ***Engineering Structures***,175,(2018),339-354,https://doi.org/10.1016/j.engstruct.2018.08.033.
6. Jianxing Hu, Sha Yin, T.X. Yu, Jun Xu, "Dynamic compressive behavior of woven flax-epoxy-laminated composites", ***International Journal of Impact Engineering***,117,(2018),63-74,https://doi.org/10.1016/j.ijimpeng.2018.03.004.
7. S. Kamarian, M. Shakeri, "Thermal buckling analysis and stacking sequence optimization of rectangular and skew shape memory alloy hybrid composite plates", ***Composites Part B*: Engineering**,116,(2017),137-152,https://doi.org/10.1016/j.compositesb.2017.01.059.
8. Radoslaw J. Mania, Christopher Bronn York, "Buckling strength improvements for Fibre Metal Laminates using thin-ply tailoring", ***Composite Structures***,159, (2017),424-432,https://doi.org/10.1016/j.compstruct.2016.09.097.
9. M. D. Pandey, "Effect Of Fiber Waviness On Buckling Strength Of Composite Plates***", Journal of Engineering Mechanics***, 1999, 125(10): 1173-1179
10. Fares Naccache, Rached El Fatmi, "Buckling analysis of homogeneous or composite I-beams using a 1D refined beam theory built on Saint Venant's solution", ***Thin-Walled Structures***,127,(2018), 822-831,https://doi.org/10.1016/j.tws.2018.02.028.
11. Ahmadi, Masoud & Ansari, Reza & Rouhi, H.Multi-scale bending, buckling and vibration analyses of carbon fiber/carbon nanotube-reinforced polymer nanocomposite plates with various shapes. Physica E: ***Low-dimensional Systems and Nanostructures***. (2017) 93. 10.1016/j.physe.2017.05.009.
12. Zia Mahboob, Ihab El Sawi, Radovan Zdero, ZouheirFawaz, HabibaBougherara, "Tensile and compressive damaged response in Flax fibre reinforced epoxy composites", ***Composites Part A: Applied Science and Manufacturing***,92,(2017),118-133,https://doi.org/10.1016/j.compositesa.2016.11.007.
13. M. Rafiee, F. Nitzsche, M.R. Labrosse, "Modeling and mechanical analysis of multiscale fiber-reinforced graphene composites: Nonlinear bending, thermal post-buckling and large amplitude vibration", ***International Journal of Non-Linear Mechanics***,103, (2018),104-112,https://doi.org/10.1016/j.ijnonlinmec.2018.05.004.
14. M. Rajesh, JeyarajPitchaimani, "Experimental investigation on buckling and free vibration behavior of woven natural fiber fabric composite under axial compression", ***Composite Structures***,163,(2017),302-311,https://doi.org/10.1016/j.compstruct.2016.12.046.
15. Hui-ShenShen, Y. Xiang, Feng Lin, D. Hui, "Buckling and postbuckling of functionally graded graphene-reinforced composite laminated plates in thermal environments", ***Composites Part B: Engineering***, 119, (2017), 67-78,https://doi.org/10.1016/j.compositesb.2017.03.020.
16. MariuszUrbaniak, Adrian Gliszczyński, ŁukaszBorkowski, "Numerical studies on stability and load capacity of compressed channel section columns made of composite reinforced with flax fibers", ***Composite Structures***, 206, (2018),https://doi.org/10.1016/j.compstruct.2018.07.123.
17. Riccardo Vescovini, Michele D'Ottavio, Lorenzo Dozio, Olivier Polit, "Buckling and wrinkling of anisotropic sandwich plates, ***International Journal of Engineering Science***,130, (2018),136-156,https://doi.org/10.1016/j.ijengsci.2018.05.010.
18. K.F. Wang, B.L. Wang, "A mechanical degradation model for bidirectional natural fiber reinforced composites under hydrothermal ageing and applying in buckling and vibration analysis", ***Composite Structures***,206, (2018),Pages 594-600,https://doi.org/10.1016/j.compstruct.2018.08.063.
19. P. Phani Prasanthi, K. SivajiBabu, M. S. R. Niranjan Kumar & A. Eswar Kumar, "Analysis of Sisal Fiber Waviness Effect on the Elastic Properties of Natural Composites Using Analytical and Experimental Methods", ***Journal of Natural Fibers***, https://doi.org/10.1080/15440478.2019.1697987
20. P Phani Prasanthi, K SivajiBabu, M S R Niranjan Kumar, G Raja Vamsi and N Raghu Ram,"Analysis of hybrid composite with moisture defects using finite element method and micromechanics", ***Materials Research Express***, 4, (2017), https://doi.org/10.1088/2053-1591/aa8d2f
21. P. Prasanthi, G. SambasivaRao & B. UmamaheswarGowd "Mechanical performance of Buckminster fullerene-reinforced composite with interface defects using finite element method through homogenization techniques", ***Composite Interfaces***, 22:4, (2015) 299-314, DOI: 10.1080/09276440.2015.1021223
22. F. Schmidt and M. Rheinfurth and P. Horst and G. Busse," Effects of local fibre waviness on damage mechanisms and fatigue behaviour of biaxially loaded tube specimens", ***Composites Science and Technology***, 72, (2012), 1075-1082,https://doi.org/10.1016/j.compscitech.2011.09.012
23. M.P.F. Sutcliffe, "Modelling the effect of size on compressive strength of fibre composites with random waviness",***Composites Science and Technology***,88,(2013),142-150,https://doi.org/10.1016/j.compscitech.2013.09.002.
24. Bradshaw, Roger & Fisher, Frank & Brinson, L.C.. Fiber waviness in nanotube-reinforced polymer composites-II: Modeling via numerical approximation of the dilute strain concentration tensor. ***Composites Science and Technology***. 63. 1705-1722. (2003). https://doi.org/10.1016/S0266-3538(03)00070-8.
25. Narayana, A.L., Rao, K. & Kumar, R.V. Buckling analysis of rectangular composite plates with rectangular cutout subjected to linearly varying in-plane loading using fem. ***Sadhana*** 39, 583–596 (2014). https://doi.org/10.1007/s12046-014-0250-9
26. Anna Y. Matveeva, Sergey V. Pyrlin, Marta M.D. Ramos, Helmut J. Böhm, Ferrie W.J. van Hattum, "Influence of waviness and curliness of fibres on mechanical properties of composites", ***Computational Materials Science***,87, (2014), 1-11,https://doi.org/10.1016/j.commatsci.2014.01.061.
27. P. Phani Prasanthi, K. Sivaji Babu, M. S. R. Niranjan Kumar and A. Eswar Kumar, "Comparison of elastic properties of different shaped particle reinforced composites using micromechanics and finite element method", ***International Journal of Computational Materials Science and Engineering*** Vol. 09, No. 02, 2050011 (2020), https://doi.org/10.1142/S2047684120500116
28. I. Arun Babu, B. Raghu Kumar, P. Phani Prasanthi, A. Eswar Kumar, Ch. Vidya, "Fatigue Characterization Of Sisal Fiber Reinforced Composites Using Experimental and Finite Element Method", ***International Journal of Innovative Technology and Exploring*** Engineering, Vol. 8, 2019.
29. B. Pordel Maragheha, A. Jalalia,b, S.Mohammad Mirhosseinia "Evaluating the Effect of Buckling-Restrained Braces in Steel Buildings Against Progressive Failure using Different Simulation Strategies", ***International Journal of Engineering, Transactions A: Basics***, Vol. 34, No. 10: PP?? doi: 10.5829/IJE.2021.34.10a.06

کامپوزیت های تقویت شده با الیاف سیزال کاربردهای بالقوه عظیمی
در بسیاری از صنایع دارند. نقص های مختلف در طول فرآیند تولید

کامپوزیت ممکن است عملکرد این کامپوزیت ها را کاهش دهد. در این کار ، یکی از نقص های مهم مانند موج دار بودن الیاف پایان نامه تحت بار فشاری مورد مطالعه قرار گرفت. دو نوع مواد کامپوزیتی برای این مطالعه در نظر گرفته شد. یکی کامپوزیت ماتریس پلیمری تقویت شده با فیبر سیزال و دیگری کامپوزیت ترکیبی یعنی فیبر سیزال و کامپوزیت ماتریس پلیمری تقویت شده با نانولوله های کربنی. نمونه های کامپوزیت سیزال و هیبرید سیزال با استفاده از تکنیک چیدن دست آماده می شوند. بار کمانش کامپوزیت های سیزال و سیزال با انجام آزمایشات مناسب برآورد می شود. علاوه بر این ، با استفاده از روش اجزای محدود ، اثر موج الیاف سیزال بر بار کمانش برآورد می شود. دو الگوی موج دار مختلف مانند موج سینوسی کامل (FSW) و موج نیمه سینوسی (HSW) برای فیبر سیزال در نظر گرفته شده است. اثر موقعیت موج دار شدن الیاف بر روی همان ویژگی نیز با تغییر نسبت (A/λ) از ۰.۱ به ۰.۳۵ و دامنه موج از ۵ تا ۱۷.۵ میلی متر (A) و حفظ طول موج (λ) تا ۱۰۰ میلی متر مطالعه حاضر برای طراحی بار کمانش کامپوزیت طبیعی با موج استفاده می شود. زیرا استخراج الیاف کاملاً مستقیم از گیاهان دشوار است.