New Flax Fiber and Polystyrene Foam Structural Insulated Panels with Wire Mesh Reinforcement: Experimental Investigation of Drilling Characteristics

Munagala Anil Reddy[1], B Navin Kumar[2*]

[1]Research Scholar, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamilnadu, India, Pincode: 602105.

[2*]Project Guide, Corresponding Author, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, SaveethaUniversity, Chennai, Tamilnadu, India, Pincode: 602105.

ABSTRACT

Aim: The objective of this research work is to evaluate the cylindricity tolerance of flax fiber and polystyrene foam structural insulated panels reinforced with wire mesh. **Materials and Methods:** Flax fiber and polystyrene foam novel structural insulated panel reinforced with wire mesh were taken as an experimental group. Flax fiber and polystyrene foam structural insulated panel reinforced composite was taken as the control group from each group 20 samples were taken for the study. The number of samples was calculated by using G-power kept at 80% power. The hand layup technique was used to prepare the composite and drilling testing was conducted using drilling. The statistical analysis was conducted with the assistance of SPSS tool software. **Results:** The cylindricity tolerance of flax fiber polystyrene foam epoxy composite was observed as 48.418, flax fiber polystyrene foam epoxy composite with wire mesh was observed as 56.704 and significant value P=0.009 which is less than 0.05. There is a significant difference between the groups. **Conclusion:** From the result, it was observed that the structural insulated panels of flax fiber and polystyrene foam reinforced composite with wire mesh was showed poor cylindricity tolerance than the flax fiber-reinforced composite with polystyrene foam and other mechanical properties of the materials given better than the control group.

Keywords: Novel Structural Insulated Panels, Flax Fiber, Epoxy LY556, Hardener HY951, Aluminium Mesh, SPSS Tool.

INTRODUCTION

Flax fibre is one of the natural fibre. Natural fibres are utilised in reinforced composite materials as an alternative to synthetic fibres. It has more mechanical properties (Sparnins 2009). Structural insulated panels are used in commercial construction and to speed up the construction of residential structures. They are made up of a core material such as foam and face material such as natural fibres, mgo boards, artificial fibres, plastics, etc.(Uddin and Kalyankar 2011). The aim of this study was to enhance the drilling characteristics and cylindricity tolerance on novel structural insulated panels, using polystyrene foam as the core and flax fibre and aluminium wire mesh as facing materials while comparing the attributes of flax fibre and polystyrene foam panels. When the aluminium wire mesh was added to the control group of insulated panels, the results were better than the control group. Composite-based materials are more durable than the ordinary materials we use on a daily basis.

At the lowest cost, flax fibre and polystyrene foam structural insulated panels reinforced with wire mesh provide higher structural behaviour than flax fibre and polystyrene foam alone (Yan et al. 2014). The flax fiber used as the upper layer and after the top layer aluminium wire mesh was placed due to these two materials gives the stiffness for the structural insulated panels and the panel will be lesser in weight. The aluminium mesh was also one of the corrosion-resistant materials. These insulated panels can be used for roofing, construction of instant houses for the temporary stay, and they also can be used for making doors (Habibi et al. 2017)&(Zimniewska et al. 2012).

The total number of journal papers published related to this work was 154 in research gate and 532 in ScienceDirect in the past ten years. This research studies the behaviour of the structural insulated panels when it undergoes the long-term loading and short-term loading under single loading and multiaxial loading with typical joints. This work shows the initiation of the failure and types of failure of Structural Insulated Panels (Rungthonkit 2012). This work was about examining the new structural insulated panels properties. Wood based composite boards as the facing material and core layer was insulated rubber filled with wooden particles. Polyurethane was used as the adhesive bond between the surfaces. From that water absorption tests and fire-resistant tests are conducted (Thongcharoen et al. 2021). This work was about the effects of chemical treatment on properties of flax fiber-reinforced composite material. While doing the fabrication of the flax fiber reinforced with chemical composite, chemicals react with the material, and properties of the material will be changed . This study was about the experimental investigation of aSIP panels (Structural Insulated Panel) with polystyrene foam core against the strong wind impact for the constructional purpose against natural disaster). One of the best studies was done by . In this paper two types of Structural Insulated Panels are fabricated are OSB (Oriented strand board) and Mgo board these boards are used as the skin of the Structural Insulated Panels panels. These Structural Insulated Panels panels impact resistance performance by air cannon testing system. A steel wire mesh was placed between the layers as the reinforcement layer. Finally, the windborne debris impact strength was increased.Previously our team has a rich experience in working on various research projects across multiple disciplines(Madhesh et al. 2021; Bishir et al. 2020);(Vimalraj et al. 2020; Sivasamy, Venugopal, and Mosquera 2020)(Madhesh et al. 2021; Bishir et al. 2020)

Now the emerging trend and development in the SIP panel motivated us to do research in this field. This study was about the sandwich composite combination of the flax fiber and polystyrene foam based structural insulated panels reinforced with wire mesh. This research work made use of experimental and theoretical knowledge on the lamination of the laminated composite material with their material flax fiber, polystyrene foam, wire mesh and mechanical properties of the laminated plates were tested. The objective of this research work is to study the drilling characteristics of flax fiber and polystyrene foam-based structural insulated panels reinforced with wire mesh. It was compared with the laminated combination of flax fiber and polystyrene foam.

MATERIALS AND METHODS

The laminated plates were made in the mechanical workshop, and testing samples were tested in the Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. This research about composite materials doesn't involve human samples. This paper mainly consist of two groups they are control group(combination of the flax fiber and polystyrene foam-based structural insulated panels) and the experimental group (flax fiber and polystyrene foam-based structural insulated panels reinforced with wire mesh) the no of samplestaken for each group was 20 and total no of each group are 40. The number of samples was calculated by using the G-power calculator from cliniCalc.com by keeping the alpha value 0.05, G-power calculator at 80% power from the previous studies the mean and the standard deviation for the experimental group is 8.76 ppm and 0.04whereas for the control group 9.63 ppm and 0.42 (Erdfelder, Faul, and Buchner 1996).

The lamination of the experimental group was flax fiber and polystyrene foam reinforced with wire mesh that the required materials are flax fiber, aluminium wire mesh, epoxy LY556, hardener H951 and polystyrene foam. The whole process was done by the hand lay-up method. The flax fiber and polystyrene foam were trimmed into sizes of 300*300mm. The mylar sheet was trimmed into a size of 500*500mm. Flax fiber was used as the outer or facing material. The flax fiber was trimmed for the two layers and polystyrene foam was only for the one layer. The aluminium mesh was cut the same as per the dimension of the flax fiber. The epoxy LY556 and hardener H951 were taken in the 10:1 ratio. This mixture was mixed by a mechanical stirrer process for about 5 minutes to mix the mixture properly. The mylar sheet was spreaded on the plane surface, pour the epoxy resin mixture on the mylar sheet, and spread the epoxy mixture through the rolling process. Then place the flax fiber, apply resin on the layer and entrap the air gaps by using the rolling process. The layers are followed in this manner aluminium mesh, polystyrene foam, aluminium mesh, and flax fiber to bond the layers the epoxy resin was used. To entrap the air between the layers, a rolling process was used and properly spread the resin. At last, the mylar sheet was placed on it. Then the plane surface was placed on it and applied weight in an evenly distributed manner to avoid the thickness variation from one point to the other- point of the lamination plate. Leave the laminated plates for 24 hours to harden the resin. After 24 hours remove the weight and also remove the mylar sheet. Figure. 1. shows the laminated plate of flax fiber and polystyrene foam structural insulated panel reinforced with wire mesh.

The control group was a combination of flax fiber and polystyrene foam in presence of the epoxy composite. The flax fiber and polystyrene foam are trimmed into 300*300mm. The flax fiber was used as the facing material. It was used as 2 layers in the lamination plate. The epoxy LY556 and hardener H951 were taken in the 10:1 ratio. The mixture mixes through the mechanical process for about 5 min. Mylar sheet was placed on the plane surface, applied resin on the sheet, placed the flax fiber on it, and spread the resin properly without air gaps. Then place the polystyrene foam on that, then place the flax fiber on the foam and place the mylar sheet. This is followed by the mechanical rolling process to entrap the air gaps between the layers. Place the plane surface on it and apply weight to it. Leave the laminated plate for 24 hours to set the epoxy then remove the weight and the mylar sheets for the laminated sheets. Figure. 2. shows the laminated plate of flax fiber and polystyrene foam structural insulated panel reinforced composite.

The laminated plates are trimmed into 100*100 mm. For both the groups (control and experimental groups) test specimens are placed over the worktable of the CNC drilling machine and 20 holes on the experimental group,20 holes on the experimental group using the 8mm drilling bit under normal conditions offered rate. Fig. 3 & Fig. 4.shows the drill holes of the experimental group and control group.

To find the cylindricity error in the drilling of the flax fiber and polystyrene foam-based structural insulated panels reinforced with wire mesh composite material. The drilled holes are captured images individually under the led lights using a camera and captured images are given to the ImageJ software to find the damaged area by using the freehand sketch module available in the software. The cylindricity error in the drilling of the flax fiber and polystyrene foam structural insulated panels reinforced without wire mesh damaged area are shown in Fig. 5. The damaged area of the flax fiber and polystyrene foam structural insulated panels reinforced with wire mesh are shown in Fig. 6. The damage was compared between the two groups. Repeat the same procedure for all the 20 holes of the experimental group and control group.

The software used in this research work was ImageJ software which was used for the calculation of the damaged area that occurred during the drilling operation and both the groups are compared. To get the cylindricity tolerance error in the drilling of the composite material.

Statistical Analysis

By using Statistical Software SPSS tool v.26, an independent t-test analysis was done taking flax fiber and polystyrene foam-based structural insulated panels reinforced with wire mesh as independent variables and cylindricity tolerance error was taken as a dependent variable (Pallant 2020). The descriptive and graph were obtained for the test results. Statistical software SPSS tool v.26 was used to determine the descriptive table and graph.

RESULTS

This work obtained that the novel Structural Insulated Panels Panel flax fiber reinforced with polystyrene foam gives better cylindricity tolerance than the flax fiber, polystyrene foam reinforced with wire mesh. P=0.009 is the significant value for polystyrene foam reinforced with wire mesh. The cylindricity tolerances of the control group were less than the experimental group. Other than that it consists of better mechanical properties. The cylindricity tolerances of the experimental group 10.3% decreased compared to the control group.

The graph shows the cylindricity tolerance difference between the flax fiber reinforced with polystyrene foam and flax fiber, polystyrene foam reinforced with wire mesh for the total 40 samples shown in Fig. 7. This study observed that the cylindricity tolerance of flax fiber, polystyrene foam reinforced with wire mesh decreased than the flax fiber reinforced with polystyrene foam. The results were obtained when subjected to the independent sample t-test analysis using SPSS tool v. 26 statistical software. the descriptive table gives the group statistics andindependent samples test. The mean value of cylindricity tolerance of flax fiber and polystyrene foam reinforced composite is 48.418 and the standard deviation is 2.136. The mean value of flax fiber and polystyrene foam reinforced with aluminium wire mesh composite is 56.704 and the standard deviation is 1.251 from Table 1. Significant level for cylindricity tolerance of novel flax fiber and polystyrene foam reinforced with wire mesh was P=0.009(P<0.05) from Table 2.

DISCUSSION

This study observed that the mean value and standard deviation for cylindricity tolerance of flax fiber and polystyrene foam reinforced composite were 48.418 and 2.136 respectively. The obtained mean value and standard deviation for the flax fiber and polystyrene foam reinforced with aluminium wire mesh were 56.704 and 1.251respectively.

This study about a novel structural insulated panel was developed and tested in an experimental study. The core layer of the Structural Insulated Panels prototypes was insulated foam made from rubber packed with wood panels, and the surface layers were three types of commercial wood-composite boards. Between the surface and the core layer, polyurethane was used as an adhesive (Jorda et al. 2021). This prefabricated panel was squeezed in a clamping mechanism until the adhesives had completely dried. As a result, the physical and mechanical characteristics of the Structural Insulated Panels were evaluated. The results of the tests showed that the types of surface layer materials had a major effect on Structural Insulated Panels properties. The Structural Insulated Panels, which was coated with cement particle board and fiber-cement board, had excellent characteristics and water resistance. The plywood-covered Structural Insulated Panels prototype exhibited desired characteristics. The Structural Insulated Panels coated with plywood, on the other hand, had significant water absorption and low fire resistance. These characteristics should be improved (Thongcharoen et al. 2021). On using SIPs and the other using a traditional wood frame, are presented in this report. There were no significant effects on other construction performance measures, but the size of the panels required the use of a lift truck and a construction crane (Mullens and Arif 2006). The delamination behaviour and hole quality of flax/epoxy composite laminates are investigated in the present study. According to the analysis of variance data, drill bit type and feed have stronger impacts on thrust force. The drill bit appeared to have a considerable impact on the delamination factors and surface roughness. The delamination factor (67.27%) and surface roughness (74.44%) are both strongly affected by the drill bit used(Rezghi Maleki et al. 2019).

Some of the factors affecting the results of the novel Structural Insulated Panels were the mixing ratio of epoxy resin and hardener should be exact in a 10:1 ratio. The air gaps between the layers to be avoided between the layers affect the results of the panels, orientation of layers, and quality of the material will affect the result of the final product.The fabrication process of the laminated plates required skilled labour and the hand layup technique is a time taking process.it is not applicable for the bulk production of the material. No protection against moisture, structural strength will decrease; there will be no fire protection. Delamination occurs between the layers and moreover improper bonding between the fiber and wire mesh. (Mugahed Amran et al. 2020). This work will be extended in the future by taking the different fibers and different structural layers to check the physical, chemical and mechanical properties of the composite material.

CONCLUSION

Within the limits of the experiments, it is concluded that Structural Insulated Panels Panel flax fiber and polystyrene foam reinforced composite exhibited better performance than the flax fiber and polystyrene foam reinforced composite with wire mesh. When compared to the control group, the experimental group's cylindricity tolerances reduced by 10.3%. From the analysis of the result, it is anticipated that decreasing the thickness of the wire mesh gives a good result for the cylindricity tolerance.

DECLARATIONS

Conflicts of interest

The author of this paper declares no conflict of interest.

Author's contribution

Data collection, data analysis, and paper writing have all been done by author MAR. Author NKB was engaged in the manuscript's development, guidance, and critical review.

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TABLES AND FIGURES

Table 1. Group Statistics were obtained for the mean cylindricity tolerance test for a total sample of 20 per group with a standard error mean of 0.466 for flax fiber and polystyrene foam without wire mesh and 0.279 for flax fiber and polystyrene foam with wire mesh

Group Statistics					
Composites		**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Cylindricity_Tolerance	Flax fiber Reinforced with polystyrene foam	20	48.418	2.136	0.466
	Flax fiber and polystyrene foam Reinforced with wire mesh	20	56.704	1.251	0.279

Table 2. Cylindricity tolerance test; t-test for equality of means for cylindricity tolerance test with a significance value of P=0.009 achieved among the considered group's group 1 flax fiber and polystyrene foam without wire mesh and group 2 flax fiber and polystyrene foam with wire mesh.There is a significant difference between the groups.

Independent Samples Test									
Cylindricity Tolerance	Levene's Test for Equality of variances		t-test for equality of Means						
	F	Sig.	t	df	Sig. (2 tailed)	Mean Difference	Std. Error Difference	95% confidence interval of the Difference	
								Lower	Upper
Equal variances assumed	7.56	0.009	-14.96	38	0.000	-8.286	0.553	-9.407	-7.165
Equal variances not assumed			-14.96	30.664	0.000	-8.286	0.553	-9.416	-7.156

Fig. 1. Laminated plate of flax fiber and polystyrene foam structural insulated panel reinforced with wire mesh(Experimental group)

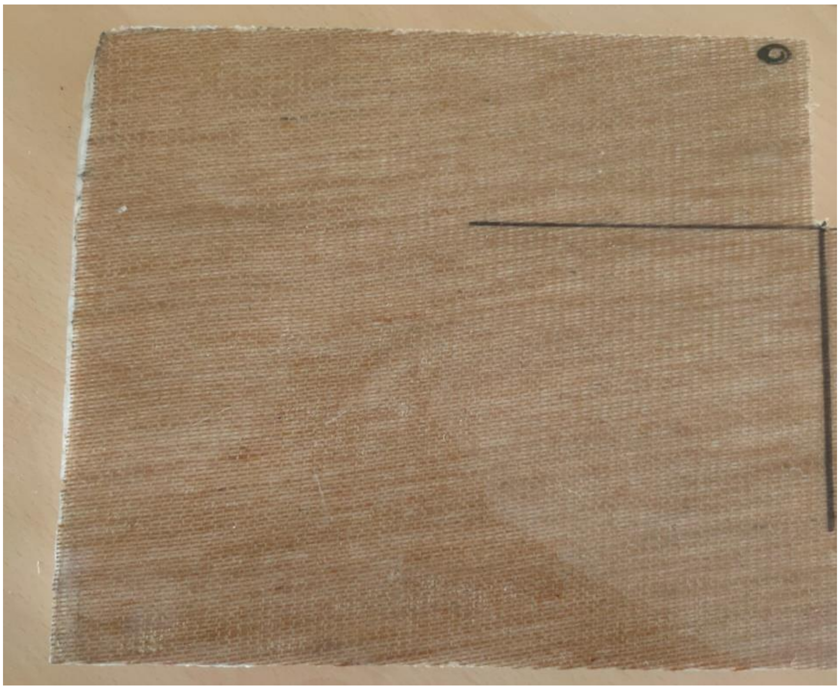

Fig. 2. Laminated plate of flax fiber and polystyrene foam structural insulated panel reinforced composite (Control group)

Fig. 3. The above figure shows the holes are drilled for the flax fiber and polystyrene foam structural insulated panel reinforced with wire mesh laminated plate under the CNC machine (Experimental group)

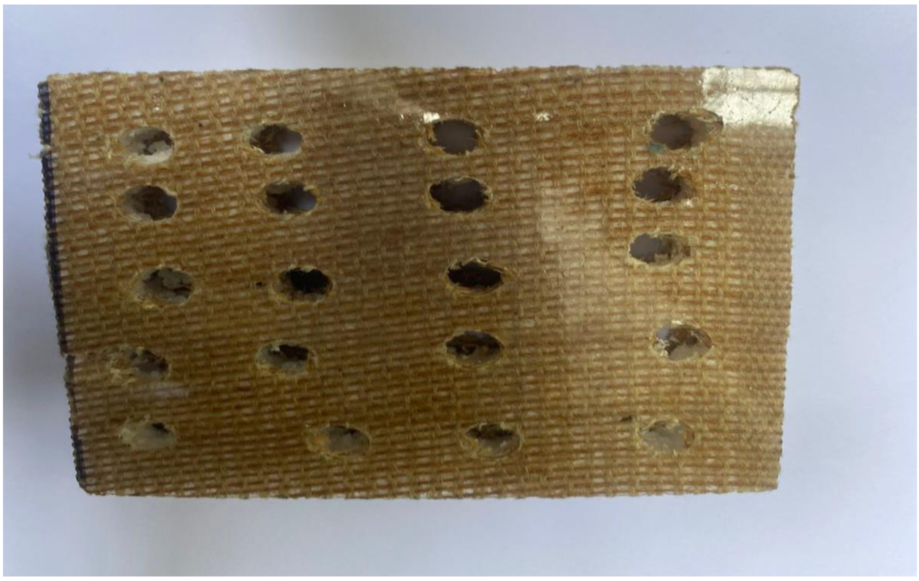

Fig. 4. The above figure shows the holes are drilled for the flax fiber and polystyrene foam structural insulated panel reinforced composite laminated plate under the CNC machine (Control group)

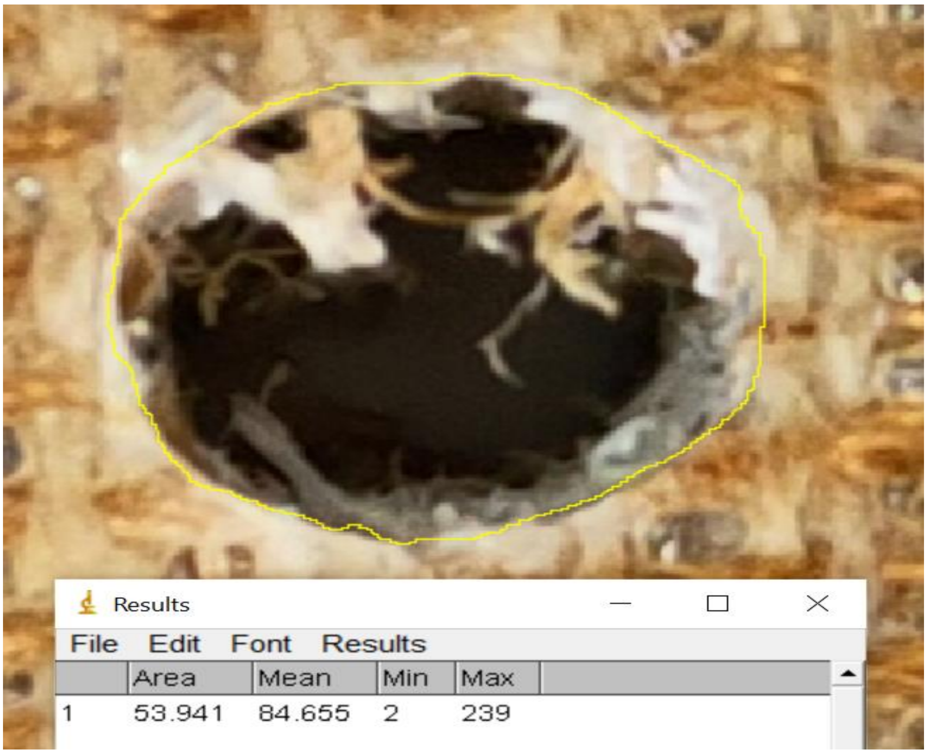

Fig. 5. The figure shows the area of the hole by using the ImageJ software for flax fiber and polystyrene foam structural insulated panel reinforced with wire mesh (Experimental group)

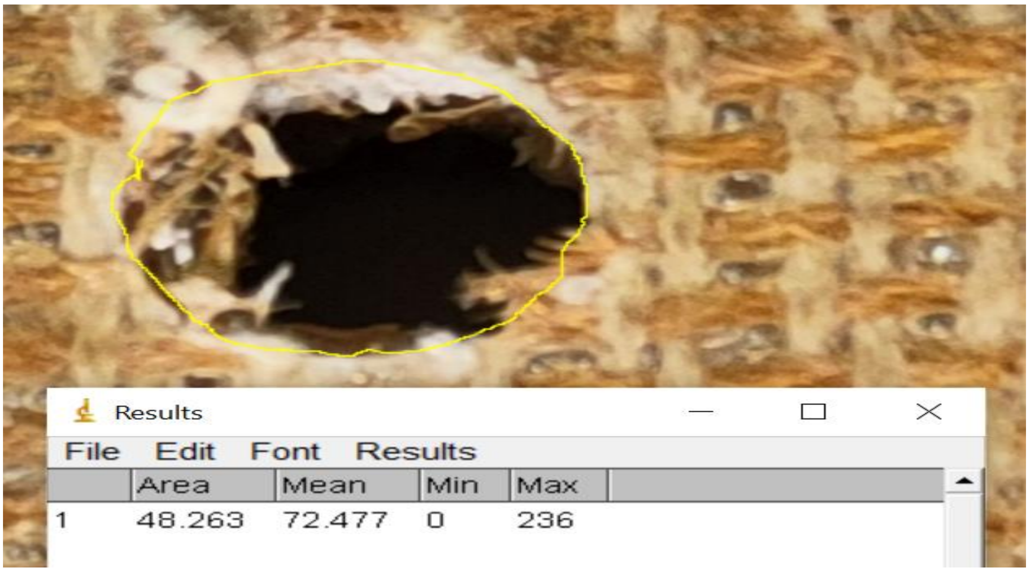

Fig. 6. The figure shows the area of the hole by using the ImageJ software for flax fiber and polystyrene foam structural insulated panel reinforced epoxy composite (Control group)

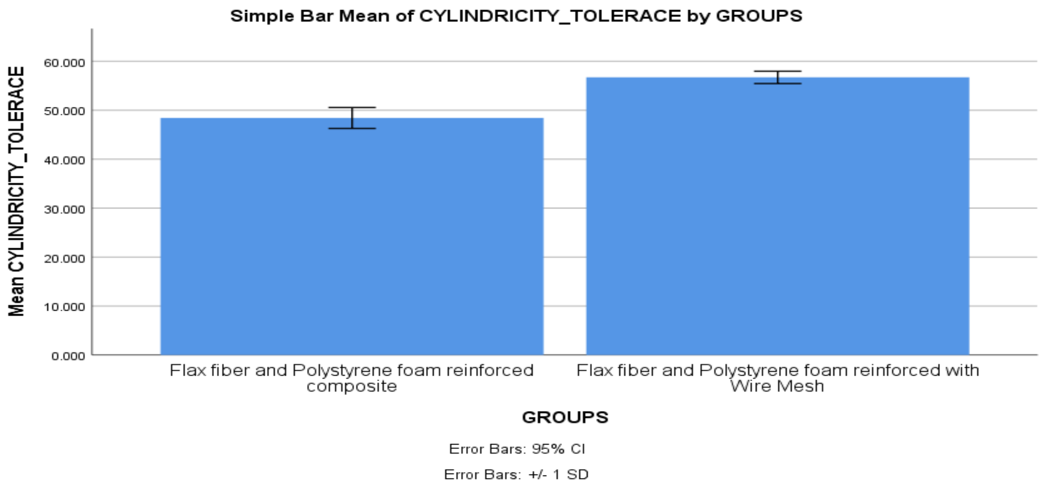

Fig. 7. Bar graph showing the comparison of mean cylindricity tolerance for the flax fiber and polystyrene foam structural insulated panel reinforced epoxy composite and flax fiber and polystyrene foam-insulated panel reinforced with wire mesh. Cylindricity tolerance value increases after adding wire mesh material to the insulated panels. X-Axis: flax fiber and polystyrene foam structural insulated panel reinforced epoxy composite and flax fiber and polystyrene foam structural insulated panel reinforced with wire mesh. Y-Axis: Cylindricity tolerance ± 1 SD