“Rice Stubble: Cotton Fly Waste Composites for Acoustic Applications”

MUKESH Kumar SINGH (mukesh70ster@gmail.com)
Uttar Pradesh Textile Technology Institute https://orcid.org/0000-0002-3432-2038
Kaushal Kishor
Uttar Pradesh Textile Technology Institute

Research Article

Keywords: Rice stubble, cotton fly waste, noise reduction coefficient, water absorption, acoustic

Posted Date: April 1st, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1500779/v1

Rice Stubble: Cotton Fly Waste Composites for Acoustic Applications

Mukesh Kumar Singh, Kaushal Kishor
Department of Textile Technology
Uttar Pradesh Textile Technology Institute, 11/208 Souterganj, Kanpur-208001

Highlights

- Rice stubble: cotton waste based panels were developed for acoustic purposes in building applications.
- Porosity, acoustic, and water absorbing performance was investigated.
- Indigenously developed instrument was used to measure noise reduction constant of acoustic panel.
- Sample preparation and characterization was optimized through Box Behnken design of experiment.

Abstract

Management of noise in everyday life is critical task to enhance the comfort level in present environment or not to resentfully affectthe external environment. The burning of rice stubble particularly in rice growing Asian countries makes the situation bad to worst. Rice stubble, cotton fly waste were used to manufacture composite material to be used as acoustic panel. Rice stubble powder 60,70 and 80 %, cotton fly waste 20,30, and 40 % by weight, and polyurethane (PU) resin were used to produce composite for acoustic applications. The composites were tested for pore size, morphology, water absorbability, and noise reduction coefficient mainly. Acceptable level of NRC and other features were achieved. This study will provide a new pathway to use the discarded challenging waste materials to manufacture wealth generating products.

Keywords: Rice stubble, cotton fly waste, noise reduction coefficient, water absorption, acoustic

Introduction

Noise is an undesired sound, nevertheless of its severity or period. Sound tainting has been admitted as a vital menace to human health regarding hearing potential and wellness disorders [1]. A noise level higher than 80 decibels (dB) generates physiological impacts, and long-span exposure above 100 dB causes enduring impairment to human hearing. Materials that suppress the acoustic intensity as the sound wave passes through it by absorption are acoustic materials [2]. The acoustic mechanism can be divided into two major classes: passive sound absorption and active sound absorption. The external energy is needed to neutralize the sound energy that comes under the active sound absorption mechanism, and the sound energy disseminated and converted into heat is called passive sound suppression [3].

The architecture of acoustic absorbing structures to control the noise in buildings, auditoriums, and vehicles is challenging for material scientists [4]. Most of the acoustic materials are porous and can be classified as cellular materials (foam-like structures), granular structures (concrete-like structures), and fibrous composites [5]. Fiber-based compositions like knitted, woven, and nonwoven have acquired enough attention in acoustic applications due to their low price and high effectiveness ([6],[7],[8]). The nonwovens were found excellent for sound absorption but unable to give a desired aesthetic look and thus required a coverall of conventional woven fabric [9]. The knitted structure was also appropriate for sound absorption, but their acoustic potential remains limited due to their low thickness [10]. The natural fibers are explored to engineer acoustic composites to replace conventional synthetic fibers [11]. The acoustic potential of natural fibers motivated to explore the possibility of some other agricultural waste for sound absorbing purposes. Three-dimensional woven fabrics are still waiting for a systematic study in acoustic applications due to their higher thickness than traditional woven fabrics. A similar thickness is achieved in a composite structure where desired thickness is easily achieved [12]. Microperforated panels (MPPs) are also accepted with an average orifice diameter of 0.5–1 mm as an effective acoustic medium.

As one of the most promising alternatives for next-generation sound-absorbing material, the sound absorption potential of MPPs was enhanced significantly by opting for a sound-absorbing backing cloth as a double absorption system [13]. The textile materials have enormous holes naturally in structures that gained ample attention to be used as future acoustic materials. The low cost and ease in manufacturing are two additional advantages associated with woven, nonwoven, and knitted textile materials [14].

3D spacer knitted fabrics was also influential in indoor acoustic applications [15]. Rice stubble as an agricultural waste is suggested in acoustic panel manufacturing [16]. Recycled cotton fibers were used for acoustic panel manufacturing with polyethylene/polypropylene packaging waste as matrices material [18]. Cotton fabric waste had a higher sound absorption coefficient among the silk, polyester, linen, and viscose fabrics [19]. A variety of resins and hardeners were tried to manufacture acoustic panels in which polyurethane (PU) resins were found suitable for underwater applications ([20],[21],[22]). Agriculture wastes were also found useful to manufacture acoustic items. Rice straws were dispersed with cationic starch followed by freeze-drying to form aerogels and coated with methyltrimethoxysilane to get a water repellent acoustic structure [23].

The combination of rice stubble, cotton waste, and PU resin has not been opted to manufacture acoustic panels. PU opted as matrices during acoustic panel manufacturing to utilize the rice stubble, the most air polluting material after burning by farmers, and cotton fly waste generated in the cotton industry. Box and Behnken surface response method was used to optimize the acoustic potential of composites.

2 Material and methods

2.1 Material

Rice stubble was collected from local field and found bulk density 90-150kg/m^3.. The rice stubble composition was analysed in laboratory and found, cellulose, hemi-cellulose, lignin and silica as major component . The rice stubble consist silica 11%, lignin 19.9 %, cellulose 39.8%, pectin 2.3% fat and waxes 11.5 % and hemmicellulose 20.4%.

Cotton fly waste having 12-15 mm length was collected from Shatabdi Knitware Industry, Kanpur.

Polyurethane (PU) resin, a copolymer of polyol and isocynate with low molecular weight and high porosity, CHS-G530 was procured from Kumar Rotoflex Pvt ltd Kanpur.

Box-Behnken designs are used to generate higher order response surfaces using fewer required runs than a normal factorial technique, This and the central composite techniques essentially suppress selected runs in an attempt to maintain the higher order surface definition.

Table 1 Box and Behnken Surface Response Design

Running experiment	Rice Stubble Coded Factor	Cotton Fly Waste Coded Factor	PU Coded factor	Rice Stubble Actual factor	Cotton fly waste actual factor	PU Actual factor
RS 1	1	1	0	80%	40%	7.5
RS2	-1	0	-1	60%	30%	5.0
RS3	0	-1	-1	70%	20%	5.0
RS4	-1	0	1	60%	30%	10.0
RS5	-1	-1	0	60%	20%	7.5
RS6	-1	1	0	60%	40%	7.5
RS7	1	0	1	80%	30%	10.0
RS8	0	0	0	70%	30%	7.5
RS9	0	1	1	70%	40%	10.0
RS10	1	0	-1	80%	30%	5.0
RS11	0	0	0	70%	30%	7.5
RS12	0	0	0	70%	30%	7.5
RS13	1	-1	0	80%	20%	7.5
RS14	0	1	-1	70%	40%	5.0
RS15	0	0	0	70%	30%	7.5
RS16	0	-1	1	70%	20%	10.0
RS17	0	0	0	70%	30%	7.5

2.2 Method

The rice stubble was cut into small pieces using shredding machine, dried at 80°C for 4h and further ground using mixer grinder. To develop composite samples, a mould of 20 × 20 × 1 cm was prepared. First, PU resin was uniformly distributed within the boundaries of the mould, followed by distribution of rice stubble powder. The cotton fly waste was spread layer by layer to minimize the mass variation and to get 10 mm thickness (Fig.2). The moulds were kept for 12h to get it fixed at room temperature. As per Box and Behnken design of experiment, seventeen samples were prepared (Table 1).

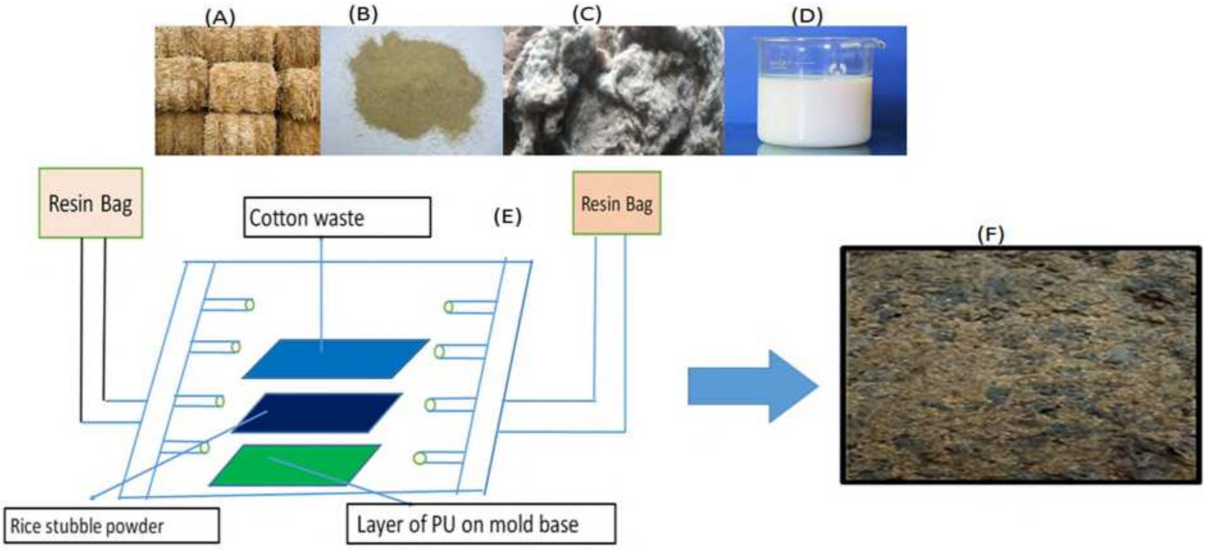


Fig1(A)Rice stubble (B) Powdered Rice Stubble (C) Cotton Fly Waste (D) Polyurethane Resin (E) Composite Processing Technique (F) sample composite

2.21 Acoustic Performance Test

A simple 4'×2'×2' wooden box is fabricated to measure sound transmission loss through the composite material.The outer wall of the box is covered by a ceramic sheet and the inner wall is covered by acoustic foam to absorb the reverberation sound .Inside the vertical wall of this box, a sound source (JBL GO Bluetooth speaker) is fixed which is purchased from appario retail pvt ltd . Outside the top wall of this box two decibel meter are placed; one is fixed at the source and another is movable (to adjust the distance between sound source and receiver decibel meter) to measure the sound intensity.These decibel meters (Mextech SL 36) was purchased from global medical shop. In between these two decibel meters, a sliding arrangement is there to fix 20×20 cm composite sample vertically. The sound absorption coefficient of samples was obtained by using indigenous sound absorption tester (inventor has applied for Indian patent) as per ISO 10534–2:1998

2.22 Scanning electron microscopy (SEM).-

The microstructure and morphology of the stubble, fibers, their composites and PU foam were investigated by using Jeol Scanning Electron Microscope (JCM 7000 NeoScope) at accelerating voltage of 10 kV. The specimens were coated with gold to get conductive surface. Thin sections of cured specimens were sputter-coated for 45 s using a Cressington Q108 sputter coater, which deposited gold at a 30mA current, and imaged using scanning electron microscopy. Images (n=3 per formulation) were analyzed for pore size using Image J 1.47 image analysis software.

Water Absorption Test

Water absorption test was carried out by ASTM D570. Samples were placed in an oven at 65°C for 48h and weighed. The water absorption was allowed at 25°C, followed by sample cleaning and weighing. The specimen was weighed periodically for 24 h intervals and up to 216 h until the specimen reached saturation peak.

3. Result and Discussion

The acoustic panels were subjected to different characterization techniques to verify its performance.

5.1 pore size

The cavities and pores in acoustic structures which may cause a sound absorption [24].The pores content of the composite panels was calculated according to ASTM D2734-16 standard by using equation (1) .

$$\Delta v = \frac{\rho_{ct} - \rho_e}{\rho_{ct}} \times 100 \quad \textbf{..............................(1)}$$

where ρ_{ct} is the theoretical density of the composite, and ρ_e is the experimental density of the composite. The theoretical density of the composite plates was calculated by the equation

$$\rho_{ct} = \frac{1}{\left(\frac{W_f}{\rho_f} + \frac{W_m}{\rho_m}\right)} \times 100 \quad \text{.........................} \ (2)$$

Table 2Pore size distribution

Std	Run	Rice Stubble	Cotton Fly Waste	PU	Pore Size (µm)
4	1	1	1	0	134.015
5	2	-1	0	-1	32.062
9	3	0	-1	-1	76.105
7	4	-1	0	1	78.102
1	5	-1	-1	0	136.235
3	6	-1	1	0	76
8	7	1	0	1	33.377
16	8	0	0	0	78
12	9	0	1	1	100.005
6	10	1	0	-1	92.022
15	11	0	0	0	130.138
17	12	0	0	0	112.018
2	13	1	-1	0	134.015
10	14	0	1	-1	111.19
13	15	0	0	0	129
11	16	0	-1	1	98
14	17	0	0	0	101.1

Experimental density of the composite panels was determined by dividing the measured weight (g) of the sample by the measured volume of the sample (cm^3), and by using the weight and volume values determined by the optical microscopy method.The rice stubble and cotton fly waste densities were considered 0.70 g/cm^3 and 1.52 g/cm^3 respectively. The density of PU resin was considered as 1.07 g/cm^3.

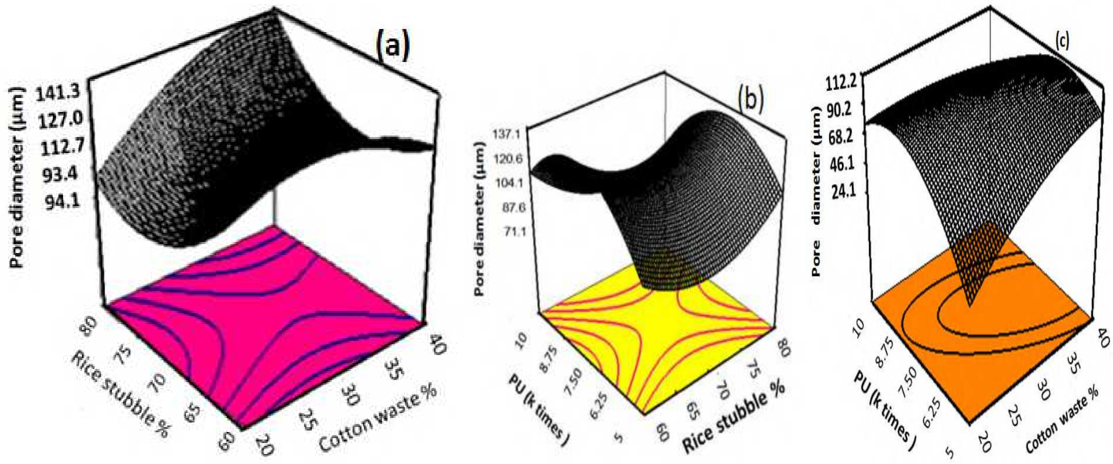
The maximum pore size was observed in sample RS5 which consist 60% rice stubble, 20% cotton fly waste and PU Resin fraction 7.5 %, which is followed by RS1 and RS13 with 134.01 µm mean pore size. Minimum pore size (76.0 µm) was observed with sample RS6 consist 80% rice stubble, 30% cotton fly waste and 7.5 % PU resin. The ANOVA for Response Surface Quadratic Model for pore size is presented in Table

Table 3- ANOVA and stastical parameters for pore size

Source model	**Sum of Square**	**DF**	**Mean Squares**	**F value**	**Prob > F**	
	11437.05	6	1906.17	3.59	0.0364	Significant
A- Rice stubble	630.66	1	630.66	1.19	0.3011	
B- cotton waste	66.96	1	66.96	0.13	0.7297	
C- PU	0.45	1	0.45	8.464E-004	0.9774	
B^2	2234.16	1	2234.16	4.21	0.0672	
C^2	6152.34	1	6152.34	11.60	0.0067	
AC	2739.74	1	2739.74	5.17	0.0463	
Residual	5303.43	10	530.34			
Lack of Fit	3429.62	6	571.60	1.22	0.4429	not significant
Pure Error	1873.81	4	468.45			
Cor Total	16740.48	16				
R-Squared	**0.8010**		**Adj R-Squared**	**0.5451**	**Pred R-Squared**	**-0.5680**

The ANOVA analysis and statistical parameters for the porosityare presented in Tables 3. ANOVA table shows the sum of the squares and mean square of each parameterwhere the p-value and F-value are defined as the ratio of the respective mean square effect and the mean square error. The significance of main and interaction effects in the predictive model were considered based on their probability values (p-values) .The p-values less than 0.1 call for the rejection of the null hypothesis indicating that the particular term significantly affects the response of the system. The insignificant "Lack of Fit" with p-value of 0.4429 for porosity indicated that the model satisfactorily fitted the data. The higher correlation coefficients confirmed the suitability of the models and correctness of the calculated constants. The R^2values obtained were 0.8010 for the response of porosity, which ensures a satisfactory fit of the model to the experimental data. The adjusted R^2 was 0.5451 for porosity, which accounts for the number of predictors in the model. The predicted R^2 values obtained was -0.5680. The values ofR^2, adjusted R^2 and predicted R^2 indicated the high correlation between observed and predicted values. The coefficients in the second-order polynomial equation were estimated by multiple regression analysis based on the ANOVA results. The analytical expression, obtained from analyzing the influences of the various dominant parameters on the porosity is given by

Porosity = 110.05 +8.87 × cotton -2.89 × rice stubble -0.23 × PU-13.70×cotton ^{2} +23.72 × rice stubble ^{2} -37.45 × PU^2 +15.05 ×cotton ×rice stubble -26.17 × cotton × PU - 8.27 × rice stubble ×PU……………………………………….(3)



Fig–2 effect of (a) PU and rice stubble (b) rice stubble and cotton waste % (c) PU and cotton waste on porosity

Fig2 (a) show 3D surface response plots for the relationship between two factors rice stubble loading and PU on the pore size while cotton fly waste was kept at 30% by weight In Fig. , it can be observed that porosity decreased with increase in magnitude of rice stubble loading upto a certain level then after that porosity continuously increased
Fig2(b) show 3D surface response plots for the relationship between two factors rice stubble loading and cotton fly waste on the pore size while PU was kept at 7.5 times In Fig.2(b), it can be observed that porosity increased with increase in magnitude of rice stubble loading
Fig 2 c show 3D surface response plots for the relationship between two factors cotton waste loading and PU on the porosity while rice stubble was kept at 30% by weight In Fig.2(c), it can be observed that on increasing the both parameters value porosity firstly increased then after reaching a threshold value decreased

Optimization of porosity

The optimization of porosity was carried out using the response optimizer part of the design expert software. For this purpose the maximum values for porosity from optimization via software was obtained as 138 µmand the correspondingvalues for rice stubble fiber loading, cotton fly waste and PUare demonstrated in Fig. 6.

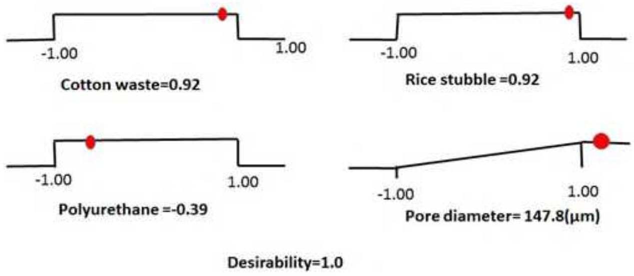


Fig 3Optimization of porosity

Water absorbency test

The response surface method coupled with the experimental results shown in Table 4is implemented for predicting the mathematical relationships that link water absorbency as a function of the rice stubble fiber loading, cotton waste % and PU content.

Table 4 – Water Absorbency of Composites

Std	Run	Factor A: Rice stubble	Factor B: Cotton Waste	Factor C: PU	water absorbency
3	1	-1	1	0	60.5
14	2	0	0	0	67.9
10	3	0	1	-1	87.5
4	4	1	1	0	74.9
17	5	0	0	0	68.3
13	6	0	0	0	69.1
16	7	0	0	0	68.6
2	8	1	-1	0	56.3
12	9	0	1	1	64.2
9	10	0	-1	-1	91.4
5	11	-1	0	-1	75.9
7	12	-1	0	1	53.2
15	13	0	0	0	69.3
1	14	-1	-1	0	48.1
6	15	1	0	-1	75.8
11	16	0	-1	1	54.2
8	17	1	0	1	61.3

Fig 4(a) show 3D surface response plots for the relationship between two factors rice stubble loading and cotton fly waste on the pore size while PU was kept at 7.5 times . In Fig. 4(a), it can be observed that water absorbency increased with increase in magnitude of rice stubble loading and then decreased and effect of cotton waste follow same trend as rice stubble .

Fig 4(b) show 3D surface response plots for the relationship between two factors rice stubble loading and PU on the water absorbency while cotton fly waste was kept at 30% by weight . In Fig.4(b), it can be observed that water absorbency increase in magnitude of rice stubble loading upto a certain level then after that water absorbency continuously decreased.

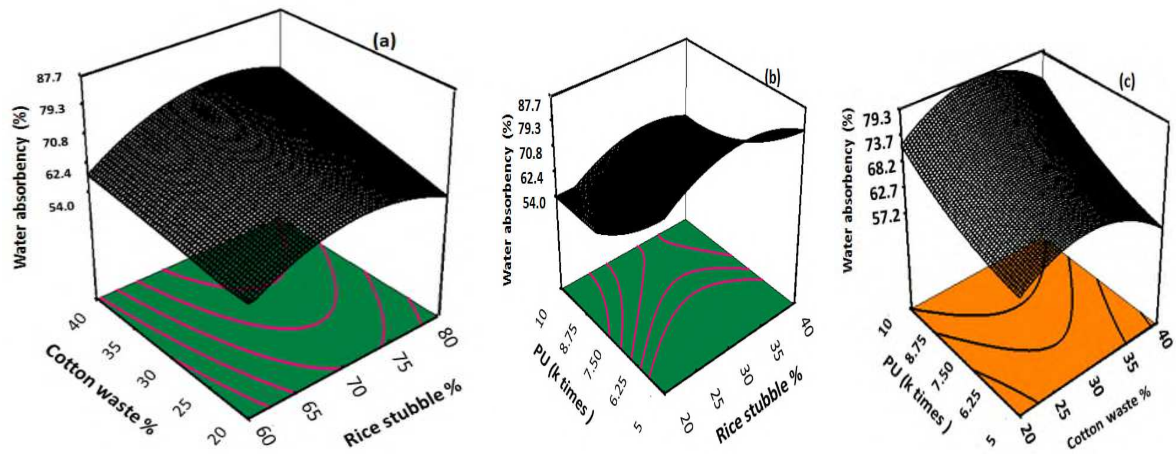


Fig 4Effect of (a) Rice Stubble and Cotton waste (b)) Rice Stubble andPU Content (c) Cotton waste and PU Content on water absorbency

Fig4 c show 3D surface response plots for the relationship between two factors cotton waste loading and PU on the water absorbency while rice stubble was kept at 30% by weight . In Fig.4(c), it can be observed that on increasing the both parameters value water absorbency firstly increased then after reaching a threshold value decreased

5.3 Scanning Electron Microscopy

The scanning electron microscope photographs are shown in Fig.5. It is clearly shown in SEM photographs that as the rice stubble content increases, the pore size is increasing in the ratio. The role of cotton fly content is also clearly illustrated in SEM photograph. The pore shape irregularity was increased by increasing the cotton fly waste. The pore shape is irregular and shape can be not standardized. However in PU foam, the pore size distribution is quite uniform and small. In addition, the structure of pores change with fiber reinforcement, and the open pores in PU foam is replaced by semi-closed or closed pores in the composites

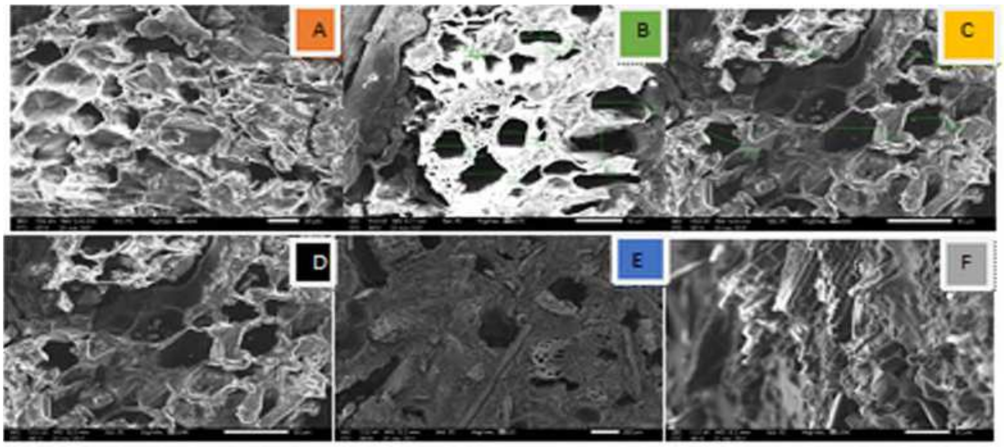


Fig 5- Morphology study of composite structures of fibre loading of (a) 60%,(b) 70% and (c)80 % and their side views (d), (e) and (f)respectively

5.6 Sound absorption properties: Noise reduction coefficient

The noise reduction coefficient (NRC) and sound transmission loss (R) were determined using the following equations:

$$NRC = 1 - 10^{-\left(\frac{d}{20}\right)} \qquad (4)$$

Where,

d is the difference in sound power between transmitting room and receiving room in decibel

$$R = L_1 - L_2 \qquad (5)$$

Where,

L_1 is the sound pressure level in transmitting room

L_2 is the sound pressure level in receiving room

Table 5- Noise Reduction Coefficient (NRC)

Standard	run	Rice Stubble	Cotton Fly Waste	PU	NRC
14	1	0	0	0	0.32016
17	2	0	0	0	0.31016
12	3	0	1	1	0.371737
1	4	-1	-1	0	0.30016

15	5	0	0	0	0.329307
10	6	0	1	-1	0.29205
8	7	1	0	1	0.364346
5	8	-1	0	-1	0.28205
6	9	1	0	-1	0.30205
3	10	-1	1	0	0.31016
2	11	1	-1	0	0.339307
13	12	0	0	0	0.329307
7	13	-1	0	1	0.376265
9	14	0	-1	-1	0.29386
11	15	0	-1	1	0.386265
4	16	1	1	0	0.30016
16	17	0	0	0	0.31016

Table 6 ANOVA Analysis for Noise Reduction Coefficient (NRC)

SourceModel	Sum ofSquares	DF	Square	F value	Prob > F	
	1950.466324	9	216.7184804	7880.672	< 0.0001	significant
A- Rice stubble	111.75125	1	111.75125	4063.682	< 0.0001	
B- cotton waste	171.125	1	171.125	6222.727	< 0.0001	
C- pu	1173.70125	1	1173.70125	42680.05	< 0.0001	
A2	279.6736842	1	279.6736842	10169.95	< 0.0001	
B2	1.392105263	1	1.392105263	50.62201	0.0002	
C2	164.4736842	1	164.4736842	5980.861	< 0.0001	
AB	9.3025	1	9.3025	338.2727	< 0.0001	
AC	12.96	1	12.96	471.2727	< 0.0001	
BC	46.9225	1	46.9225	1706.273	< 0.0001	
Residual	0.1925	7	0.0275			
Lack of Fit	0.0525	3	0.0175	0.5	0.7022	not significant
Pure Error	0.14	4	0.035			
Cor Total	1950.658824	16				
R-Squared	**0.999901**		**Adj R-Squared**	**0.999774**	**Pred R-Squared**	**0.999457**

The ANOVA analysis and statistical parameters for the NRC are presented in Tables 6. ANOVA table shows the sum of the squares and mean square of each parameterwhere the p-value and F-value are defined as the ratio of the respective mean square effect and the mean square error. The significance of main and interaction effects in the predictive model were considered based on their probability values (p-values) .The p-values less than 0.1 call for the rejection of the null hypothesis indicating that the particular term significantly affects the response of the system. The insignificant "Lack of Fit" with p-value of 0.7174 for sound absorbance properties indicated that the model satisfactorily fitted the data. The higher correlation coefficients confirmed the suitability of the models and correctness of the calculated constants. The R^2values obtained were 0.9991 for the response of NRC, which ensures a satisfactory fit of the model to the experimental data. The adjusted R^2 was 0.9997 for NRC, which accounts for the number of predictors in the model. The predicted R^2 values obtained was 0.9994. The values ofR^2, adjusted R^2 and predicted R^2 indicated the high correlation between observed and predicted values. The coefficients in the second-order polynomial equation were estimated by multiple regression analysis based on the ANOVA results. The analytical expression, obtained from analyzing the influences of the various dominant parameters on the NRCis given by:

NRC =0.31+1.55 × rice stubble +0.02 × fly waste +7.92× PU +3.00 × rice stubble ^{2}+7.89 × fly waste^2+0.01 × PU+0.02× rice stubble × fly waste -8.08× rice stubble ×PU+5.92×fly waste × PU……………………………………………………….(6)

Fig 6a show 3D surface response plots for the relationship between two factors rice stubble and cotton fly waste fraction on noise reduction coefficient while PU was kept at 7.5 times by weight. The noise reduction coefficient increased with increase in magnitude of fiber loading as shown in Fig 6a.

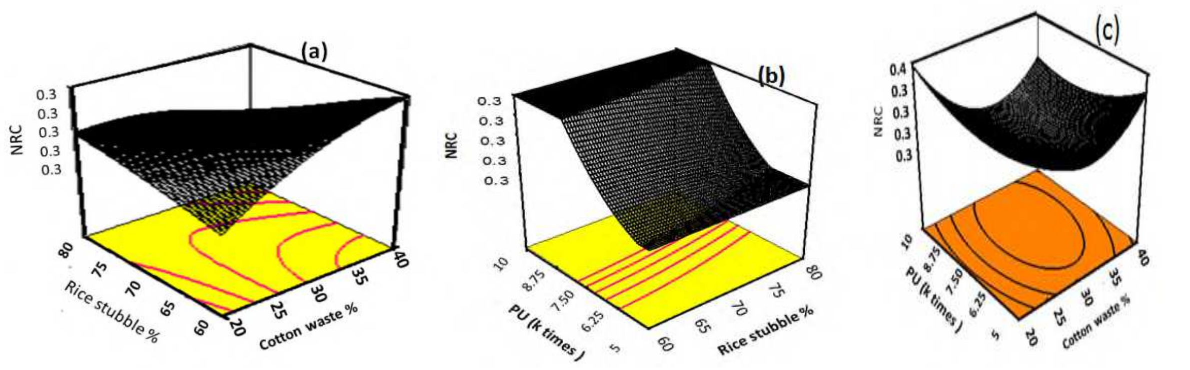


Fig 6Effect of (a) Rice Stubble and Cotton waste (b)) Rice Stubble andPU Content (c) Cotton waste andPU Content on NRC

Fig6b show 3D surface response plots for the relationship between two factors rice stubble loading and PU on the noise reduction coefficient while cotton fly waste was kept at 30% by weight . In Fig.6b, it can be observed on increasing the magnitude of rice stubble the NRC increases and on other hand on increasing the content of PU the noise reduction coefficient will be decreases .

Fig6c show 3D surface response plots for the relationship between two factors cotton waste loading and PU on the noise reduction coefficient while rice stubble was kept at 30% by weight . In Fig.6c, it can be observed that on increasing the both parameters value NRC firstly decreased then after reaching a threshold value increased

5.8.1 Optimization of sound absorption properties

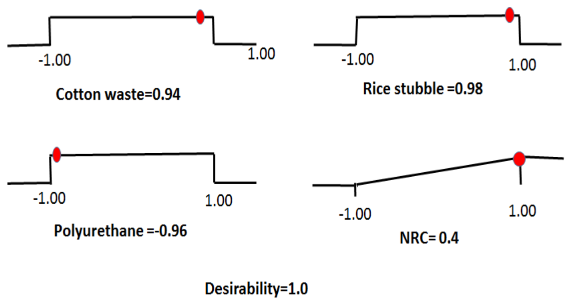


Fig 7 optimization of sound properties

After studying the effect of the experimental variables on the sound absorption properties of biocomposite, the levels of these parameters that give the optimal NRC was determined. In this section, optimization of NRC was carried out using the response optimizer part of the design expert software. For this purpose the maximum values for porosity from optimization via software was obtained as 0.4 and the correspondingvalues for rice stubble fiber loading, cotton fly waste and PU were demonstrated in Fig 7.

Conclusion

Rice stubble a challenging agriculture waste is successfully used to convert it into wealth in the form of acoustic composite panel with another industrial cotton fly waste. The composite acoustic panels posed the following inferences:

- Rice stubble in powder form is useful to enhance noise reduction coefficient
- Cotton fly waste enhances the binding potential of rice stubble with PUresin and NRC
- Effective porosity was achieved in acoustic panel which is an essential feature of acoustic structures
- Maximum NRC was achieved by using rice stubble 70%, cotton fly waste 30% and PUresin 7.5 % by weight by optimization of process parameters by Box and Behnken surface response method.

Declaration of Interest Statement

- This is original research work and did not submitted to any other journal for publication.
- Authors declare that this research work does not have any conflict of interest.

We both authors declare the interest statement.

Mukesh Kumar Singh Kaushal Kishor

References

1. Thompson M (2017) Beyond unwanted sound: noise, affect and aesthetic moralism. Blumsburry Pub. Ltd. Ney York.

2. Hong O, Kerr M J, Poling GL, Dhar S, (2013)Understanding and preventing noise-induced hearing loss. Disease-a-Month. 59: 110-118

3. Bingham B., Kraus N., Howe B., Freitag L., Ball K., Koshi P., Gallimore E., **2012.** Passive and active acoustics using an autonomous wave glider. J of Field Robot. 29 (6), 911-923

4. Talebi, Z., Soltani, P., Habibi, N., & Latifi, F. (2019). Silica aerogel/polyester blankets for efficient sound absorption in buildings. Construction and Building Materials, 220, 76–89. doi:10.1016/j.conbuildmat.2019.06.031

5. Yang, T., Xiong, X., Mishra, R., Novak, J., & Militk_y, J. (2018). Acoustic evaluation of struto nonwovens and their relationship with thermal properties. Textile Research Journal, 88(4), 426–437. doi:10.1177/0040517516681958

6. Kang, Y. A., Lee, E. N., Lee, K. C., Choi, S. M., & Shin, E. J. (2019). Acoustic properties of sound-absorbing polyester fabrics woven with thick staple and thin draw textured yarn for use in interior decoration. The Journal of the Textile Institute, 110(2), 202–210. doi:10.1080/00405000.2018.1508798

7. Soltani, P., & Zarrebini, M. (2013). Acoustic performance of woven fabrics in relation to structural parameters and air permeability. Journal of the Textile Institute, 104(9), 1011–1016. doi:10.1080/00405000.2013.771427

8. Tang, X., Zhang, X., Zhuang, X., Zhang, H., & Yan, X. (2018). Acoustical analysis of corduroy fabric for sound absorption: Experiments and simulations. Journal of Industrial Textiles, 48(1),201–220. doi:10.1177/1528083717725912

9. Shoshani, Y. K. (1991). Noise absorption by a combination of woven and nonwoven fabrics. The Journal of the Textile Institute, 82(4), 500–503. doi:10.1080/00405009108659237

10. Liu Y, Hu H, 2010. Sound Absorption Behavior of Knitted Spacer Fabrics. Text. Res. J. 80(18) 1949-1958

11. Yang T, Hu L, Xiong X, Petru M, Noman M T, Mishra R, Militky J, 2020, Sound Absorption Properties of Natural Fibers: A Review, Sustainability. 12, 8477; doi:10.3390/su12208477

12. Echeverria, C A., Pahlevani, F., Handoko W., Jiang C, Doolan C, Sahajwalla V, 2019. Engineered hybrid fibre reinforced composites for sound absorption building applications. Resources, Conservation and Recycling. 143, 1-14

13. Liu Z, Zhan J., Fard M., Davy L., 2017. Acoustic measurement of a 3D printed micro-perforated panel combined with a porous material. Measurement. 104, 233-236 doi.org/10.1016/j.measurement.2017.03.032

14. Tascan, M., and Vaughn, E. A., (2008). Effects of total surface area and fabric density on the acoustical behavior of needlepunched nonwoven fabrics, *Textile Res. J.* **78**(4), 289–296

15. Arumugam, V., Mishra, R., Militky, J., & Novak, J. (2015). Thermoacoustic behaviour of 3D knitted spacer fabrics. Fibers and Polymers, 16(11), 2467–2476. doi:10.1007/s12221-015-5602-5

16. Fatima A, Qayyum N, Zaid M, Rafat Y, Khan M Z., Ali R., Salem B, 2021 Feasibility of manufacturing sustainable bio-composites from agricultural waste. Materials Today: Proceedings. 47(19), 7136-7139 https://doi.org/10.1016/j.matpr.2021.06.260 2214-7853

17. Sezgin H., Ozturk M K., Berkalo O B., Enis I Y., 2021, Design of composite insulation panels containing 100% recycled cotton fibers and polyethylene/polypropylene packaging wastes. J of Clean. Prod. 304, 1-9

18. Jailani M E A., and Isa M H M., 2020. Potential Application of Fabric Waste as Acoustic Materials in Building. Malaysia Architectural J., 2(2), 31-35

19. Jayakumari V. G., Shamsudeen R. K., Rajeswari R., Mukundan T., 2019. Viscoelastic and acoustic characterization of polyurethane-based acoustic absorber panels for underwater applications. J of Appl. Poly. Sci., 136(10), 47165, 1-9 doi.org/10.1002/app.47165

20. Bertolini M S., Morais C A G., Christoforo A L., Bertoli S R., Santos W N, Lahr F A R., 2019., Acoustic absorption and thermal insulation of wood panels: influence of porosity, BioResource 14(2), 3446-3457

21. Bhingare N H., Prakash S., Jatti V S., 2019. A review on natural and waste material composite as acoustic material, Polymer Testing**,** **80**, 106142**,** **1-8,** doi.org/10.1016/j.polymertesting.2019.106142

22. Aygün H., McCann F., 2020. Structural and acoustical performance of recycled glass bead panels Construction and Building Materials, 258, 119581, 1-13

23. Tran D T.,Nguyen S T., Do n d., Thai N N T., Thai Q B.,Huynh h k p., Nguyen V T T., Phan A N., 2020., Green aerogels from rice straw for thermal, acoustic insulation and oil spill cleaning applications. Materials Chemistry and Physics. 253, 123363, 1-26, doi.org/10.1016/j.matchemphys.2020.123363

24. Lee HP, Ng BMP, Rammohan AV, et al. An investigation of the sound absorption properties of flax/epoxy composites compared with glass/epoxy composites. J Nat Fibers 2017; 14: 71–77