Acoustic Performance of Mixing EFB and OPF Low-Density Fibreboards in Different Thickness

Mageswaran Ravi Chandran, Ewe Lay Sheng, Mohammad Nazhan Nasir, Yew Weng Kean, and Zawawi Ibrahim

Abstract Fast growth of worldwide oil palm industry and nation's economics have affected the environment for the mishandling of oil palm waste, which has endangered the flora and fauna that surrounds it. The wastes of oil palm can be turned into good source of material for sound absorption or other usages. Furthermore, the awareness about the harmful effects of fibreglass as sound absorbing material has certainly increased and the demand of replacing it with natural fibres are growing day by day. This research highlights the acoustic properties of mixing empty fruit bunch (EFB) and oil palm frond (OPF) at mixing ratios of 50% EFB-50% OPF, 40% EFB-60% OPF, 30% EFB-70% OPF and 20% EFB-80% OPF in thickness of 12, 14, 16 and 18 mm with density of 120 kg/m^3. The sound absorption coefficient, SAC (α) test was conducted using the impedance tube method (ITM) and the morphology of the samples were examined using scanning electron microscope, SEM. The results showed no trend for the sac values with increasing of thickness and OPF contents. Nevertheless, it is noteworthy that the frequency range with 0.8 sac values and above are increased with thickness, it may be attributed to tortuosity effects. The morphology of EFB and OPF mixture may play a crucial role in determining the sound absorption.

Keywords Sound absorption coefficient · Empty fruit bunch · Oil palm frond

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1 Introduction

Malaysia being one of the largest producers of oil palm industry in the world. Based on research from 2016, there are 5.76 million hectares of oil palm plantation across Malaysia [1]. But rough estimation shows about 84 million tons of oil palm biomass wastes are available throughout Malaysia [2]. The Malaysian government is facing a hard time to dispose this oil palm biomass wastes because the amount of waste is huge. The oil palm trunk (OPT), empty fruit bunch (EFB), oil palm frond (OPF), palm kernel shell (PKS), etc. all belong to the palm oil industry. Due to the moisture content of EFB is 67%, that natural fibre can be considered as a very good source for fuel. Given that EFB undergoes a proper pre-pressing process [3]. EFB is usually subjected to open burning once the oil is extracted from them. Instead of open burning and polluting the environment, the heat energy from the burning could be directed to boilers in oil palm mills [4]. Even in power generation sector, EFB natural fibre is considered as valuable natural resource [5]. Besides that, natural fibres from palm oil tree can be used to produce daily products such as soap, cosmetic, sound absorbing material for acoustic purposes and etc. [6].

Technology around us are evolving at a very fast rate day by day. So, does technology on enhancing sound absorption characteristic, which have been studied over the years by researchers around the world. The motivation that drives these researchers is because the fibreglass and asbestos are infamous to have health effects of humans and could also harm animals as well [7]. Synthetic fibre, mineral wool, polyester are the base for sound absorbing panels that currently in production [8]. Therefore, researchers are opting to test out natural fibres as a decent replacement for fibreglass as it is environmentally friendly and have good acoustic properties. Based on investigation by past researchers, it is said that both fibrous and non-fibrous natural fibres are proven to be a sustainable acoustical material and it can be commercialized [9]. Besides that, waste fibre from paddy has good sound absorption, as good as synthetic glass wool. Waste fibre from paddy achieved sound absorption coefficient up to 0.80 at frequency of 2500 Hz [10]. Another research done on coir natural fibre, where the absorption coefficient average result of 0.80 was obtained [11].

For few years now, researchers have been testing various natural fibres on their acoustic properties. Natural fibres such as oil palm trunk [12], empty fruit bunch [13], oil palm frond [14], kapok [15], bamboo [16], arenga pinnata [17], paddy straw [18], coconut coir [19] and etc. Currently, OPT natural fibre has proved to have the best sound absorption coefficient thus far. The material was able to achieved SAC of 0.99 at frequency of 3000–6000 Hz for sample thickness 12 mm [12]. Sugarcane bagasse showed an average sound absorption of 0.80 at frequency range of 2000–4500 Hz [20].

Tortuosity is the expansion of pathway trough the pores in the material. Other than that, tortuosity also influences the internal structure of porous material on its acoustic performance [21]. A tight space structure will be small and there will also be less volume of air, resulting in a narrow passage for the sound wave to travel [22]. Hence, sound waves will travel in longer distance and the tortuosity will increase.

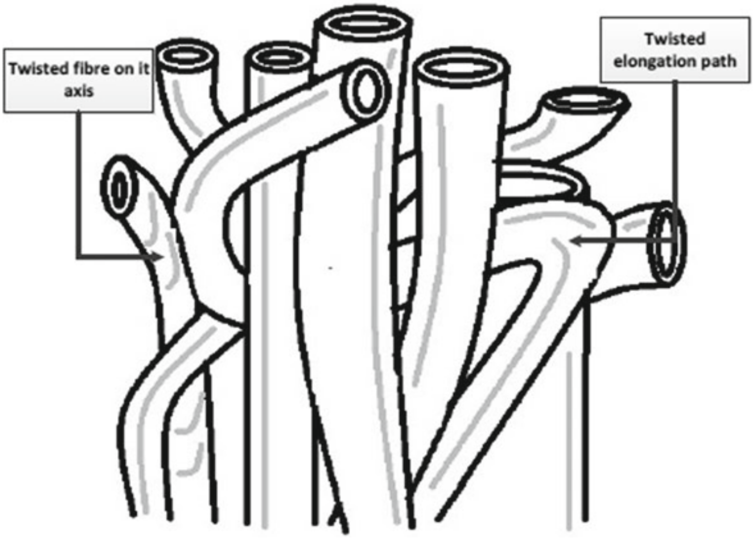

Fig. 1 Pathway of fibres (tortuosity)

High tortuosity will produce good sound absorption at high range frequency. Figure 1 shows how the pathway of fibres look like [23].

This research mainly focusses on the mixture of empty fruit bunch and oil palm frond natural fibres and their acoustic properties in thickness of 12, 14, 16 and 18 mm. By completing this research, the environmental problems and the noise pollution problem will be able to be solved at one go.

2 Methodology

The mixture of EFB and OPF low density fibreboard (LDF) at different mixing ratio were prepared. The fabrication process involved chipping, refining, glue bending, mat forming, pre-press, hot press and cool down. For further interpretation, can refer to my previous publication and other publication [24, 25].

3 Results and Discussions

Sound Absorption Coefficient, SAC (α) is the term that is used to measure the sound absorption rate of a material. SAC (α) is the ratio of sound transmitted through a material and the incident sound that emitted from the material. For instance, when a material achieved SAC (α) value of 0.95 at certain frequency. It means at that

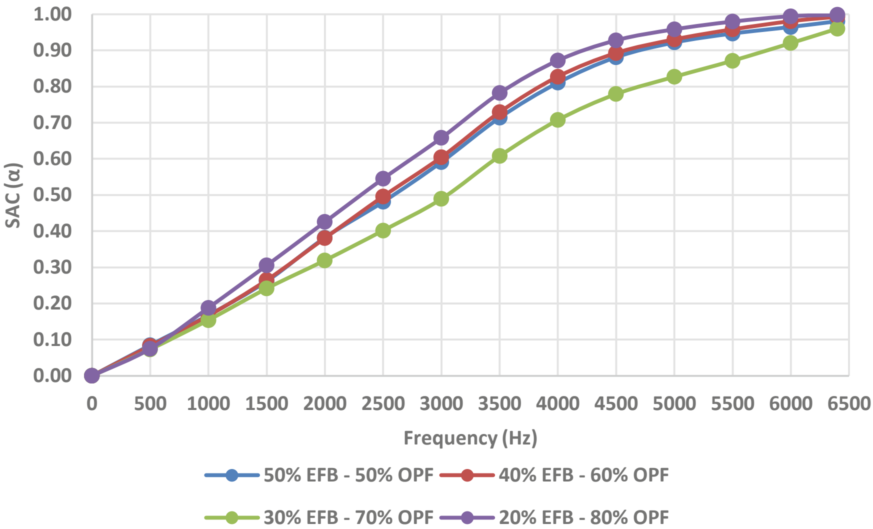

Fig. 2 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 12 mm

frequency; the material is able to absorb 95% of the sound and only 5% of the remaining sound is reflected back to the surrounding as heat energy.

Figure 2 shows the SAC, α values of four different mixing ratios with the same thickness of 12 mm. SAC, α values are found to increases as the frequency increase from 0 to 6400 Hz for all samples. It can be clearly seen that the sac values for all samples increased with increasing in OPF contents except for sample with mixing ratio of 30% EFB-70% OPF. All samples performed outstandingly (sac values, α > 0.8) at high range of frequency 5000 Hz and above. The SAC results are comparable with OPT because of SAC, α values are more than 0.80 at frequency of 4000 Hz [8]. Compared to mixture of EFB and OPF sample thickness 12 mm, the OPT performed better at low frequency meanwhile mixture of EFB and OPF performs better at higher frequency. The average SAC, α for thickness 12 mm is higher when compared to other thickness.

Based on Fig. 3 the best SAC, α values obtained from sample 50% EFB-50% OPF, 40% EFB-60% OPF and 20% EFB-80% OPF were 0.98, 0.99 and 1.00 respectively at frequency 6400 Hz. Sample 30% EFB-70% OPF only achieved SAC, α more than 0.90 at frequency of 6000 Hz, whereas the other sample did it at frequency of 5000 Hz. The SAC, α values for all samples are found to increase linearly from 5000 to 6400 Hz. The average acoustic performance of sample 30% EFB-70% OPF may be affected by sample fabrication process [26].

Figure 4 shows the SAC, α values of four different mixing ratios with the same thickness of 14 mm. All the samples show very consistency in the increase of sound absorption as the frequency increases. Sample 40% EFB-60% OPF has a superior acoustic property at the frequency range of 1500–5000 Hz compared to other

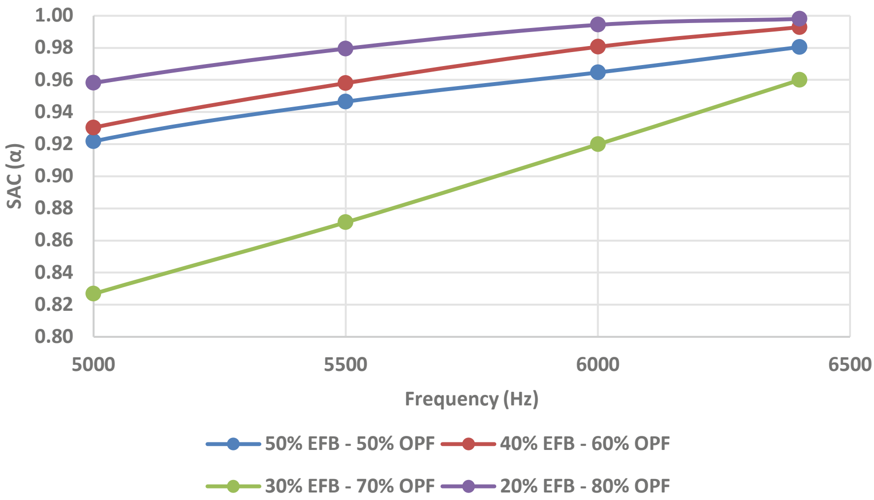

Fig. 3 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 12 mm from frequency range of 5000 to 6400 Hz

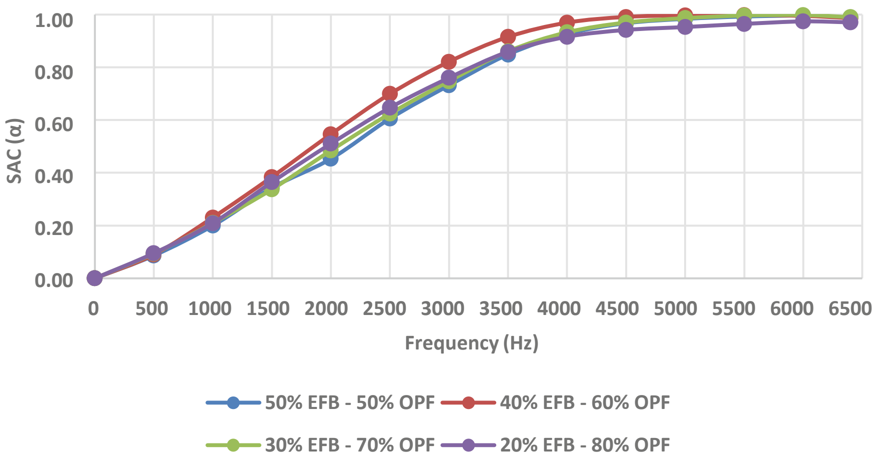

Fig. 4 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 14 mm

samples. Whereas, sample 50% EFB-50% OPF has a marginally low SAC, α values at frequency 1000–3500 Hz contrasted to other samples.

Figure 5 shows all the LDF samples of thickness 14 mm with different mixing ratios reached the SAC values of 0.8 and above from the frequency range of 3500 to 6400 Hz. The SAC, α values are found to increase with frequency. Sample mixture of 40% EFB-60% OPF has the SAC, α of 0.90 at the frequency of 3500 Hz while the other samples only in the range of 0.80. Sample 50% EFB-50% OPF, 40% EFB-60%

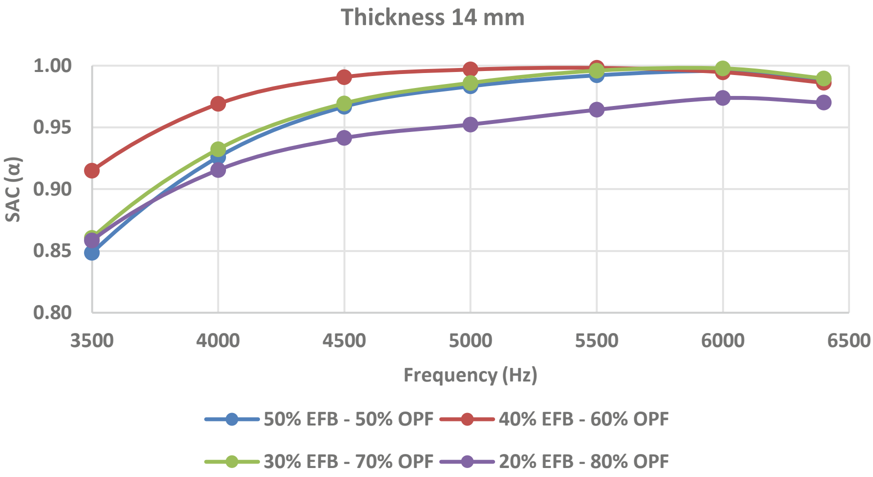

Fig. 5 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 14 mm from frequency range of 3500 to 6400 Hz

OPF and 30% EFB-70% OPF all achieved unity, which is 100% sound absorption at frequency range of 5000–6000 Hz. Sample 20% EFB-80% OPF did not achieved 100% sound absorption but able to achieve 97% sound absorption at frequency of 6400 Hz.

Figure 6 shows the SAC, α values of four different mixing ratios with the same thickness of 16 mm. All the samples show very consistency in increasing of sound absorption as the frequency increased. Based on Fig. 5, sample mixture of 40% EFB-60% OPF and 20% EFB-80% OPF portraits the same SAC, α values from the

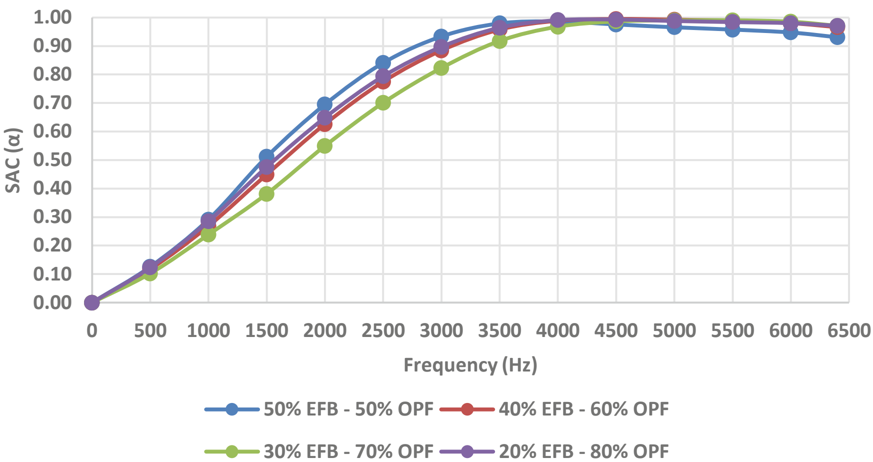

Fig. 6 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 16 mm

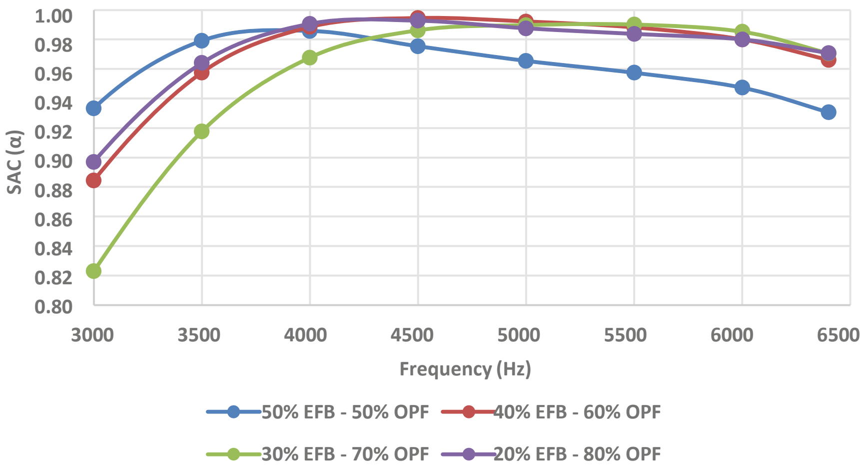

Fig. 7 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 16 mm from frequency range of 3000 to 6400 Hz

frequency range of 3500 to 6400 Hz. Comparing this result with rice straw sound absorption, rice straw performs better at mid-range frequency. SAC, α of rice straw at frequency 2000 Hz is 0.70, but low at high frequency of 8000 Hz with SAC, α of 0.50 [27]. Although mixture of EFB and OPF did not performs as well as rice straw at mid-range frequency, mixture of EFB and OPF did very well at high frequency.

Figure 7 shows all the LDF of thickness 16 mm in different mixing ratios obtained the SAC values of 0.8 and above from the frequency range of 3000 to 6400 Hz. Sample with a mixture of 50% EFB-50% OPF and 20% EFB-80% OPF have the SAC, α values exceeded 0.90 at the frequency of 3000 Hz while samples 40% EFB-60% OPF and 30% EFB-70% OPF only exceeded SAC, α value more than 0.80 at frequency of 3000 Hz. Sample 50% EFB-50% OPF performed better than other three samples at frequency range of 1500–4000 Hz. All the samples except 50% EFB-50% OPF, almost achieved unity with SAC, α value of 0.99 with only 1% of remaining sound reflected.

Figure 8 shows the SAC, α values of four different mixing ratios with the same thickness of 18 mm. All the sample shows high consistency in increasing of sound absorption as the frequency increased. Based on Fig. 7, its observed that all the samples have very similar trend of SAC, α values from frequency range of 0 to 6400 Hz except for sample mixture 50% EFB-50% OPF, where it has a marginally lower SAC, α values from frequency range of 1500 to 3000 Hz. When compare to hollow bamboo, which performs excellently at mid-range frequency of 3600 Hz SAC, α of 0.95 [28]. However, mixture of EFB and OPF samples have an average SAC, α of 0.97 at frequency of 3500 Hz.

Figure 8 shows the LDF of thickness 18 mm with different mixing ratios that possessed the SAC values of 0.8 and above from the frequency range of 2500 to 6400 Hz and 0.9 and above from the frequency range of 3000 to 6400 Hz (Fig. 9).

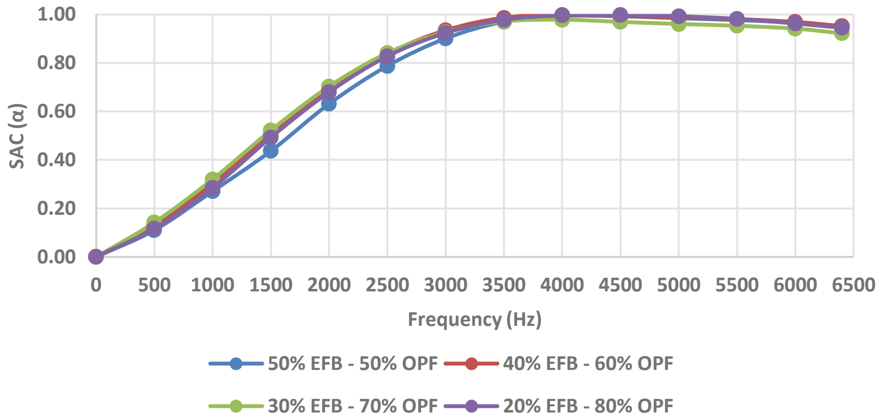

Fig. 8 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 18 mm

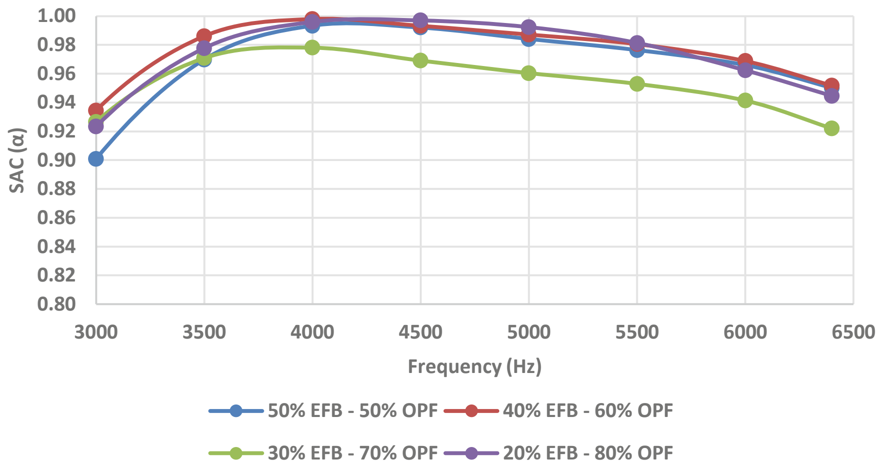

Fig. 9 SAC, α values versus frequency (Hz) in four different mixing ratios with thickness of 18 mm from frequency range of 3000 to 6400 Hz

Sample 40% EFB-60% and 20% EFB-80% achieved 100% sound absorption at frequency of 4000 Hz. After 4000 Hz, all the sample experience a decrease in SAC, α values. However, that is not a big issue because the SAC, α values are still more than 0.90 which means more than 90% sound absorption.

Tortuosity plays a large role in determining the acoustic performance of the natural fibre. The more fibre used to fabricate the fibreboard, the more tortuous the path will become [29, 30]. This will lead to a higher flow of resistivity. Thus, the time taken for the sound wave to strike is longer and more sound can be absorbed. The path of the natural fibre is more tortuous for all the thickness and it may be due to the combination of two different natural fibres. All the samples contain a certain porous percentage, which allows the reflection of sound wave travel and hence increases the absorption rate.

4 Conclusion

In a nutshell, by conducting this research using natural fibres for sound absorption material able to solve the two trending main issues. First, the waste from the natural fibres were able to reduce and put the waste into good use. Second, the sound absorption material will be able to replace synthetic fibres in the market. Natural fibres does not only show good acoustic properties but also plays a vital role in design ergonomics. Since natural fibre is renewable and biodegradable, they will produce lower emission during production compare to synthetic fibres [31]. The sound absorption coefficient test SAC, α was carried out for EFB and OPF mixed fibreboard with four different ratios in four different thickness of 12, 14, 16 and 18 mm. All the LDF samples are able to achieve unity ($\alpha = 1.00$) at high frequency. It's also notable that by increasing the thickness from 12 to 18 mm for all mixing ratios, it is able to widen the frequency range for SAC values of 0.8 and above from 5000–6400 Hz to 2500–6400 Hz. The mixture of EFB and OPF have never been tested for acoustic properties, hence therefore this research study is a new beginning into determining natural fibres as a substitute of synthetic fibre.

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