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Sound Absorption Analysis of Foamed Rubber Composites from Kenaf and Calcium Carbonate

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Sound absorption is any means of reducing the sound pressure by converting it's energy into heat within a material. The types of sound absorbing materials determine the frequency distribution of noise to be absorbed. Rubber composites as sound insulators were prepared by incorporation of two types of fillers, namely kenaf and calcium carbonate in blends of 50 mole % epoxidised natural rubber (ENR 50) and methyl methacrylate (MMA)-grafted natural rubber latex. A two-microphone impedance tube was used to investigate the sound absorption coefficient value of the composites prepared. Rubber composites exhibited excellent sound absorption properties with sound absorption coefficient values up to 0.87. The presence of kenaf in the composite was found to create void sections during the drying process, hence increasing the absorption coefficient value of the composite. The presence of calcium carbonate that was scattered on the walls of voids had increased stiffness of the composite, providing better absorption of sound waves.

Keywords: sound insulation; absorption coefficient; NR latex

A sound and vibration absorbing material is necessary to reduce or control reverberation and improve the listening environment for speech and music. It plays an important role in architectural acoustics, the design of recording studios and automobile interiors. Noise or unwanted sound can be dissipated by transforming the energy into low grade heat[1]. There are a few factors to consider during structuring a damping to reduce impact generated and steady noise at source such as hardness, density, foam type *etc*.

Noise barriers or sound deadening materials execute two functions. They allow all incoming sounds to pass the coating by minimising reflection at its surface and then absorb this acoustic energy before it can be reflected at the boundary between the coating and original surface. Currently, porous materials are widely used for noise control. Open cells in porous materials enable it to convert sound wave motions into viscous flow of air and then dissipate the energy. It is believed that the impedance characteristic between air and the damping material is higher for a porous material[2].

The level of a continuously generated noise in a room will rise by reverberation until the

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output of energy balances the lost energy by absorption. The efficiency of a material to absorb sound waves can be given in terms of the sound absorption coefficient, α_{ab}. Sound absorption coefficient is a ratio of the sound energy absorbed by a surface to the sound energy incident upon that surface or otherwise not reflected by the surface.

Certain types of material used in cars may reduce about 50% of cabin noise[3]. Numerous studies have shown that polymer[4], foam, fabric[2,5] and composite[6] materials can be excellent sound insulators in acoustic engineering. Using polymers for sound and vibration damping resembles a close relationship to the glass transition, T_g of the polymers when showing high damping characteristics nearer their T_g[7]. Rubber possesses properties that can confer good insulation against noise and high frequency vibration[8].

Carbon black and silica are the most commonly used fillers for reinforcement of rubber[9]. Reinforcement of rubber using naturally occurring fillers such as plant fibre has attracted considerable attention and much research in this area[10–12]. Among the advantages reported for natural fibre filled rubber were design flexibility, high modulus low strain, stiffness and damping. In addition, natural fibres are environmentally beneficial due to their natural occurrence and renewable nature.

In the present work, sound insulators were mainly prepared using materials based on natural rubber and plant material, which are sustainable and environmentally friendly in order to improve the reduction of noise and enhance the damping properties of automotive panels. The noise absorbent capacity of the materials, the absorption co-efficient and the acoustic impedance were determined[13].

EXPERIMENTAL

Materials

ENR50 with 51.8% dry rubber content (DRC) was prepared at Malaysian Rubber Board (MRB) and Gapoly PM30 with 48% DRC was purchased from Getahindus (M) Sdn. Bhd. Fillers used were ground kenaf of size ± 0.5 mm (bark and core) and calcium carbonate within the size of 200 mesh courtesy of Jabatan Tanah dan Galian Perak. Additives added in the compound were sulphur, N-Cyclohexyl-2-benzothiazole sulphonamide (CBS) and zinc oxide.

Methods

Preparation of Compounds. 50 g of each ENR 50 and Gapoly PM30 were poured into a beaker and stirred for ten minutes. Sulphur, CBS and zinc oxide dispersions were then added into the latex solution and the mixture was stirred for a further ten minutes. Filler was added into the mixture under continuous stirring until the mixture became homogenous. The homogenous mixture was then stored at room temperature for three days to allow its viscosity to stabilise. The mixture was then poured into a tray before the drying process.

Drying process. The mixture was dried in an oven at 120ºC for 4 h or until completely dry to form a composite. For testing purposes, the composite was cut into a disc of 29 mm diameter and 7 mm thickness and then bonded onto a 1.8 mm thick metal plate.

Acoustic Testing. A two-microphone Impedance Tube Type 4206 as illustrated in *Figure 1* was used to measure the absorption coefficient in the frequency range of 50 Hz to 6.4 kHz. A sample of material to be tested was placed in a sample holder and mounted to one end of a straight tube. The tube was then closed tightly and acoustic absorption coefficients determined.

Sound insulators were made with varying filler content as tabulated in *Table 1* and the sound absorption coefficient versus frequency for these materials were determined.

RESULTS AND DISCUSSION

The normal audible spectrum for the human ear is in the range of 20 to 20 000 Hz with a speed of about 330 ms^{-1}. The absorption efficiency of a material can be measured in terms of the sound absorption coefficient, which is the ratio of sound energy absorbed by the surface to the sound energy incident upon the surface. *Table 2* lists the density and hardness of composites prepared and their sound absorption coefficient values at a frequency range of 2000 to 4000 Hz, which is most commonly used in the acoustic engineering testing of materials for passenger cars.

Effect of Kenaf Loading

Increasing of kenaf content was found to decrease the density and hardness of the composites. This is due to absorption of water in the mixture by kenaf during compounding, and subsequent evaporation during the drying process. The evaporation of water left void sections in the material, making the material more porous.

Figure 2 shows that sample SD 3 containing 30 p.h.r. of kenaf fibre has a higher absorption coefficient value compared to those containing 25 p.h.r. (SD 2) and 20 p.h.r. (SD 1) of kenaf fibre. The absorption coefficient of sample SD 3 increased linearly from 0.03 at 150 Hz to 0.58 at 2200 Hz, while SD 1 and SD 2 increased slightly with increasing frequency. Results indicate that the absorption coefficient value increased with increasing kenaf fibre content. Increase of kenaf loading has increased air cavities in the material, hence increasing the efficiency of sound absorption[14].

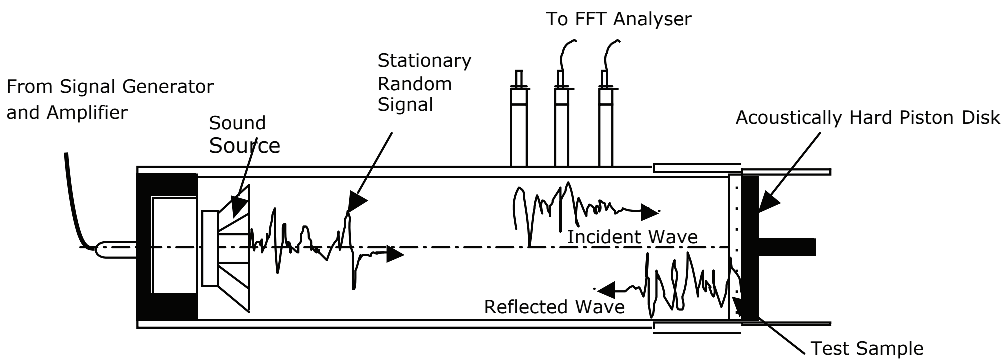

Figure 1. Schematic diagram of the impedance tube for the two-microphone transfer function method

TABLE 1. FORMULATIONS WITH DIFFERENT AMOUNTS OF KENAF AND CALCIUM CARBONATE.

Samples	Parts in compound (p.h.r.)		
	Latices	Kenaf fibre	$CaCO_3$
SD 1	100	20	-
SD 2	100	25	-
SD 3	100	30	-
SD 4	100	20	80
SD 5	100	30	80
SD 6	100	40	80
SD 7	100	50	80
SD 8	100	30	40
SD 9	100	30	60
SD 10	100	30	100

TABLE 2. DENSITY, HARDNESS AND SOUND ABSORPTION COEFFICIENT VALUES OF COMPOSITES

Samples	Density (kg/m^3)	Hardness (IRHD)	Sound absorption coefficient (2000- 4000 Hz)
SD 1	32.5	39.5	0.13-0.22
SD 2	25.5	35.4	0.17-0.26
SD 3	22.6	31.2	0.58-0.50
SD 4	43.3	46.1	0.20-0.52
SD 5	40.4	45.4	0.67-0.77
SD 6	38.1	34.2	0.56-0.77
SD 7	35.8	29.9	0.48-0.25
SD 8	28.7	37.3	0.64-0.53
SD 9	31.9	41.7	0.66-0.47
SD 10	42.2	49.8	0.78-0.53

Effect of Kenaf Loading with 80 p.h.r. Calcium Carbonate

Samples SD 4, SD 5, SD 6 and SD 7 contain 20, 30, 40 and 50 p.h.r. of kenaf fibre respectively plus 80 p.h.r. calcium carbonate. The density and hardness of materials were found to decrease with increasing kenaf loading. The porosity of composites were determined by the amount of kenaf as it becomes more porous with increasing kenaf loading (*Figure 3*).

Figure 4 shows the absorption coefficient values of samples SD 4 to SD 7. Among the samples, SD 4 had the highest density and hardness, with its ability to dampen sound waves increasing linearly from 0.07 at 1000 Hz to a maximum value of 0.63 at 5300 Hz. However, with increasing kenaf content and

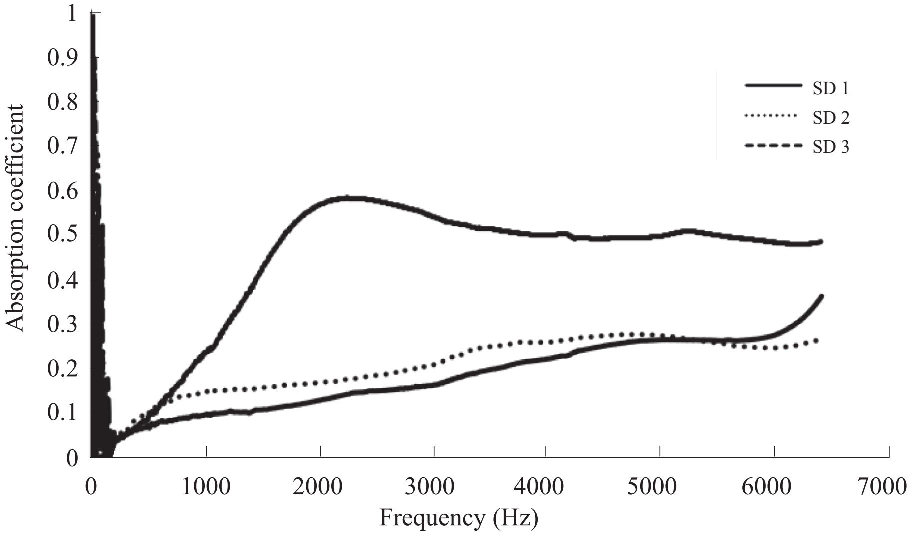

Figure 2. Curves of absorption coefficient values versus frequency of sound deadener with different kenaf fibre contents.

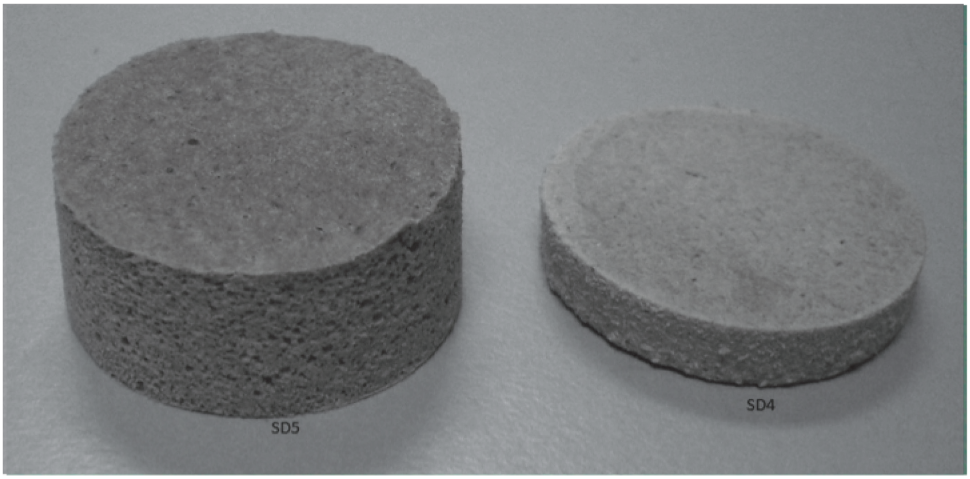

Figure 3. Showing composites SD 4 and SD 5.

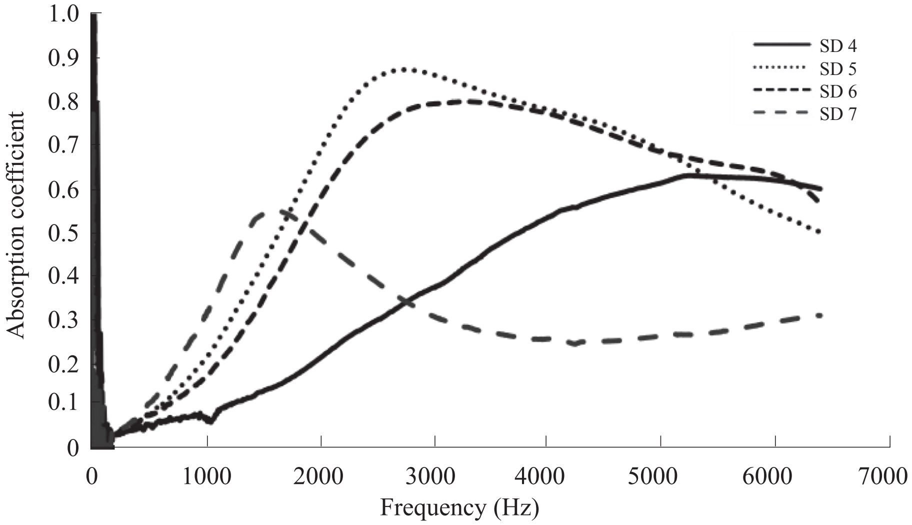

Figure 4. Curves of absorption coefficient values versus frequency of sound damping with different kenaf content and 80 p.h.r. calcium carbonate.

subsequent decrease in density and hardness, absorption coefficient values reached their maximum at a lower frequency. For samples SD 5 and SD 6, absorption coefficient values reached a maximum of 0.87 at 2700 Hz and 0.79 at 3100 Hz respectively before reducing slightly with increase of frequency. However, SD 7 showed lower absorption characteristics and reached its maximum absorption coefficient value of only 0.56 at 1600 Hz before decreasing with increase of frequency.

The damping properties are closely related to cell size, density and rigidity of material[15]. The presence of calcium carbonate as filler increases the stiffness of composites and subsequently increases sound damping by scattering or reflecting the sound waves in air cavities of the material. With increase of kenaf content, air cavities within the material increased, providing better sound absorption. However, SD 7 which contained 50 p.h.r. of kenaf fibre became too porous and its decrease in density affected its efficiency of sound absorption[14–15].

Effect of Calcium Carbonate Loading at 30 p.h.r. Kenaf

Samples SD 3, SD 8, SD 9, SD 5 and SD 10 contained 0, 40, 60, 80 and 100 p.h.r. of calcium carbonate respectively in the presence of 30 p.h.r. kenaf. The density and hardness of the composites prepared were found to increase with increasing calcium carbonate content. Absorption characteristics of each sample are shown in *Figure 5*. Absorption coefficient values of the samples were found to reach their maximum at a lower frequency when calcium carbonate content was increased. Sample SD 5 gave the highest maximum value of absorption coefficient of 0.87 at 2800 Hz, but decreased with further increase of frequency. This is due to increasing cell wall stiffness and overall hardness of materials in the presence of calcium carbonate, which provided better energy dissipation by scattering or reflecting the sound waves. In addition, calcium carbonate may act as a wall for blocking the movement of sound waves. A similar observation has been reported for

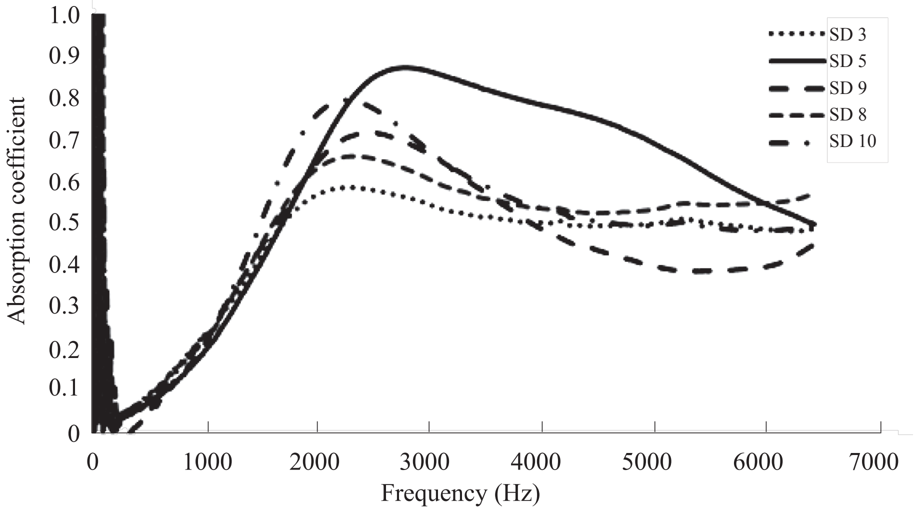

Figure 5. Curves of absorption coefficient values versus frequency of sound damping with different calcium carbonate contents at 30 p.h.r. kenaf.

polyurethane/nano silica foam[14]. *Figure 6* shows the cross sectional micrographs of SD 3, SD 5 and SD 10. The micrographs show that kenaf fibre and calcium carbonate were stuck and distributed around the cell wall of the composite.

Increasing calcium carbonate from 80 p.h.r. (SD 5) to 100 p.h.r. (SD 10) showed reduction in absorption coefficient values over a wide frequency range and reached a maximum absorption coefficient of 0.78 at 2000 Hz before gradually decreasing and stabilised to 0.49 after 5000 Hz. This may be due to a high degree of hardness at a very high filler level which then increased the reflex effect of sound waves. The presence of high loading of calcium carbonate may also block the opening between voids in the composite as shown in the micrograph of SD 10. The reduction of cell opening would reduce the absorption efficiency when it exhibits the characteristics of a closed cell material.

Effect of Samples Thickness

Formulation for sample SD 5 was used to study the effect of thickness of composites on sound damping. *Figure 7* shows that increasing the sample thickness increased the ability to absorb sound at lower frequencies and the maximum values of absorption coefficient were also reached at lower frequencies. However, the absorption coefficient values of the thicker samples tended to be significantly lower at higher frequencies. Thinner samples reached maximum values of absorption coefficient at higher frequencies and are much more stable at these frequencies compared to thicker samples.

CONCLUSION

Rubber composites with relatively high sound absorption coefficients have been successfully prepared from a mixture of

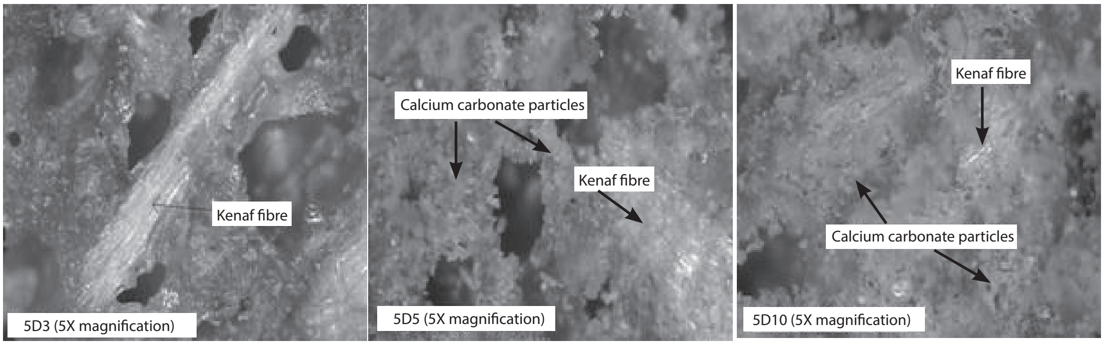

Figure 6. Micrographs of SD 3, SD 5 and SD 10.

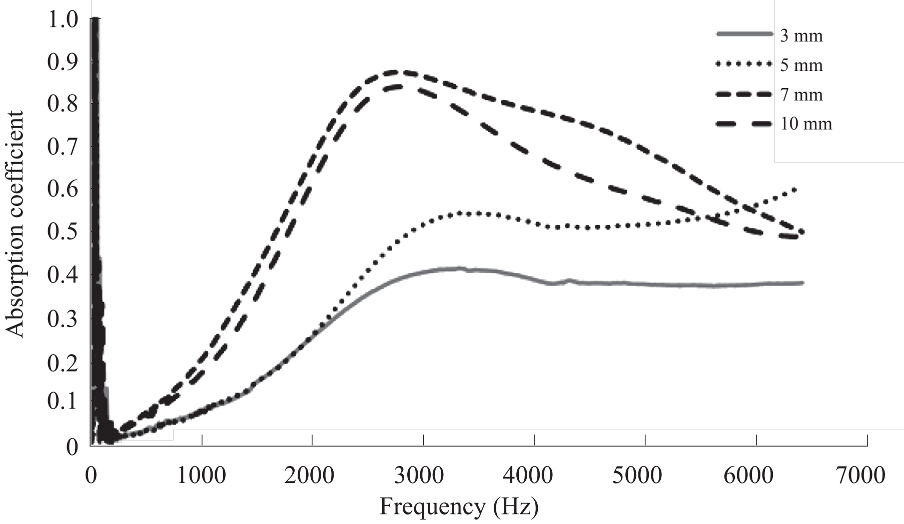

Figure 7. Absorption coefficient values for samples with different thicknesses.

ENR 50 latex and MMA-grafted natural rubber latex, ground kenaf and calcium carbonate. The effectiveness of the rubber composites to behave as sound insulators closely relates to the amount of kenaf and calcium carbonate filled. Kenaf content was found to determine the porosity of the composite, while calcium carbonate had an effect on the stiffness of the material. Increasing air cavities and stiffness of rubber composites raised the sound absorption property to a certain limit.

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REFERENCES

1. COX, T.J. AND D'ANTONIO, P. (2009) Acoustic Absorbers and Diffusers: Theory, Design and Application, 2nd Edition. Oxon: Taylor and Francis.

2. SGARD, F.C., OLNY, X., ATALLA, F. AND CASTEL, F. (2005) On the Use of Perforations to Improve the Sound Absorption of Porous Materials. *Appl. Acoustic*, **66**, 625–651.

3. BONILHA, M.W. AND FAHY, F.J. (1994) Measurements of Vibration Field Correlation on a Car Body Shell. *Appl. Acoustic*, **43**, 1–18.

4. KARI, L., LINDGREN, K., FENG, L. AND NILSSON, A. (2002) Constrained Polymer Layers to Reduce Noise: Reality of Fiction?- An Experimental Inquiry into their Effectiveness. *Polym. Testing*, **21**, 949–958.

5. DAUCHEZ, N., SAHRAOUI, S. AND ATALLA, N. (2003) Investigation and Modelling of Damping in a Plate with a Bonded Porous Layer. *Journal of Sound and Vibration*, **265**, 437–449.

6. FARSHAD, M. AND LE ROUX, M. (2004) A New Active Noise Abatement Barrier System. *Polym. Testing*, **23**, 855–860.

7. SPERLING, L.H. (1990) Sound and Vibration Damping with Polymers. ACS Symposium Series, Washington DC.

8. AHMADI, H.R., FULLER, K.N.G. AND MUHR, A.H. (1995) Noise Reduction Using Rubber. *Proceeding of Workshop on Rubber-in-Engineering Application in the Transport Industry (Non-Tyre Sectors)*, Kuala Lumpur, Malaysia, 17-18 July.

9. WAGNER, M.P. (1987) Nonblack Fillers. Rubber Technology (*Ed. Morton*, M.). New York: Van Nostrand Reinhold. 60–104.

10. HANAFI ISMAIL, EDYHAM, M.R. AND WIRJOSENTONO, B. (2002) Bamboo Fibre Filled Natural Rubber Composites: The Effect of Filler Loading and Bonding Agent. *Polym. Testing*, **21**, 139–144.

11. ROZMAN, H.D., TAY, G.S., KUMAR, R.N., ABUSAMAH, ISMAIL, H. AND MOHD ISHAK, Z.A. (2001) Polypropelene-Oil Palm Empty Fruit Bunch-Glass Fibre Hybrid Composites: A Preliminary Study on the Flexural and Tensile Properties. *Polym. Testing*, **23**, 559–565.

12. IBRAHIM, N.A., YUNUS, W.M.Z., ABU-ILAIWI, F.A., RAHMAN, M.Z.A., AHMAD, M. AND DAHLAN, K.M.Z. (2002) Graft Copolymerisation of Methyl Methacrylate onto Oil Palm Empty Fruit Bunch Fibre Using H_2O_2/Fe^{2+} as an Initiator. *J. Appl. Polym. Sci*., **89**, 2233–2238.

13. SMITH, C.D. AND PARROT, T.L. (1983) Comparison of Three Methods for Measuring Acoustic Properties of Bulk Materials. *J. Acoustic Soc. Am*., **74**, 1577–1582.

14. LEE, J., KIM, G.H. AND HA, C.S. (2012) Sound Absorption Properties of Polyurethane/nano-silica Nanocomposite Foams. *J. Appl. Polym. Sci*., **123(4)**, 2384–2390.

15. SUNG, C.H., LEE, K.S., LEE, K.S., OH, S.M., KIM, J.H., KIM, M.S. AND JEONG, H.M. (2007) Sound Damping of a Polyurethane Foam Nanocomposite. *Macromol. Res*., **15**, 443–448.