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Effect of Using Palm Wastes as Additive to Unsaturated Polyester on the Thermal and Acoustic Isolation Properties of a Composite Materials

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ABSTRACT

The thermal and acoustic isolation properties of unsaturated polyester composites reinforced by palm waste filler have been experimentally investigated. The composites have been prepared using hand lay-up technique with filler weight fraction of (0%, 3%, 5% and 7%). Three types of palm waste that (Date seed, old leaf bases and petiole) were ground and sieved separately to produce the filler with particle size ≤ 400μm. Thermal conductivity, thermal diffusivity, and specific heat capacity were examined using Hot Disk thermal analyses. The acoustic isolation property examined in a sound-insulated box. The experimental results show that the thermal conductivity and thermal diffusivity of the composite specimens reinforced by seed or old leaf bases filler increased with increasing the fillers weight fraction. While increasing the petiole filler decreased the thermal conductivity and thermal diffusivity by 19% and 40% respectively at 5% weight fraction as compared with a pure unsaturated polyester material. So, the composite reinforced with petiole filler has improved the thermal insulation properties. The composites samples reinforced with palm waste show higher sound absorption in compared to the pure unsaturated polyester material. The sound absorption properties of composite reinforced with 7% old leaf bases filler improved by 15% and 23% at low and high frequency respectively rather than of pure unsaturated polyester material.

1. Introduction

Now days, thermal and acoustic isolation is one of the most problems raised with the construction of building, car, airplane, etc. This is created the need to seek new composite materials that meet the required acoustical and thermal performance with a low impact on the human health environment [1]. A composite material is a combined of resins with reinforced materials in granular or fiber form. The results of these mixtures are a metal with intermediate properties depending on the combined action of the components [2]. Many researches used the synthetic additives with the polymers as a reinforced one to modify the properties of the polymer. Farag M. and Drai A. [3], experimentally demonstrate the effect of graphite filler contents on the mechanical and tribological behavior of (30% volume fraction) glass-polyester composite system. Drai A., Farag M. and Hussam L. [4], used a Taguchi approach to study the effect of synthetic filler type on tribological behavior of polymer composite under dry conditions.

In view of finding alternative reinforcements, that are environmentally friendly and can provide the same performances as synthetic counterparts, researchers' interest has focused on the use of natural fibers as reinforcement in different matrices, because of their low density, low cost, renewability, and biodegradability, low energy consumption, nonabrasive nature, and good insulator of heat and sound. Major industries such as automotive, construction and packaging have shown enormous interest in the development of new bio-composite materials and are currently engaged in searching for new and alternative products to synthetic fiber reinforced composites. Unsaturated polyesters are extremely versatile in properties and applications [5,6].

Ramesh C., Antaryami M., and Bibhuti B. [6], investigate the thermal conductivity of the palm fiber reinforced polyester composites at different volume fractions. The palm fiber reinforced polyester composites have been prepared by using hand- lay-up technique. The experimental results show that the thermal conductivity of the composite increases with increase in fiber percentage. Budrun N., and etal. [7], collected the palm fiber from ten different trees of different age group. Three sets of samples were prepared for three different weight fractions (wt%) of (5%, 10% and 20%) of fiber contents. The mechanical and physical properties were measured.

Ammar [8], demonstrate the effect of using date palm fibers and rice husks as a reinforced on the thermal and acoustic properties of a composite. At (30%) volume fraction with different ratios of rice husk/ date palm fibers. It was present that the insulation properties of thermal and acoustic increased with the volume fraction of date palm fiber and rice husks increased. But decreased with fiber length increased. The polyester composite reinforced by rice husk show a better thermal insulator. The composite reinforced with date palm fibers present best acoustic insulation.

Iraq has more than 16 million date palms. It produces approximately 630000 tons of date palm residues per year [9]. Date seed has (10-20) % of date weight, and each palm tree has other waste such as old leaf bases and petiole. Therefore, the palm waste must be used correctly in agriculture, industry and others applications. So, the main objective of this study is to investigate the thermal and acoustic isolation properties behavior of unsaturated polyester composite material reinforced with a filler of palm wastes (Date seed, Old leaf bases and Petiole).

2. Thermal and Acoustic Models

The thermal properties (thermal conductivity, thermal diffusivity, and specific heat capacity) are main properties required in the analysis the thermal property of materials. The most important characteristic of heat transfer properties is the thermal conductivity. If the thermal conductivities of the media are known, the temperature in composite materials be determined. There are many approaches (theoretical and experimental) used to determine this parameter. Maxwell [10] studied the effective thermal conductivity of materials. The models used to predict the thermal conductivity of two phase mixtures. The simplest alternative for two component composites, the materials arranged in either series or parallel with respect to heat flow to get the effective thermal conductivity of upper and lower bounds.

Acoustics, is a science, deals with sound creation and transmission through materials. The sound can be heard by humans, ranged in the audio frequency of approximately 20 Hz–20 kHz. The sources of noise found both outside and inside the buildings, in which generate higher noise levels. Such as systems for reproducing sound, traffic, domestic electrical, appliances, and etc. There are many mathematical models to describe the acoustic behavior of these soundproof layers based on elastic properties [11]. The absorbent materials acoustical behavior cannot be described from the same properties [12]. So, the properties to be considered are tortuosity, viscosity, and porosity based on the fibers distribution. For both airborne as well as impact noise, there are many models to predict the acoustic isolation.

3. Experimental work

3.1 Materials

The materials used in this work are the unsaturated polyester resin used as the matrix system, medium reactive based on Phthalic Anhydride in which commercial known by TOPAZ - 1110 TP. The mechanical and physical characteristics of the unsaturated polyester resin used in this work are presented in table 1. The hardener (Methyl Ethyl Kenton Peroxide (MEKP)), and the additive. The additives used was the palm wastes filler. Three samples of date palm waste that (Date seed, old leaf bases and petiole) were ground separately to produce the filler. The chosen samples were cleaned with water to remove the dust and impurities and then naturally dried during 3 days in order to reduce water content, then it was ground in a hammer mill to particles. The particulate was then sieved used sieve sizes of 400µm. The product is a filler with a particle size of ≤ 400µm.

Table 1: The unsaturated polyester resin properties [13].

Modulus of Elasticity (GPa)	Density gm/cm^3	Fracture toughness MPa-m$^{0.5}$	Tensile strength MPa	Elongation %	Thermal expansion Coeff. 10^{-6}/C°	Thermal conductivity w/m.K	Specific heat J/kg.k
2.06-4.41	1.2	0.6	41.4-89.7	<2.6	100-180	0.17	710-920

3.2 Specimens Preparation

All the specimens were manufactured using dry hand lay-up procedure. The unsaturated polyester and corresponding hardener were mixed in a ratio of 98:2 by weight as recommended. The filler material adds to matrix material with a weight fraction of (0%, 3%, 5% and 7%) and blended with it. A glass mold having dimensions of (230×230×10) mm was used for this purpose. Silicon spray was used to facilitate easy removal of the composite from the mold after curing. The whole assembly was then pressed in a (0.3 MPa) then released and allowed to cure for (24) hours at room temperature before it was removed from the mold. Then this cast was post cured in air for another 24 hours. The products are ten composite plates with (230x230x4) mm dimensions. The details of the composites plate are shown in table 2. Using CNC vertical milling machine, the (230x230x4) mm plate was machining to produce the required test specimens.

3.3 Thermal Analysis test

To estimate the effect of date palm waste on the thermal properties of the unsaturated polyester composite plate. Hot Disk thermal analyses were used. The Transient Plane Source technique was used to determine the (thermal conductivity, thermal diffusivity and specific heat). The Hot Disk includes heat source and temperature probe as a flat sensor with a continuous double spiral of electrically conducting Nickel metal with a resistance (11.56 Ω) to transform the thermal power which passes through the sample to measure thermal transport properties. During the test, the sensor was normally placed between the surfaces of the two pieces of the specimen to be measured [14] as shown in Fig. 1[15]. The Hot Disk TPS be used from (-45°C) up to (1000°C) [16]. The specimen with 5cm diameter shown in fig. 2, placed inside the device. The computerize gauge read the values of thermal diffusivity, thermal conductivity, and specific heat as shown in fig. 3.

3.4 Sound Absorption Test

To investigate the effect of using palm wastes as an additive to unsaturated polyester on the acoustic isolation properties of composite materials. The test specimens of (230x230x4) mm dimensions, shown in fig. 4, were examined in a sound-insulated box. The sound-insulated box shown in fig.5, designed to measure the materials sound absorption. The sound source mounted at one end of the box, in the form of broadband stationary random waves. The sound pressure meter fixed at the other end of the box. The generated audio travels to hit the specimen of the composite plate attached at the middle of the box. The sound pressure meter measures the sound pressure level. The frequency span of the experiment was 100Hz-10KHz with it took approximately 10 seconds for the instrument to achieve the absorption spectrum.

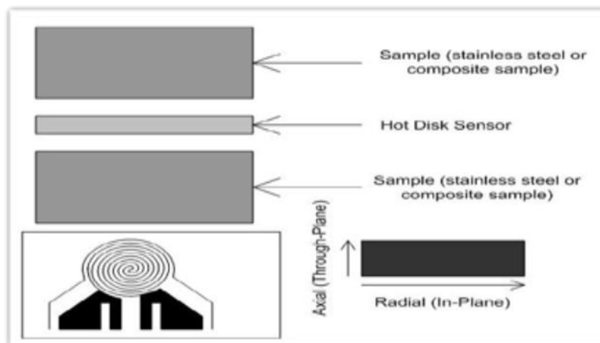

Fig. 1: The Schematic of Hot disk sensor.

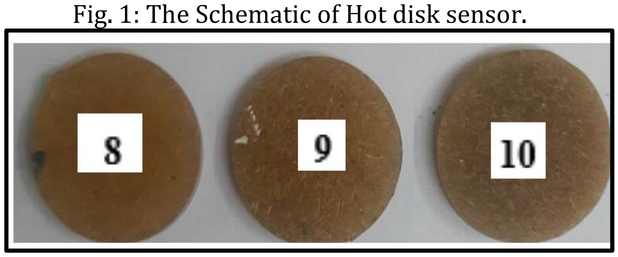

Fig. 2: Some specimen of thermal test.

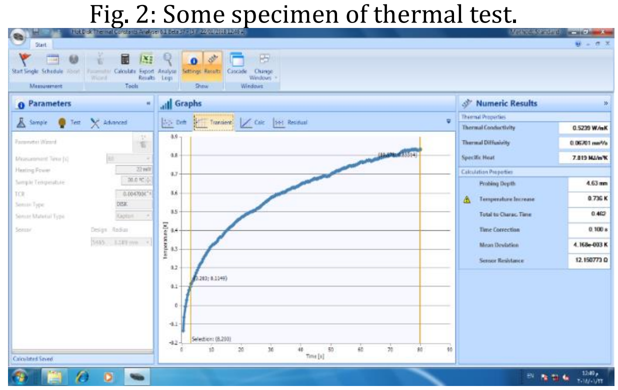

Fig. 3: The Hot Disk test results.

Table 2: Specification of the samples.

Palm wastes Wt. %

Sample	Polyester	Filler type	Wt. %
1	100	None	0
2	97	Date seed	3
3	95	Date seed	5
4	93	Date seed	7
5	97	Old leaf bases	3
6	95	Old leaf bases	5
7	93	Old leaf bases	7
8	97	Petiole	3
9	95	Petiole	5
10	93	Petiole	7

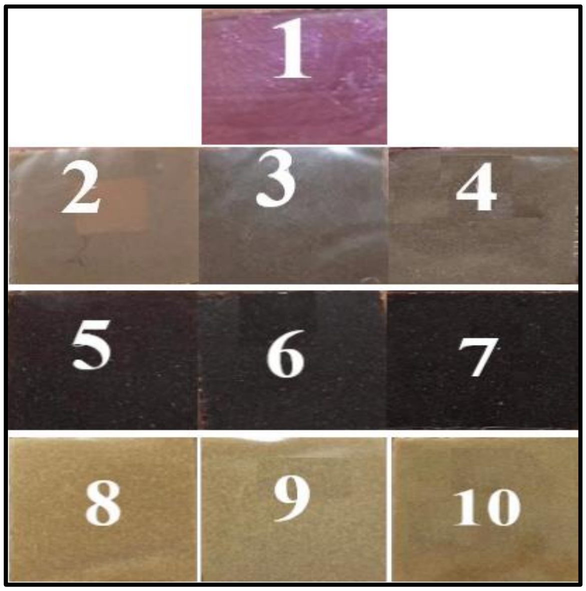

Fig. 4: The sound test specimens.

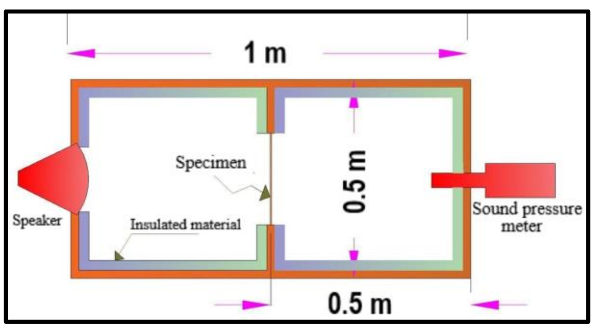

Fig. 5: The sound-insulated box.

4. Results and discussion

The experiments of this work done in the laboratories of material engineering department/ university of technology.

4.1 Thermal Test Results

The thermal properties (thermal conductivity, thermal diffusivity, and specific heat capacity) are properties gained from the hot disk test for composite samples, at room temperature. The test results for the investigation of the thermal isolation properties behavior of unsaturated polyester composite material reinforced with filler of palm wastes are shown in figs. 6,7 and 8. From figs. 6 and 7 be observed the thermal conductivity and thermal diffusivity of the composite specimens increased with increasing the date seed or old leaf bases fillers weight fraction. Because, the date seed and old leaf bases have higher thermal conductivity than unsaturated polyester matrix. When the weight fraction exceeds 3%, The composite specimen of using date seed filler present greater thermal conductivity and thermal diffusivity rather than of using old leaf bases. The higher values of thermal conductivity and thermal diffusivity reach to (0.6834 W/mok and 0.09361mm2/sec) respectively at 7% weight fraction of date seed filler.

While, with increasing the petiole filler weight fraction the thermal conductivity and thermal diffusivity of the composite specimen decreased. The thermal conductivity and thermal diffusivity reach the lower values of (0.4028 W/mºK and 0.03378 mm2/sec) respectively at 5% weight fraction, in which decreased by 19% and 40% respectively in compared with pure unsaturated polyester material. After that become increased but still have lower values than others. Therefore, the polyester composite reinforced with petiole filler has good thermal insulation properties rather than pure unsaturated polyester material. While the polyester composite reinforced with date seed or old leaf bases fillers present poor thermal insulation properties. Fig. 8, shows the relationship between the specific heat and the weight fraction of the palm waste filler. The specific heat magnitudes decreased with increasing the filler weight fraction of the date seed or old leaf bases. While the specific heat increased with increasing the filler of petiole. The higher values of specific heat found with composite specimens at 5% weight fraction. The specific heat present inverse behavior than the thermal conductivity and thermal diffusivity. This behavior is compatible with the relationship between the thermal properties that given by [17]:

$$D_{th} = (K / C_p.\rho) \quad .... (1)$$

Where; D_{th}: Thermal diffusivity, C_p: Specific heat at constant pressure, K: Thermal conductivity and ρ: Mass density.

4.2 Sound absorption test results

The acoustic absorption is the main critical parameters in the determination of the acoustic properties. Tables 3 and 4 present the experimental results for composite materials specimens of unsaturated polyester reinforced by a palm waste filler at weight fraction of (0%, 3%, 5% and 7%). It was observed that, in general for all the unsaturated polyester composite reinforced with a palm waste filler specimen having lower sound pressure levels than that of pure unsaturated polyester material specimen. It means that the composites samples show higher absorption in compared to the pure unsaturated polyester material.

Figs 8 and 9 show the variation of the sound pressure levels with variations of type and weight fraction of the palm waste at 100HZ and 6kHZ frequency respectively. It was present that the polyester composite reinforced with old leaf bases filler having higher absorption properties in compared with the other polyester composite reinforced with date seed and petiole filler. In which indicated that the old leaf bases filler has good acoustic insulation rather than others. The lower value of sound pressure level reach to (98.1 and 90) dB for 100 HZ and 6 kHZ respectively at 7% of old leaf bases weight fraction. The acoustic absorption properties of polyester composite reinforced with old leaf bases filler improved by 15% and 23% at low and high frequency respectively rather than that of pure unsaturated polyester material.

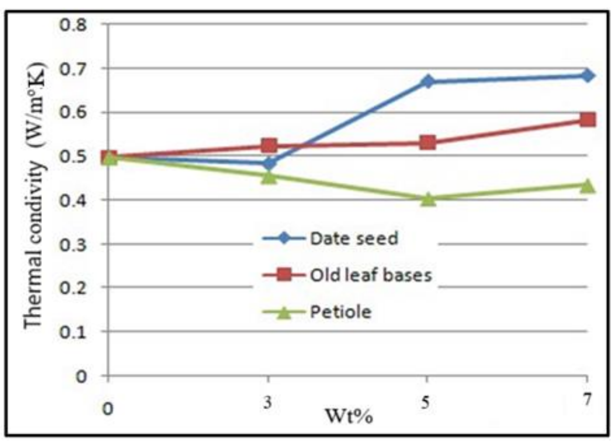

Fig. 6: The effect of filler (type and weight fraction) on the thermal conductivity.

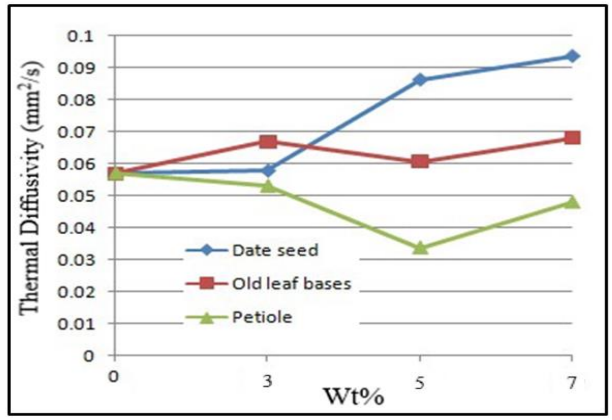

Fig. 7: The effect of filler (type and weight fraction) on the thermal diffusivity.

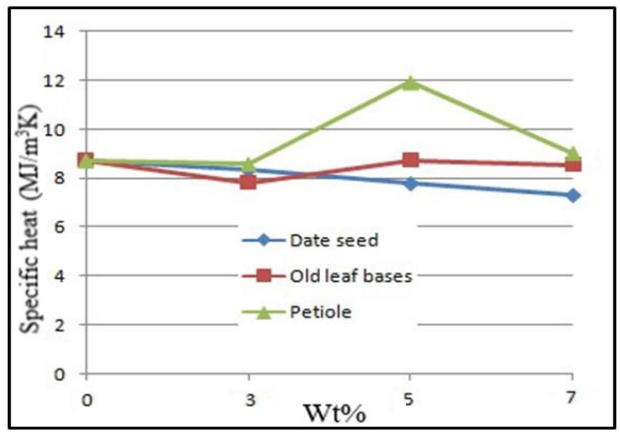

Fig. 8: The effect of filler (type and weight fraction) on the specific heat.

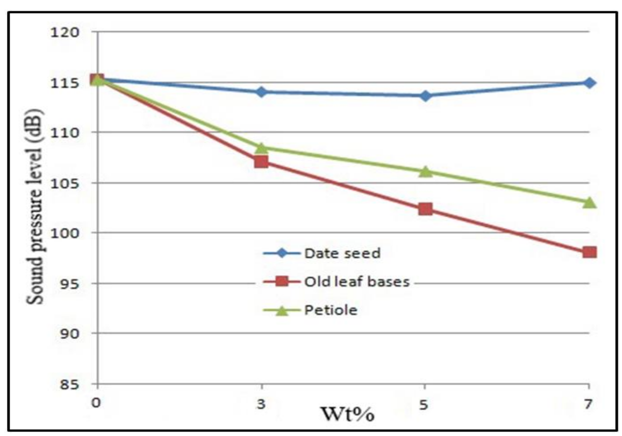

Fig. 9: Effect of filler content and type on the sound pressure level at 100 HZ frequency.

Table 3: Test results of sound pressure level at low frequency sound generated.

Frequency (HZ)	Sound pressure level (dB)									
	0%	Date seed			Old leaf bases			Old leaf bases		
		3%	5%	7%	3%	5%	7%	3%	5%	7%
100	115.3	114.1	113.7	115	107.1	102.4	98.1	108.5	106.1	103.1
200	115.4	114.1	113.8	115.1	107.2	102.4	98.1	108.6	106.3	103.2
300	115.6	114.2	113.9	114.9	107.2	102.5	98.2	108.7	106.4	103.4
400	115.7	114.3	114	115.3	107.3	102.6	98.2	108.8	106.5	103.5
500	115.7	114.3	114	115.3	107.4	102.6	98.3	108.8	106.5	103.5
600	115.8	114.4	114	115.4	107.5	102.7	98.4	108.9	106.6	103.5
700	115.9	114.6	114.1	115.6	107.6	102.7	98.5	109.1	106.7	103.6
800	116	114.7	114.1	115.2	107.6	102.8	98.6	109.2	106.7	103.7
900	116.1	114.8	114.2	115.7	107.7	102.8	98.6	109.3	106.8	103.9
1000	116.2	114.9	114.3	115.8	107.8	102.9	98.6	109.4	106.9	103.9

Table 4: Test results of sound pressure level at high frequency sound generated

Frequency (kHZ)	Sound pressure level (dB)									
	0%	Date seed			Old leaf bases			Old leaf bases		
		3%	5%	7%	3%	5%	7%	3%	5%	7%
1	116.2	114.9	114.3	115.8	107.8	102.9	98.6	109.4	106.9	103.9
2	116.5	115.1	114.5	116.1	108.1	102.9	98.7	109.5	107	104.1
3	116.6	115.2	114.5	116.3	108.2	103	98.8	109.5	107.1	104.2
4	116.8	115.3	114.6	116.4	108.2	103	98.8	109.6	107.2	104.3
5	117	115.4	114.7	116.3	108.3	103.1	98.9	109.7	107.3	104.3
6	117.1	115.5	114.7	116.4	108.3	103.2	90	109.8	107.4	104.3
7	117.2	115.5	114.8	116.5	108.3	103.2	90.1	110	107.5	104.4
8	117.3	115.7	114.9	116.6	108.4	103.4	90.2	110.1	107.6	104.6
9	117.3	115.9	114.9	116.7	108.5	103.4	90.3	110.2	107.7	104.6
10	117.4	116	115	116.8	108.6	103.4	90.4	110.3	107.8	104.7

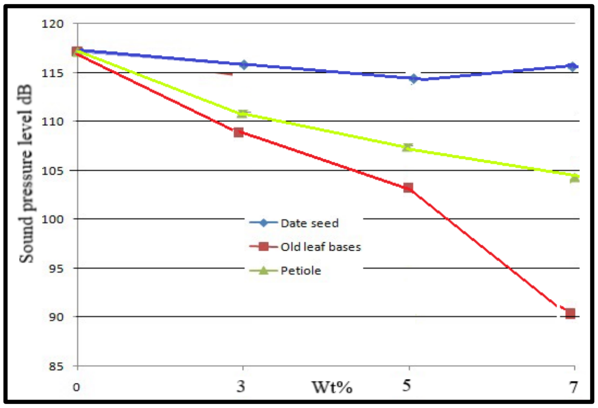

Fig. 10: Effect of filler content and type on the sound pressure level at 6 kHZ frequency.

5. Conclusions

The present work investigates the thermal and acoustic isolation properties of unsaturated polyester composites reinforced by palm waste filler experimentally. The following concluding remarks could be drawn:

1. The thermal conductivity and thermal diffusivity of the composite specimens reinforced by seed or old leaf bases filler increased with increasing the fillers weight fraction.
2. The thermal conductivity and thermal diffusivity of the composite specimens reinforced by petiole filler decreased with increasing the fillers weight fraction. In which improved by 19% and 40% respectively at 5% petiole filler weight fraction in compared with pure unsaturated polyester material.
3. The polyester composite reinforced with petiole filler has good thermal insulation properties rather than pure unsaturated polyester material. While the composite reinforced with date seed or old leaf bases fillers present poor thermal insulation properties.
4. The composites samples reinforced with palm waste show higher sound absorption in compared to the pure unsaturated polyester material.
5. The composite reinforced with old leaf bases filler having higher absorption properties in compared with the other composite reinforced with date seed and petiole filler.
6. The sound absorption properties of composite reinforced with 7% old leaf bases filler improved by 15% and 23% at low and high frequency respectively rather than of pure unsaturated polyester material.

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