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Analysis of temperature rise in a car parked under sunlight, its effects and possible solutions

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Abstract
Thermal comfort is one among the factors that affects the driving experience. Several infants/children death reported across the globe after left in the parked car and high temperature may create heat stroke. The aim of the project is to determine the temperature variation inside the car cabin under direct sunlight and to reduce it. When a vehicle is parked under the direct sunlight, the accumulated heat is affecting many interiors inside the vehicle cabin, such as plastic and fibres including piano black plastic, faux carbon fibre and hard black plastic of the dashboard, the leather covers and the electronic components.
Vehicle interior is a specific environment of smaller volume, with a large variety of materials placed inside, including hard and soft plastics, adhesives, paints, lubricants and many others. As a result, particularly in case of new vehicles, large amounts of volatile species, especially volatile organic compounds like Benzene are emitted. The normal benzene content is 50 ml/sqft which is not harmful to us. The temperature levels in the cabin of the vehicle can be more than 20 °C above the ambient temperature (almost 60 °C). In a closed car parked under sunlight, the benzene content varies from 2000 to 4000 ml/sqft (40 times greater). Many of these compounds are harmful for human health and toxic, this is the reason for increasing concern of vehicle manufacturers and users recently.
The project is mainly carried out in three steps. Partially insulating the heat entering through the metal body, providing a pop-up layer of insulation material to reduce the heat through the glasses, protect the dash-board from the exposure to higher temperatures using wooden skin. The air inside the cabin can also be conditioned. The temperature inside a parked car could be brought from 62 ºC to 32 ºC using Cross Linked Polyethylene Sheets (XLPE Sheets) during our experiment.
The contamination level varies with different vehicles and may be influenced by atmospheric conditions, external pollution, colour of the vehicle, quality of materials used and others. The main aim of our project is to present current knowledge status on the temperature rise and the measurement, analysis, also the indication of main air pollutants and their concentrations.

Keywords: Car cabin, temperature measurement, thermal gravimetric analysis, benzene, high

1. Introduction

A car (or automobile) is a wheeled motor vehicle used for transportation mainly people rather than goods. 20th century marked the use of cars in global level, and developed economies depend on them. The year 1886 is regarded as the birth year of the modern car when German inventor Karl Benz patented his Benz Patent-Motorwagen. Cars were available widley by the early 20th century. The first cars that were accessible to the people was the 1908 Model T, manufactured by the Ford Motor Company. Cars have got many utilities such as controls for driving, parking, passenger comfort and safety, and controlling a variety of lights. Additional features and controls have been added to vehicles, making them progressively more complex. Such as rear reversing cameras, air conditioning, navigation systems, and in car entertainment. Among these air condition and cabin comfort are the most predominant feature and utility that make a person to buy a car.

This is much clearer at the government offices, universities, and shopping areas. Moreover, the available shaded parking areas do not match the existing numbers of vehicles; hence the alternative choice for those who are unable to park under shaded area is to park in an open parking space. Parking under direct sunlight gave rise of greenhouse problem. Which is the conversion of solar radiation entering through the windows of a car into long wave thermal radiation and trapped inside car cabin causes rise in temperature of cabin components. Temperature inside the vehicle cabin is very important to provide comfortness to the car passenger. The temperature can be controlled by using air conditioning system that can be operated when the car engine is in operation. However, when the car is left or parked directly under the sunlight, temperature inside the cabin will be increased. Sealed automobiles increases interior temperature conditions that are tremendously uncomfortable to the passengers.

Here in this paper we are going to discuss about the temperature rise that occurs in a car parked under sunlight, harmful gases liberated from the cabin when exposed to higher temperatures, its effects and solution to solve this problem.

2. Automobiles in the present scenario

India is fourth largest country in the manufacturing and selling of automobiles including passenger cars. The following statistic represents motor vehicle sales in India between 2005 and 2017. In 2017, some four million motor vehicles were sold here, up from approximately 3.7 million units in 2016. The interesting fact is that India is the third largest car market in Asia-Pacific.

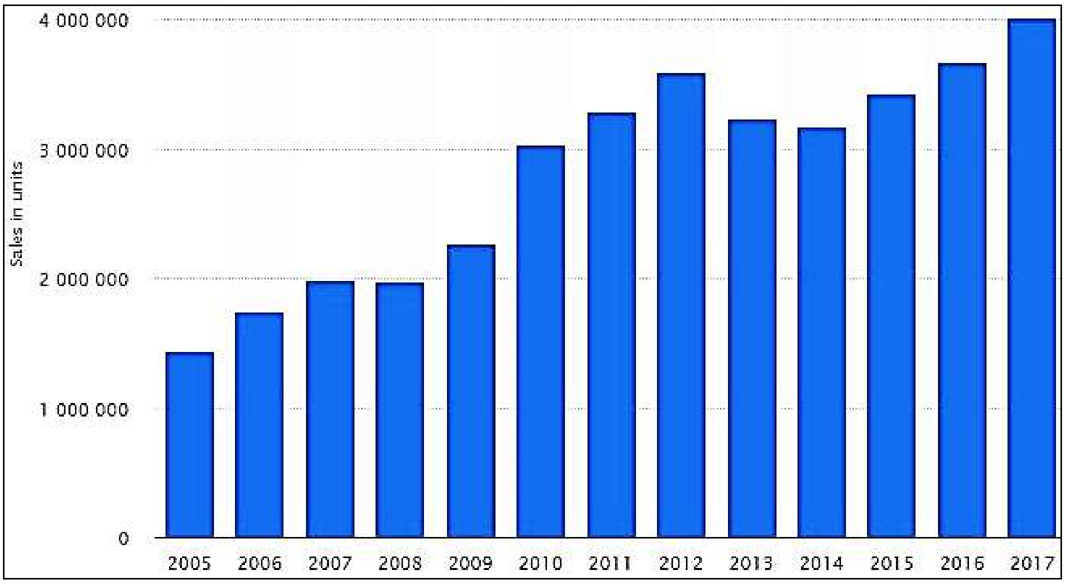

Fig 1: Car sales in India

All these statistics depicts the need and increasing trend of using automobiles in the world.

3. Car cabin or car compartment

"Passenger compartment" or "Car cabin" is the area of a vehicle designed and intended for the seating of the driver and passengers. In other aspects, it is the part of the vehicle that is designed to be as safe as possible when involved in a crash this reason, why seat belts and other restraints are implemented to prevent you from being ejected from the vehicle if you get into a crash.

For a luxury vehicle, for example; it's the main section of the vehicle, behind the bit where the drivers sit. It can be often soundproofed, may have tables so people can work, windows so you can see out and a large screen TV/DVD/screen for trying out presentations. It may well have a toilet at the back and many more features.

4. By what the interior of the car made up of?

1. **Piano black plastic:** When piano black plastic first came out, it looked great. It was shiny and opulent and found in BMW, Mercedes-Benz, and other luxury cars. Piano black plastic looks good at first, but it's a worse fingerprint magnet than a glossy touch screen and it scratches easily. That means over time it will look pretty crappy.
2. **Faux carbon fiber:** We see it all over the place. Faux carbon fiber runs rampant in affordable and semi-affordable cars. The fake stuff is usually just stylized plastic. All that it really does in most cases is making the vehicle look kind of silly.
3. **Hard black plastic (ABS):** Hard black plastic can be found in just about any car. Look at offerings from Ford, Nissan, Honda, Dodge, Fiat, and Toyota and you'll see a lot of it. While it doesn't feel especially nice, but at least it's easy to clean. Luxury automakers tend to stay away from this material as much as possible, opting instead for leather, brushed aluminum, chrome, or real wood.
4. **Fake wood trim:** Instead of using hard black plastic everywhere, some manufacturers have taken to using a fake wood on the dash, doors, and center console. Generally, this is better than plain black plastic, but it isn't as nice as leather and is usually obviously not real wood.
5. **Vinyl:** What do you do when you want leather, but can't afford it? You get leatherette, also known as vinyl. This material is common on many affordable cars, trucks, and SUVs. It's also found in many entry-level luxury vehicles. Vinyl is most commonly found on seats.
6. **Leather:** Leather is one of those materials that permeates all levels of the automotive industry. It feels good to the touch, breathes better than vinyl, and looks good. We can get leather seats on a large number of vehicles.

By analysing the above materials used inside a car compartment, it is clear that major part of it comprises of plastics and fibers. Now let us discuss-by what all components and chemicals these materials are made up of. It include the following materials.

- Polypropylene
- Polyethylene terephthalate
- Polyolefin
- Polylactic acid
- Polyphenylene sulfide
- Cellulose acetate
- Aromatic compounds and many more

5. Literature review

1) Thermal accumulation in a general car cabin model

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Automobile A/C systems are not much efficient even for use in conjunction with internal combustion engines. This problem is more critical if they are to be used in electric vehicles because conventional systems consume a large amount of energy and therefore tremendously reduces the travelling distance per charge of an electric vehicle. Apart from the development of new generation air-conditioning system, one of the easier remedies is to reduce the heating effects of a cabin so that the requirement for air-conditioning can be reduced and thus its energy consumption by the system. This work aims to identify some of the key factors that may help in reducing the cooling load of an electrical vehicle. This work explores the solar radiation effect on a 5:1 reduced scale car cabin, whose dimensions were based on the actual dimension of a Formosa Martiz. In the process of radiative heating, the temperatures in the cabin were found increase at a much higher rate in the beginning. On the other hand, the installation of window film and sun screen effectively reduce the rise in cabin temperature. Thus, their installation will help saving the overall car energy and therefore extend an electric car travel distance per charge. The colour of the cabin external surfaces should be carefully chosen so that these surfaces can effectively reflect the radiative heat energy. Also, the cabin's roof should be insulated as much as possible to reduce the amount of heat conduction into the cabin area.

2) Car indoor air pollution-analysis of potential sources

Daniel Müller, Doris Klingelhöfer, Stefanie Uibel and David A Groneberg

Air quality plays a significant role in environmental medicine and many airborne factor adversely influence human health. This review summarizes most recent data on car indoor cabin air quality published by research groups. Air pollution is the emission of toxic substances into the atmosphere by natural sources. These sources can be further differentiated into either movable or stationary sources. Anthropogenic air pollution is often summarized as being mainly related to especially exhaust gases and tire abrasion. Whereas other sources including the burning of fuels, and larger factory an important. In account to the research conducted in the field of health only a few data is available on the specific exposure situation as external sources are present in the car cabin.

3) Study on the thermal accumulation and distribution inside a parked car cabin

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When a vehicle is parked under the direct sunlight, the heat accumulated affects many interiors inside the vehicle cabin, such as the vinyl materials of the dashboard, the leather covers and the electronic components. Also, it becomes uncomfortable for the passengers. In the present study, experimental and numerical analyses were conducted under the topic entitled as vehicle cabin comfort. The experimental results were obtained from measurements on a car parked under shade. Six different cases was explored consisting of full closed windows, four different windows opening settings and sun shade usage case. The temperature at 12 different locations inside the car was noted for many days and the mean values were used as initial and boundary conditions to run the 3-D computational simulation. The CFD simulation was done with the help of fluent software. Both experimental and CFD simulation results gave an idea that the most hot air was concentrated in the top part of the cabin and natural circulation take place with large scale cavity due to natural heat transfer from the dashboard and the rear windshield. The lowering of the front side windows by 20 mm caused reduction in the front air gap by 20%. The sunshade on the front had considerably reduced the heat accumulation inside the cabin, where the dashboard surface temperature dropped by 26% and the maximum air temperature was found to be 27% lower. The use of the sunshade and/or dropdown windows on both sides reduced the heat accumulation due to fresh air exchange with the exterior environment.

4) Detection of the vapour benzene composition formed inside the car cabin

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All the gases produced inside the car cabin are considered as health hazard and need to be reduced its emission inside the car cabin by using green materials or proposed a good ventilation system for all the cars during under sun parking because all the new cars manufacturing used the petrochemicals products in their dashboards, seats covers, steering, roof and most of other parts inside the cabin. These gases are measured using Gas chromatography - Mass spectroscopy.

6. Analysis of toxic gases from abs using GC-MS

5) Gas chromatographic-Mass spectrometric analysis of some potential toxicants amongst volatile compounds emitted during large scale thermal degradation of poly (Acrylonitrile- butadiene- styrene) plastic.

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This is one of the most important journal that lead to our topic. Here in this paper, the thermal gravimetric analysis accompanied by Gas chromatography and Mass spectrometry was done for ABS. Let us quote the details of the paper as it is.

The thermal degradation was conducted in a tubing device similar to that used by Peltonen. It consisted of a glass tube (1500x17 mm I.D.), fitted with a moving oven (100x18 mm). One end of the tube was connected to the purge gas and the other to a solvent trap collector. The collector consisted of two 50-ml series-connected containers half filled with dichloromethane through which the purge gases carrying the volatiles were allowed to bubble via molecular sieves. Very volatile molecules such as hydrogen cyanide and non-volatile or high-molecular-weight compounds which condensed before reaching the solvent trap or could not pass through the molecular sieves were not expected to be found amongst the collected volatiles. The characteristic temperature distribution inside and around the oven moving at various speeds and a temperature of 350 °C have been outlined. Similar distributions were assumed for the temperature used in these experiments. About 5 g of the ABS sample were evenly distributed over a length of about 70cm of the tube. The purge gas and solvent trap collector were connected and the oven was allowed to travel over the sample at 7.26 mm/min. The oven temperature controller was set at 470 °C and purge gas, synthetic air or nitrogen flow-rates of 1000 ml/min were used. Decomposition in air and nitrogen occurs by different mechanisms because, unlike inert nitrogen, the oxygen of air is capable of reacting with the polymer molecules and is known to penetrate polymer films. An air atmosphere represents the beginning of a fire, whereas a nitrogen atmosphere represents the stage of a fire when all the oxygen has been consumed. Selection of the degradation temperature was based on preliminary thermo gravimetric (TG) experiments, which showed that the sample used in this study was completely decomposed at about 470 °C. Although the oven temperature was set at 470 °C, decomposition of the sample cannot be said to have taken place at this temperature because of mass transport effects. The temperature approaches the oven temperature as one moves from the cold to the hot end of the tube. The sampling technique can therefore be said to resemble a TG experiment in which the sample is heated from room temperature (25 °C) to 470 °C at an unknown rate related to the oven speed. On completion of the degradation, the solvent trapped compounds were collected in one container and diluted to 50ml, ready for gas chromatographic-mass spectrometric (GC-MS) analysis.

The analysis of different gases formed inside the car cabin when parked under the sun is carried out using Gas chromatography-Mass spectrometry (GC-MS). Gas chromatography-mass spectrometry (GC-MS) is an analytical method which is a combination of the features of gas chromatography and mass spectrometry to identify different substances within a test sample. The main Application of GC-MS is drug detection, fire investigation, environmental analysis, explosives investigation, and identification of unknown samples, GC-MS can also be used in airport security to detect substances in luggage or on human beings. Elements which were thought to be unidentifiable can be traced with the help of GC-MS. Like liquid chromatography-mass spectrometry, it allows analysis and detection even of tiny amounts of a substance.

The GC-MS instrument used was a Finnigan-MAT 8200 B double-focusing mass spectrometer equipped with an INCOS data system and a Varian 3700 gas chromatograph. The injector temperature was kept at 250 °C and helium at a flow-rate of 2 ml/min was used as the carrier gas. The GC column was kept at 50 °C for 1 min, then heated to 240 °C at 5 °C/min and kept at 240 °C for 20 min. A 27m x 0.2 mm I.D. SP-2330 column with a 0.2- µm stationary phase thickness was used. The solution containing the ABS volatiles was introduced into the gas chromatograph by splitless injections involving 1.0-2.0 µl of a dichloromethane solution. The split valve was kept closed for 25 s. A direct GC-MS interface kept at 250 °C was used. Sample ionization was by electron impact (EI) at 70 eV with an emission current of 0.5 mA. Resolution was set at 1000 and the scan range was m/z 45-450 at a rate of 1 scan per second. Temperature-programmed retention indices were determined using samples injected together with n-alkane (C_7-C_{36}) standards.

The library facilities of the GC-MS data system was utilized as much as possible in the identification of the collected volatiles. The Finnigan-MAT soft software includes a copy of the NBS-NIH-EPA library. It consists of ca. 38 700 common chemical compounds which form the mass spectral database of the system. The entry for each compound includes a 70-eV mass spectrum with up to 50 peaks and the compound's name, molecular weight, formula and Chemical Abstracts Service (CAS) registry number. The algorithm used in this study performs a forward search in which an unknown is compared with a number of library entries for compounds that resemble a current data spectrum. It reports the best matches together with parameters that describe the quality of the match. First it performs a data reduction of the unknown spectrum to eliminate most of the low-intensity peaks by creating mass-weighted ions which identify the compound more unambiguously. To save time, a pre-search compares the sixteen most intense peaks of the unknown with the eight most intense weighted peaks of each library spectrum to find up to 50 library spectra that most resemble the unknown for use in the main search where PURITY and FIT matches are performed. PURITY measures the match between mass limits and locally normalized ion intensities. FIT measures the degree to which the

Library spectrum is included in the spectrum of the unknown. Apart from displaying the spectrum of the unknown together with the spectra of up to three entries that best match the unknown, the program also lists up to nine library com-pounds that best match the unknown. Some of the structures in this study had to be deduced manually using fragmentation patterns owing to a lack of reference spectra in the available library facilities. The elemental compositions of less obvious compounds were obtained from high-resolution (R = 3000) GC-MS experiments. Not all the detected compounds could be identified because some were produced in minor amounts that were insufficient to give elemental compositions. In addition, some of the peaks were ignored on account of being much smaller than the analysed peaks. Some of the compounds in this study were not fully identified because their spectra could not be differentiated from similar spectra belonging to other com-pounds or isomeric forms. Confirmation of isomeric forms is usually achieved by a combination of matching spectra and GC retention indices. Owing to a lack of reference compounds, the temperature-programmed retention indices were not of much help in identification. They proved useful, however, in matching com-pounds common to decomposition in air and nitrogen.

Figures show expanded and detailed GC-MS total ion current traces for volatile compounds emitted during degradation of the ABS sample in air and nitrogen, respectively. The compounds corresponding to the peak numbers shown on the diagrams are given in the following table 1, where the temperature programmed retention indices are also reported. A total of 53 compounds for decomposition of the sample in air and 87 for decomposition in nitrogen were analysed. Of these compounds, 48 were common to decomposition in both atmospheres. Decomposition of the sample in air and nitrogen gave a total of at least 92 different compounds. The term "at least" is used here because, as pointed out above, some peaks were ignored on account of being much smaller than the analysed peaks.

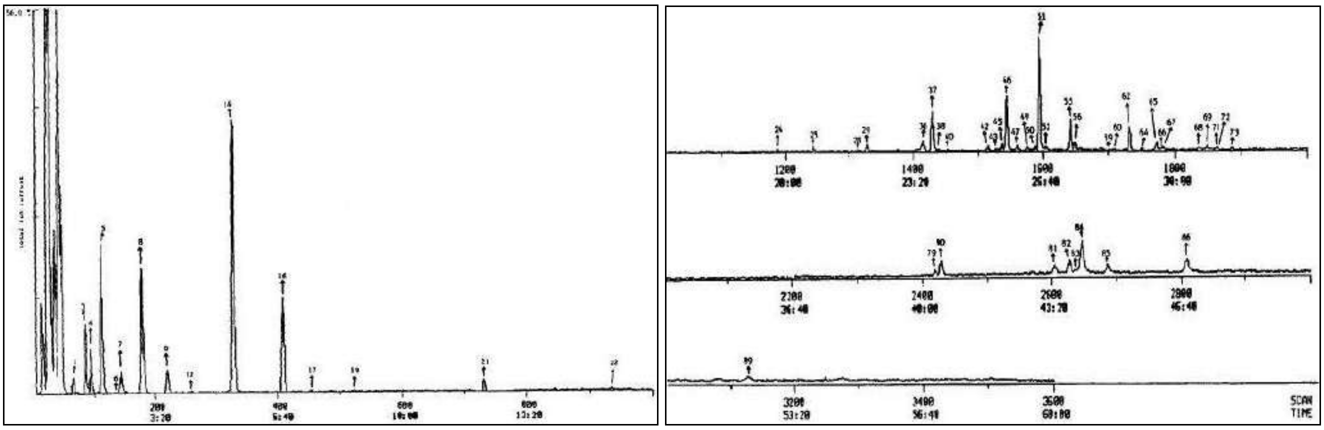


Fig 2: Expanded and detailed GC-MS totalion current trace of volatile compounds emitted during thermal degradation of ABS in air. Time in min

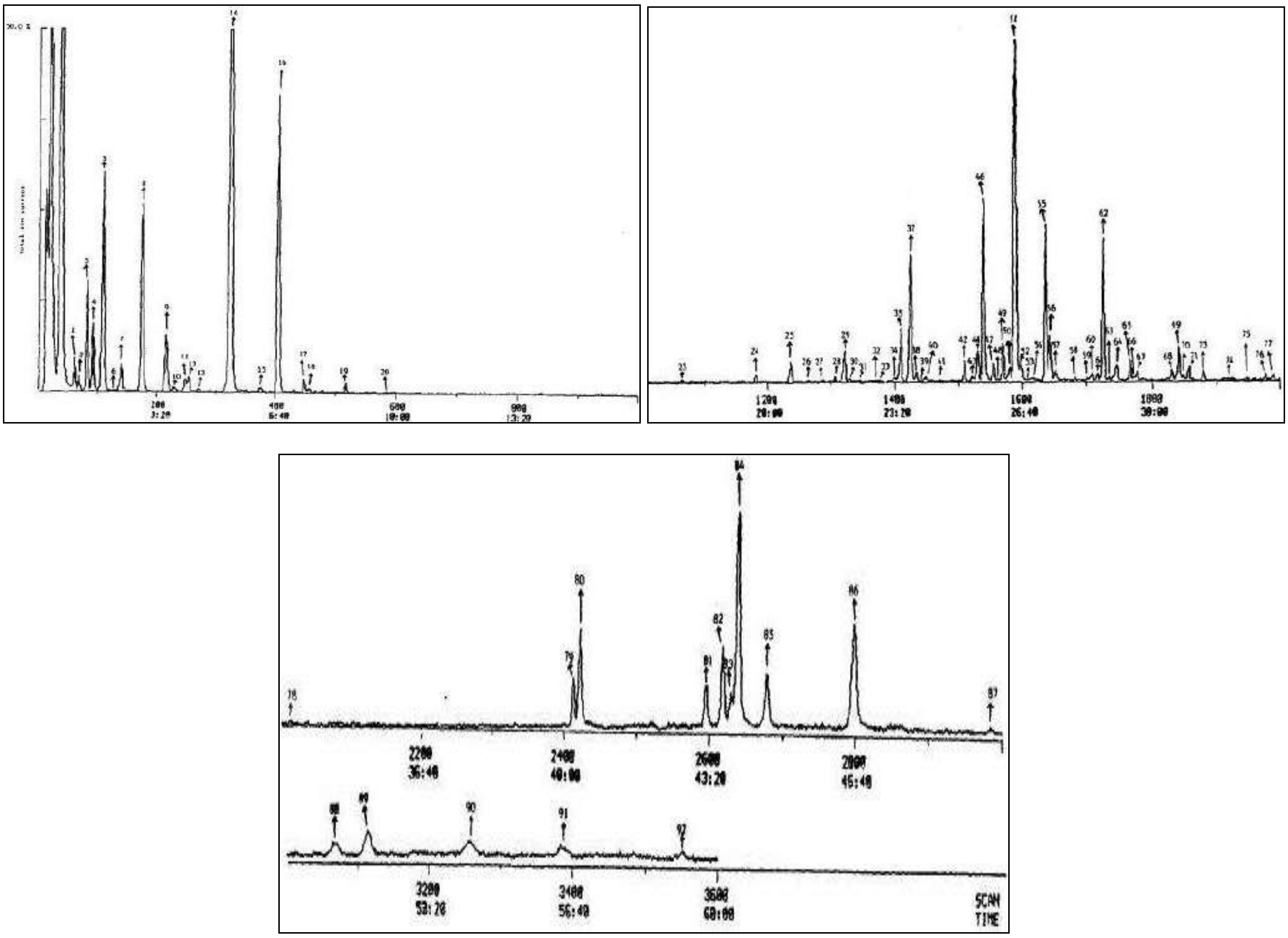


Fig 3: Expanded and detailed GC-MS total ion current trace of volatile compounds emitted during thermal degradation of ABS in nitrogen

Table 1

Peak No.	Compound	CAS registry No.	Chemical formula	MW	Relative percent in air	Relative percent in N_2	RI[a]	Number of toxicity references	Remark
1	Benzene	71-43-2	C_6H_6	78	0.8	0.5	–[b]	1927	
2	4-Ethenylcyclohexene	100-40-3	C_8H_{12}	108	Nil[c]	0.3	–	16	
3	Acrylonitrile	107-13-1	C_3H_3N	53	4.4	2.6	–	503	
4	Methylacrylonitrile or 3-butenenitrile	–	C_4H_5N	67	2.3	1.5	–	–	Isomer not known
5	Toluene	108-88-3	C_7H_8	92	11.3	6.1	–	1488	
6	2-Methylpropanenitrile	78-82-0	C_4H_7N	69	n[d]	n	1140.3	28	
7	Butanenitrile	109-74-0	C_4H_7N	69	1.7	0.8	1147.8	41	
8	Dimethylbenzene or ethylbenzene	–	C_8H_{10}	106	11.0	5.8	1200.0	–	Isomer not known
9	Isopropylbenzene	98-82-8	C_9H_{12}	120	1.8	2.0	1238.0	126	
10	–	–	–	106	Nil	0.1	1250.7	–	Unknown
11	–	–	C_8H_8	104	Nil	0.4	1264.6	–	Structure not known
12	Propylbenzene	103-65-1	C_9H_{12}	120	0.1	0.4	1273.8	99	
13	Ethylmethylbenzene or trimethylbenzene	–	C_9H_{12}	120	Nil	0.1	1288.9	–	Isomer not known
14	Styrene	100-42-5	C_8H_8	104	25.6	23.0	1333.5	698	
15	Butylbenzene	104-51-8	$C_{10}H_{14}$	134	Nil	0.1	1376.5	51	
16	α-Methylstyrene	98-83-9	C_9H_{10}	118	7.3	9.1	1400.0	100	
17	4-Phenyl-1-butene	768-56-9	$C_{10}H_{12}$	132	0.2	0.3	1435.1	2	
18	2-Phenyl-2-butene	–	$C_{10}H_{12}$	132	Nil	0.1	1441.8	–	*cis* or *trans* isomer
19	Propenylbenzene	–	C_9H_{10}	118	0.2	0.2	1490.4	–	Isomer not known
20	1-Phenyl-2-butene	–	$C_{10}H_{12}$	132	Nil	n	1543.7	Nil	*cis* or *trans* isomer
21	Benzaldehyde	100-52-7	C_7H_6O	106	0.7	Nil	1660.4	460	
22	Acetophenone	98-86-2	C_8H_8O	120	0.3	Nil	1835.9	195	
23	–	–	–	–	Nil	n	1907.7	–	Unknown
24	Phenylpropenenitrile or quinoline or isoquinoline	–	C_9H_7N	129	0.1	0.2	2081.3	–	Isomer not known
25	2-Phenylpropanenitrile	1823-91-2	C_9H_9N	131	0.4	0.4	2138.3	4	
26	1,1′-Biphenyl	92-52-4	$C_{12}H_{10}$	154	Nil	n	2167.7	444	
27	–	–	–	–	Nil	n	2193.8	–	Unknown
28	Diphenylmethane	101-81-5	$C_{13}H_{12}$	168	0.2	0.1	2211.5	28	
29	Benzeneacetonitrile	140-29-4	C_8H_7N	117	0.5	0.6	2227.4	62	
30	1,1-Diphenylethene	530-48-3	$C_{14}H_{12}$	180	Nil	0.1	2237.2	3	
31	4-Phenyl-2-butenenitrile	–	$C_{10}H_9N$	143	Nil	n	2253.2	Nil	*cis* or *trans* isomer
32	3-Phenyl-3-butenenitrile	14908-85-1	$C_{10}H_9N$	143	Nil	0.1	2281.4	Nil	
33	Methylnaphthalenecarbonitrile	–	$C_{12}H_9N$	167	Nil	n	2293.9	Nil	Isomer not known
34	Phenylpropenenitrile or quinoline or isoquinoline	–	C_9H_7N	129	Nil	n	2311.9	–	Isomer not known
35	6-Phenyl-5-hexenenitrile	–	$C_{12}H_{13}N$	171	Nil	1.1	2322.6	Nil	*cis* or *trans* isomer
36	2-(2-Phenylpropyl)propenenitrile	Undocumented	$C_{12}H_{13}N$	171	0.7	Nil	2327.0	Nil	
37	2-Phenylmethyl-3-butenenitrile	Undocumented	$C_{11}H_{11}N$	157	2.3	2.8	2341.6	Nil	
38	2-Phenyl-4-pentenenitrile	5558-87-2	$C_{11}H_{11}N$	157	0.1	0.2	2353.2	Nil	
39	2-Methyl-3-phenylpropanenitrile	33802-51-6	$C_{10}H_{11}N$	145	Nil	n	2370.3	Nil	
40	2-Phenylmethylpropenenitrile	28769-48-4	$C_{10}H_9N$	143	0.1	0.1	2383.3	1	
41	–	–	–	–	Nil	n	2419.6	–	Unknown
42	1,3-Diphenylbutane	1520-44-1	$C_{16}H_{18}$	210	0.3	0.4	2443.7	Nil	Conformation not known
43	3-Phenylpropanenitrile	645-59-0	C_9H_9N	131	0.1	0.1	2459.1	12	
44	2-Methyl-4-phenylbutanenitrile	Undocumented	$C_{11}H_{13}N$	159	Nil	0.5	2470.2	Nil	
45	5-Phenylpentanenitrile	7726-45-6	$C_{11}H_{13}N$	159	0.3	Nil	2470.2	1	
46	1,3-Diphenylpropane	1081-75-0	$C_{15}H_{16}$	196	2.9	3.9	2480.6	Nil	Conformation not known
47	4-Phenylpentanenitrile	Undocumented	$C_{11}H_{13}N$	159	0.2	0.4	2499.1	Nil	
48	–	–	–	–	Nil	n	2505.5	–	Unknown

Peak No.	Compound	CAS registry No.	Chemical formula	MW	Relative percent in air	Relative percent in N_2	RI[a]	Number of toxicity references	Remark
49	3,5-Diphenyl-1-pentene	61141-97-7	$C_{17}H_{18}$	222	0.2	0.6	2518.2	Nil	
50	Phenylpropenenitrile or quinoline or isoquinoline	–	C_9H_7N	129	0.1	0.3	2531.7	–	Isomer not known
51	4-Phenylbutanenitrile	2046-18-6	$C_{10}H_{11}N$	145	7.1	8.5	2542.2	Nil	
52	2-Methyl-4-phenyl-2,4-pentadienenitrile	Undocumented	$C_{12}H_{11}N$	169	0.2	0.4	2552.0	Nil	*cis* or *trans* isomer
53	3-Phenylbutanenitrile	20132-76-7	$C_{10}H_{11}N$	145	Nil	n	2569.3	Nil	
54	2-Phenyl-3-butenenitrile	Undocumented	$C_{10}H_9N$	143	Nil	0.1	2575.4	Nil	
55	2,4-Diphenyl-1-butene	16606-47-6	$C_{16}H_{16}$	208	1.6	2.8	2600.0	Nil	
56	5-Phenyl-5-hexenenitrile	Undocumented	$C_{12}H_{13}N$	171	Nil	1.0	2607.5	Nil	
57	1,4-Diphenylbutane	1083-56-3	$C_{16}H_{18}$	210	Nil	0.2	2618.6	2	Conformation not known
58	–	–	–	–	Nil	n	2657.5	–	Unknown
59		–	–	130	0.5	n	2681.3	–	Unknown
60	2-Ethyl-5-phenyl-3-pentenenitrile	Undocumented	$C_{13}H_{15}N$	185	n	0.1	2688.8	Nil	*cis* or *trans* isomer
61	–	–	–	–	Nil	0.1	2700.0	–	Unknown
62	3-Phenyl-4-pentenenitrile	Undocumented	$C_{11}H_{11}N$	157	1.3	2.9	2710.6	Nil	
63	1,2-Diphenyl-1,3-pentadiene	–	$C_{17}H_{16}$	220	Nil	n	2722.5	Nil	Diene *cis trans* isomer
64	1,5-Diphenylpentane	1718-50-9	$C_{17}H_{20}$	224	0.2	0.3	2736.0	Nil	Conformation not known
65	1,3-Diphenylpropene	–	$C_{15}H_{14}$	194	0.4	0.4	2760.9		*cis* or *trans* isomer
66	–	–	–	–	0.1	n	2768.5	–	Unknown
67	Naphthalenecarbonitrile	–	$C_{11}H_7N$	153	0.2	0.2	2773.9	–	Isomer not known
68	4-Phenyl-5-hexenenitrile	Undocumented	$C_{12}H_{13}N$	171	0.1	0.2	2845.2	Nil	
69	2,6-Diphenyl-2-hexene	Undocumented	$C_{18}H_{20}$	236	0.3	0.1	2861.0	Nil	*cis* or *trans* isomer
70	1,4-Diphenyl-2-butene	–	$C_{16}H_{36}$	208	Nil	0.1	2871.2	Nil	*cis* or *trans* isomer
71	1,2-Diphenylethene	–	$C_{14}H_{12}$	180	n	0.2	2881.1	–	*cis* or *trans* isomer
72	1,2-Diphenylethene	–	$C_{14}H_{12}$	180	0.2	Nil	2882.9	–	*cis* or *trans* isomer
73	Naphthalenecarbonitrile	–	$C_{11}H_7N$	153	0.2	0.2	2912.3	–	Isomer not known
74	5-Phenyl-2-ethenyl-4-pentenenitrile	Undocumented	$C_{13}H_{13}N$	183	Nil	n	2974.0	Nil	*cis* or *trans* isomer
75	2-Phenyl-5-hexenenitrile	Undocumented	$C_{12}H_{13}N$	171	Nil	n	3008.5	Nil	
76	2-Ethyl-5-phenyl-4-pentenenitrile	Undocumented	$C_{13}H_{15}N$	185	Nil	0.1	3048.2	Nil	*cis* or *trans* isomer
77	4-Phenyl-4-pentenenitrile	Undocumented	$C_{11}H_{11}N$	157	Nil	0.1	3066.7	Nil	
78	Methylnaphthalenecarbonitrile	–	$C_{12}H_9N$	167	Nil	0.1	3103.6	Nil	Isomer not known
79	2,4,6-triphenyl-1-hexene	18964-53-9	$C_{24}H_{24}$	312	n	0.6	–	Nil	
80	2-(2,4-Diphenylbutyl)propenenitrile	Undocumented	$C_{19}H_{19}N$	261	1.0	1.7	–	Nil	
81	2-(2-Phenylethyl)-4-phenylbutanenitrile	17486-90-7	$C_{18}H_{19}N$	249	0.7	0.8		Nil	
82	4,6-Diphenyl-6-heptenenitrile	Undocumented	$C_{19}H_{19}N$	261	1.0	1.4	–	Nil	
83	2-Phenylmethyl-5-phenylpentanenitrile	Undocumented	$C_{18}H_{19}N$	249	Nil	0.5	–	Nil	
84	2-(2-Phenylethyl)-4-phenyl-4-pentenenitrile	Undocumented	$C_{19}H_{19}N$	261	3.2	4.4	–	Nil	
85	2-(2-Phenylethyl)-4-methylenepentanedinitrile	Undocumented	$C_{14}H_{14}N_2$	210	0.8	1.2	–	Nil	
86	2-Methylene-4-phenylheptanedinitrile	Undocumented	$C_{14}H_{14}N_2$	210	1.6	0.5	–	Nil	
87	–	–	–	–	Nil	0.1	–	–	Unknown
88	2-(2-Phenylethyl)pentanedinitrile	89873-49-4	$C_{13}H_{14}N_2$	198	Nil	0.5	–	Nil	
89	2-(2-Phenyl-2-propenyl)pentanedinitrile	Undocumented	$C_{14}H_{14}N_2$	210	0.6	0.8	–	Nil	
90	4-Phenylheptanedinitrile	833-55-6	$C_{13}H_{14}N_2$	198	Nil	0.7	–	Nil	
91	–	–	–	–	Nil	0.2	–	–	Unknown
92	–	–	–	–	Nil	n	–	–	Unknown

[a] RI = Programmed mode retention index.
[b] – = No information.
[c] Nil = Not present.
[d] n = Less than 0.1% or negligible.

The above mentioned 92 toxic chemical fumes are produced when ABS is undergone thermal gravimetric analysis accompanied by gas chromatography- mass spectrometry. The number of toxic fumes increases as the temperature increase from the ambient condition to 470 ºC. Fortunately the maximum temperature we obtained when we have done our experiment on temperature variations inside a car cabin varies from 70 ºC to 80 ºC. Thus there won't be the presence of all these 92 toxic fumes inside the cabin. But there would be the presence of most of these fumes including benzene and its derivative constituents. This made us to work on this topic

7. Experimental methodology

As an initial step we have conducted an experiment to study the temperature rise inside a car cabin. The experiment was done on four cars. Two among them were white in colour (one is insulated using XLPE sheets and the other was non-insulated), one is of brown colour and the other was grey in colour. The cars used were Hyundai E-on, Nissan Terrano, Suzuki Celerio and Suzuki Swift.

Fig 4: Vehicles used for temperature measurement

Here in this experiment, the glasses of Hyundai E- on were insulated with XLPE sheets.

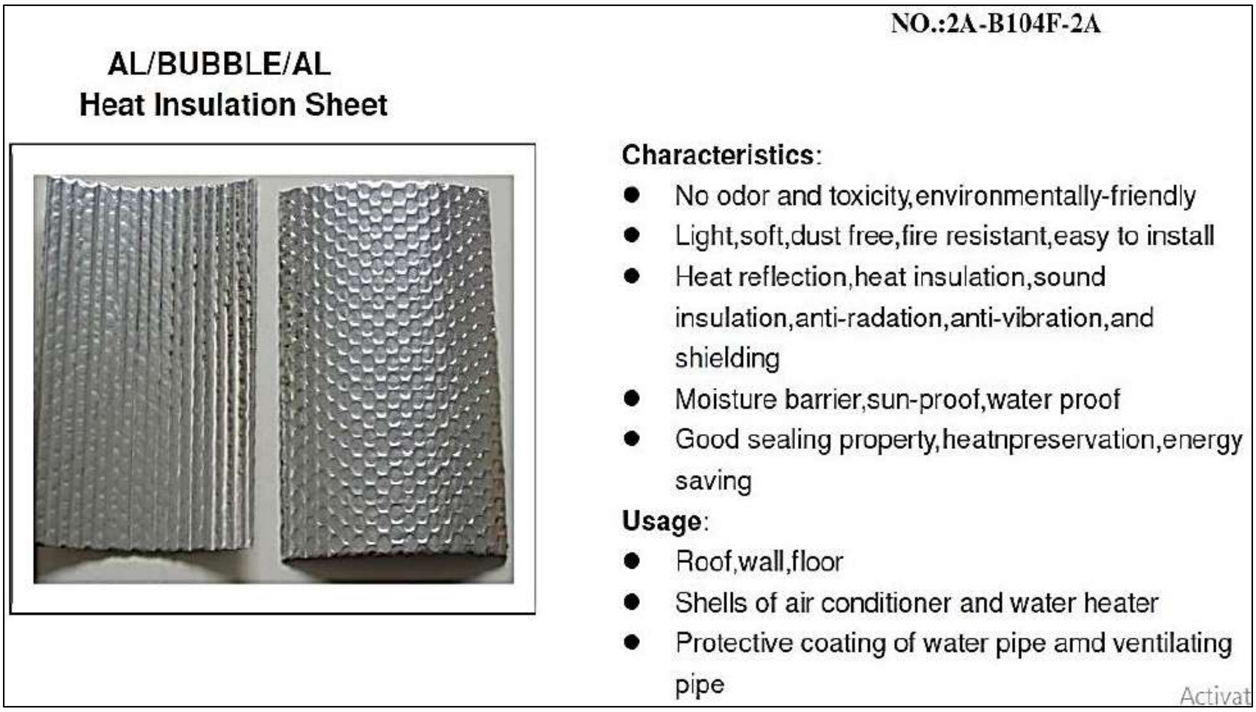
A. Insulation of car window glasses using XLPE sheets

The first step was to partially insulate the heat entering through the glasses, since the amount of heat entering in to a car cabin through the glasses is much greater than the heat entering through the metal body. A variety of materials can be used in the automotive body and chassis such as aluminium and stainless steel. The most important criteria that a material should meet are lightweight, economic effectiveness, safety, recyclability and life cycle considerations. This made us to do thermal insulation of window glasses (front glass, side glass, rear glass) are using Cross Linked Polyethylene Sheets (XLPE Sheets) of 4mm.

Fig 5: Vehicle insulated with XLPE sheets

It looks like a sandwich layer of two aluminium foils (sheets) and a polyethylene foam. Aluminium foils reflects the incident rays of light. Polyethylene sheets resists the heat coming through the light rays. XLPE sheets are closed cell polyethylene foam has been chemically cross linked. It has got smooth aesthetic feel with superior physical and chemical properties than standard polyethylene foam. This foam is available in a wide range of densities and is available in over 40 different colours. It is available in anti-static, conductive, and fire retardant formulations. It is used mainly in building services pipework systems, hydronic radiant heating and cooling systems, domestic water piping, and insulation for high tension (high voltage) electrical cables. It is also widely used for natural gas and offshore oil applications, chemical transportation, and transportation of sewage and slurries. PEX is a substitute to polyvinyl chloride (PVC), chlorinated polyvinyl chloride (CPVC) or copper tubing for use as residential water pipes. Abrasion resistance Low-temperature impact strength, and environmental stress cracking resistance can be increased significantly by crosslinking, whereas hardness and rigidity are somewhat reduced. Crosslinking enhances the temperature properties of the base polymer. Adequate strength to 120-150 °C is maintained and chemical stability enhanced by resisting dissolution. Low temperature properties are improved. Impact and tensile strength, scratch resistance, and resistance to brittle fracture are enhanced. Generally two types of XLPE sheets are used for the same.

1. Bubble type


NO.:2A-B104F-2A

AL/BUBBLE/AL
Heat Insulation Sheet

Characteristics:

- No odor and toxicity,environmentally-friendly
- Light,soft,dust free,fire resistant,easy to install
- Heat reflection,heat insulation,sound insulation,anti-radation,anti-vibration,and shielding
- Moisture barrier,sun-proof,water proof
- Good sealing property,heatnpreservation,energy saving

Usage:

- Roof,wall,floor
- Shells of air conditioner and water heater
- Protective coating of water pipe amd ventilating pipe

Table 2

Material Structure: AL/Bubble/AL		
Bubble Size:○10mm*H 4mm（10*2.5/10*4/10*6/20*7/25*10）choose the bubble size		
Bubble Weight:0.13kg/㎡（can be customized）		
Roll Width:1.2m (lenth can be customized)		
PROPERTIES	**TEST DATA**	**UNIT**
Thickness	3.5-4	mm
Weight	242	g/㎡
Emissivity	0.03-0.04	COEF
Thermal conductivity	0.0455	w/(m.k)
Apparent Density	83	kg/m³
R-Value	2.74	M2.k/w
Reflectivity	96-97	%
Water Vapour Transmission	2.703*10^-9	g/pa.m2.s
Corrosion	doesn't generate	
Tensile Strength	9.95	N/mm Width
Elongation At Break	135	%
Fire Rate	Class 2	

2. Reflective Foam Foil

INNOVO

Innovo Packaging (Shanghai) Co.,Ltd

Reflective Foam Foil

Product construction	Al foil/4mm XPE/AL foil
Product thickness	4mm
Foil thickness	44microns
Foil purity	99.00%
Foil reflectivity	97%
Weight	245g/m2
Tensile Strength	
Longitudinal direction	Min 18.05 Mpa
Transverse direction	Min 19.66 Mpa
Tear resistance	
Longitudinal direction	Min 15.2 N
Transverse direction	Min 14 N
Water Vapour	<0.012 g/M2 KPA
Thermal conductivity	0.042W/(m.k)
Foam Density	36kg/m3

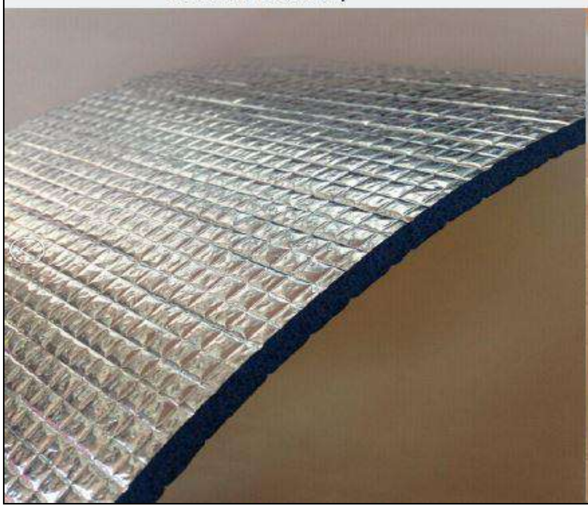
Table 3

Benefit:

- Insulation/Radiant/Vapour Barrier
- No Health or Safety Risk
- Reduce Utility Bills and Saves Money
- Fire Retardant
- Unique Anti Tear Surface
- Easy to install
- Heat Stablishied
- 15 Years Warranty

Usage:

- Roof/Wall/Floor Insulation
- Air duct
- Residential building
- Commercial building
- Agricultural building



Even though the effectiveness is almost similar, the life and strength is comparatively more for the reflective foam foil sheets. The thickness of the sheets employed was of 4mm. The arrangement of these sheets on the front, rear and side glasses is done through a pop- up arrangement. Generally three main conditions are to be satisfied to make sure the absence of any human being inside the car before the pop-up of the XLPE sheets initiates. They are as follows:

1. All windows and doors should be closed completely.
2. The engine should be In OFF condition.
3. The key should be removed from the port.

If all the above conditions are satisfied, it confirms the absence of human inside the car and then the pop-up initiates.

An IR powered laser thermometer was used for measuring the temperature variations in all those automobiles.

Fig 6: Laser thermometer

A. Results and Discussions

The ambient temperature noted from the car when the experiment started was 37 °C.

Fig 7: Ambient temperature recorded

All the above mentioned automobiles were allowed to park under sunlight for around four to five hours. To be precise, from 11 AM to 3.30 PM. The measurement of temperatures was done on car body, car interior (Dashboard), ground on which the car was parked and on the front glasses.

Following are the results obtained on evaluating the temperature variations in all those four cars.

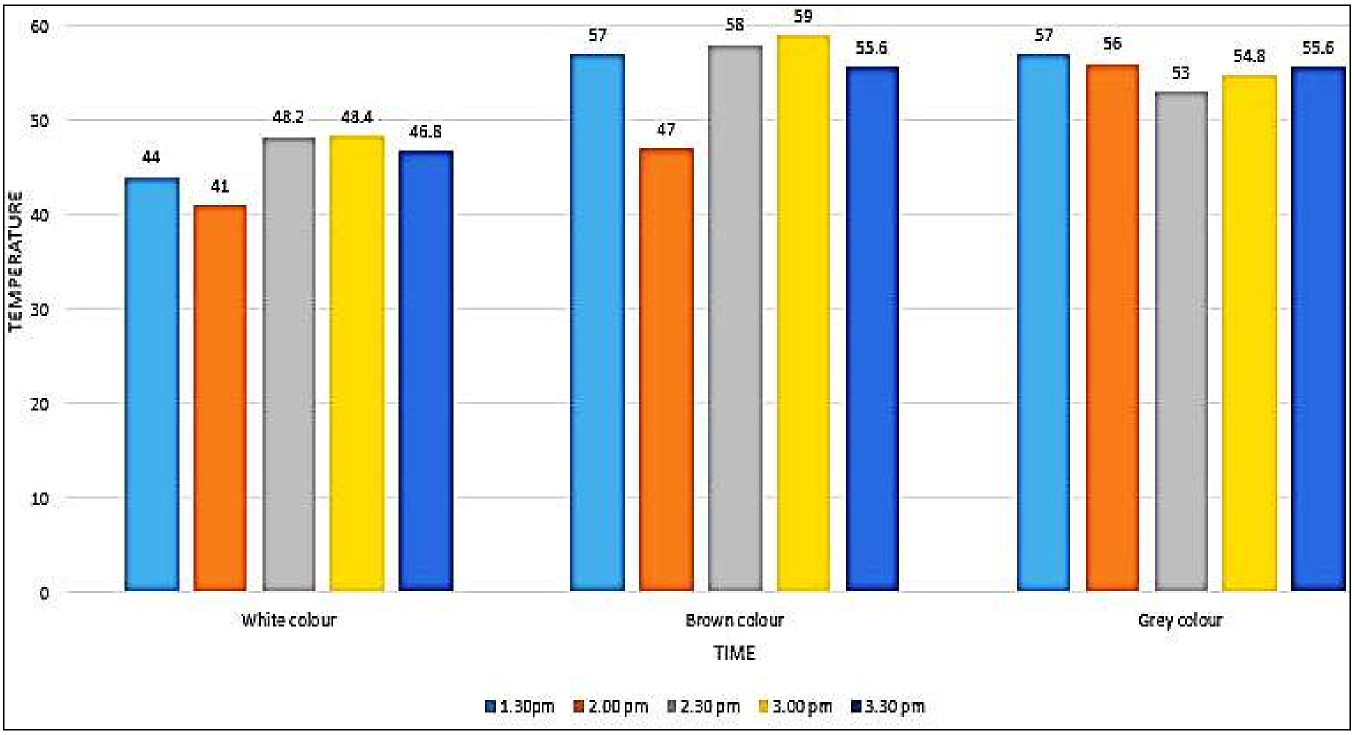


Fig 8: Temperature variations based on colour and reflectivity of the metal body of an automobile

Here in this figure, the X- axis represents the time and the Y- axis represents the temperature. The experiment was conducted during the time period 1:30pm-3:30pm at an interval of 30 minutes. The variation in temperature with respect to the time seems to be non- uniform because, even at the midst of the noon, the intensity of the sunlight varies non- uniformly. So for the time being, the errors due to this variation in light intensity is not considered. Here in this figure the first bunch of five lines gives the temperature variation based on the colour and reflectivity of a white coloured automobile. The second five lines indicate the brown colour and the next five lines indicate the grey colour body of the car. From the three graphs we can find that at all time intervals the brown colour car shows maximum temperature. This tells us that colour plays an important role in the rise in temperature also the reflectivity of dark colours is lesser than light colours.

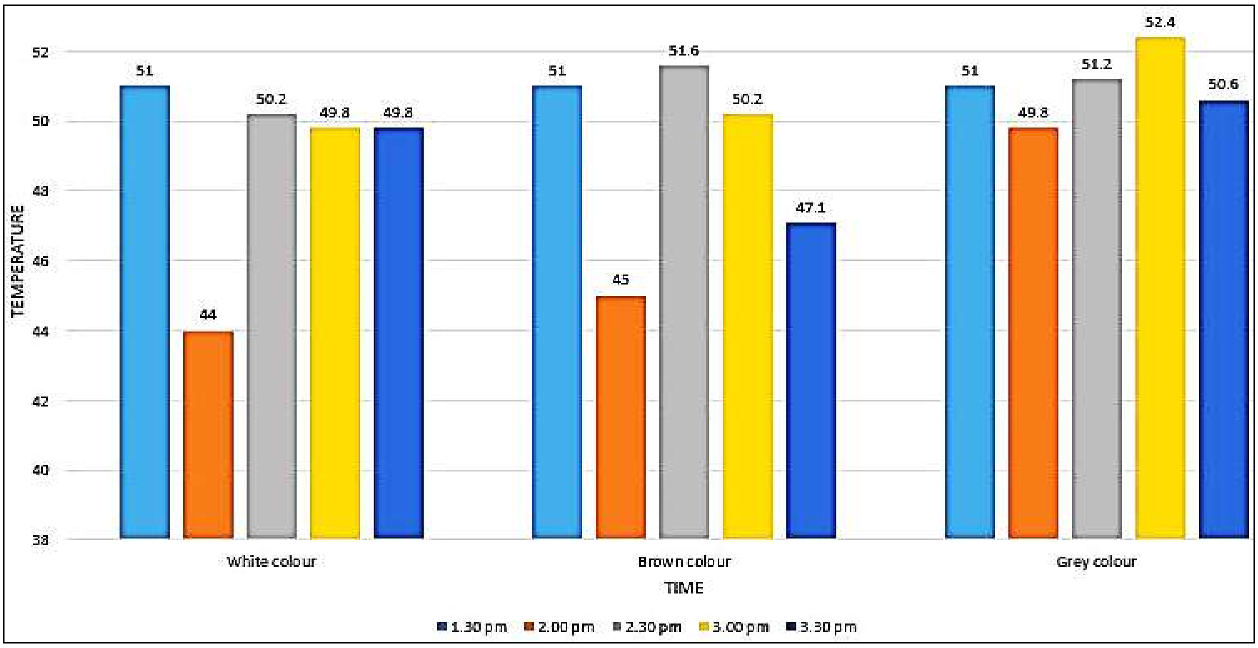


Fig 9: Temperature variations on the front glass of a non- insulated automobile

Here in this figure, the abscissa represents the time and the ordinate represents the temperature. From the above graph we can find that maximum temperature obtained on the front glass of a non -insulated automobile is 52.4 ^{o}C at 3pm.the lowest temperatures obtained in the experiment is at 2pm that is 44, 45, and 49.8 for white brown and grey colour respectively. From the graph we can infer that the temperature almost remains same for all three colours. A slight variations can be found out if the material of the glass is different the temperature may vary.

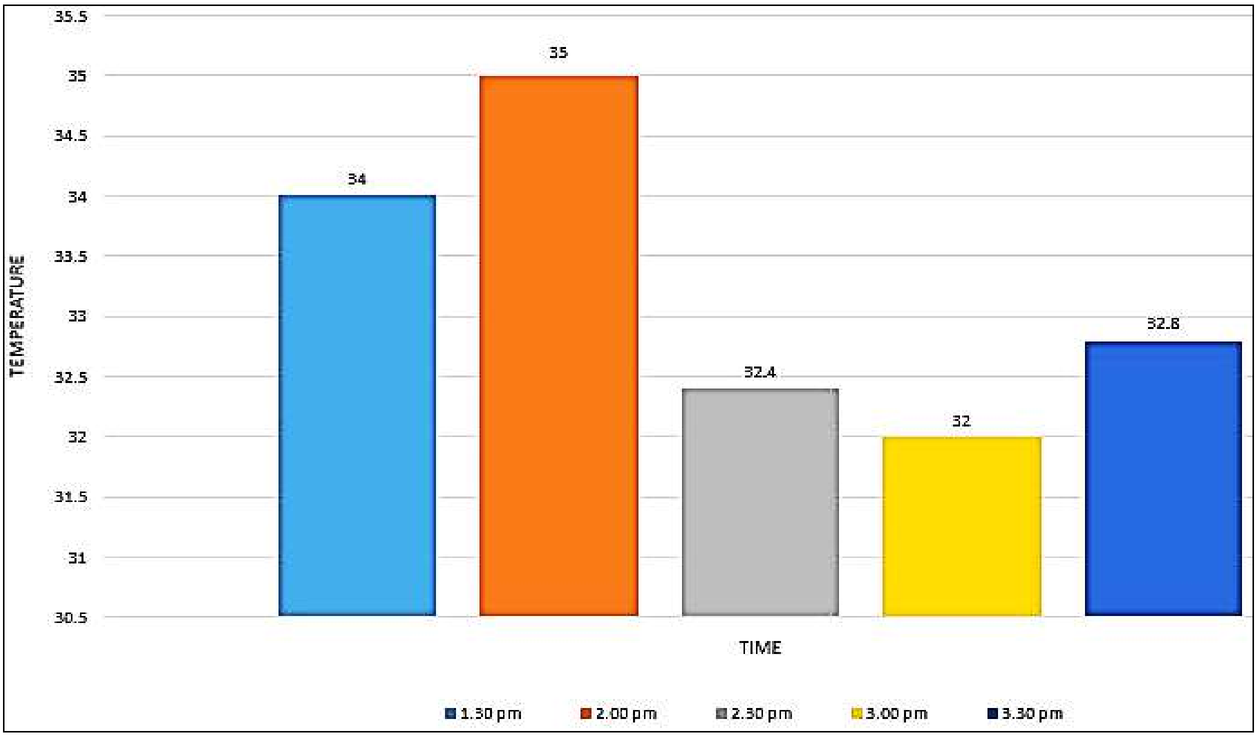


Fig 10: Temperature variations on the front glass of an insulated automobile

Here in this figure, the abscissa represents the time and the ordinate represents the temperature. In this experiment the front glass of the car is covered with XLPE sheets of thickness 4mm and the temperature reading is taken accordingly. When we compare the temperature readings of non- insulated front glass to that of insulated one, a large reduction in temperature is found for the insulated surface. The temperature is reduced upto 32 ^{o}C. The large temperature reduction is due to the high reflectivity property of XLPE sheets.

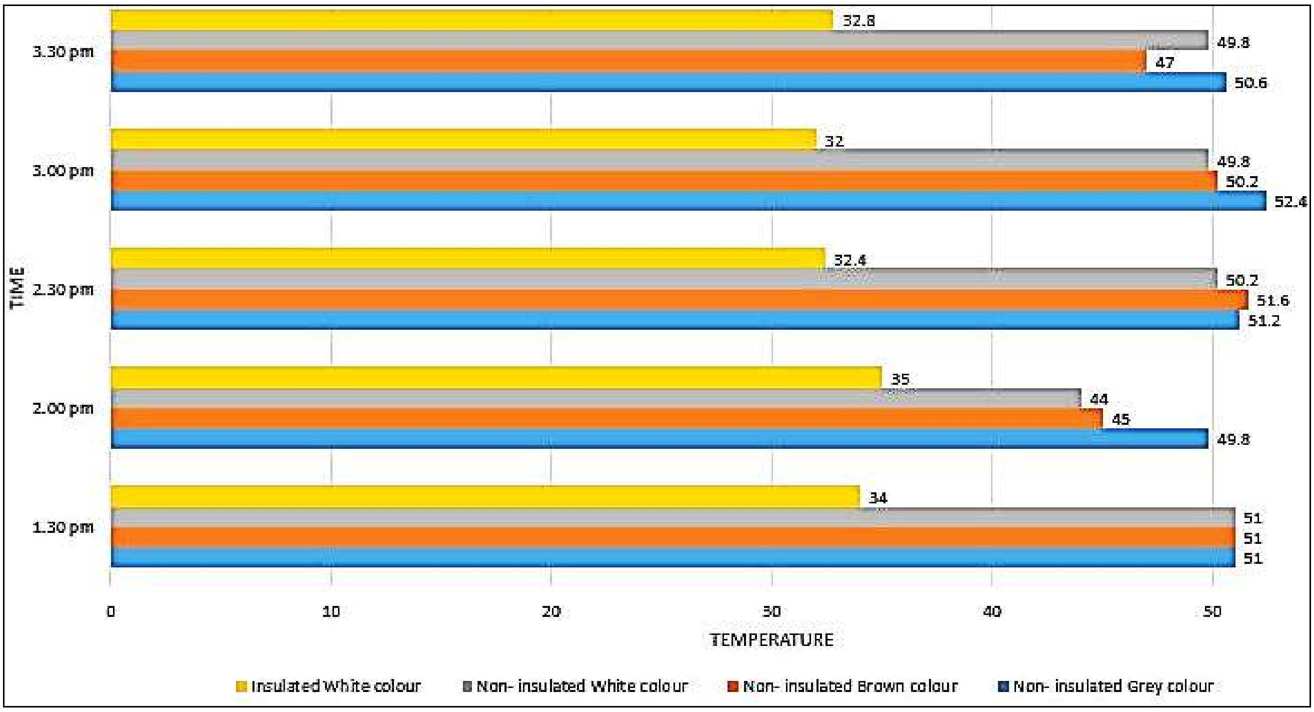


Fig 11: Comparison of temperature rise on insulated and non- insulated front glasses

Here in this figure, the abscissa represents the time and the ordinate represents the temperature. This graph is a comparison between temperature rises on insulated and non-insulated front glasses. The Yellow graph indicates temperature measurement of insulated white coloured car from the graph we can infer that for insulated car there is a considerable amount of reduction in temperature

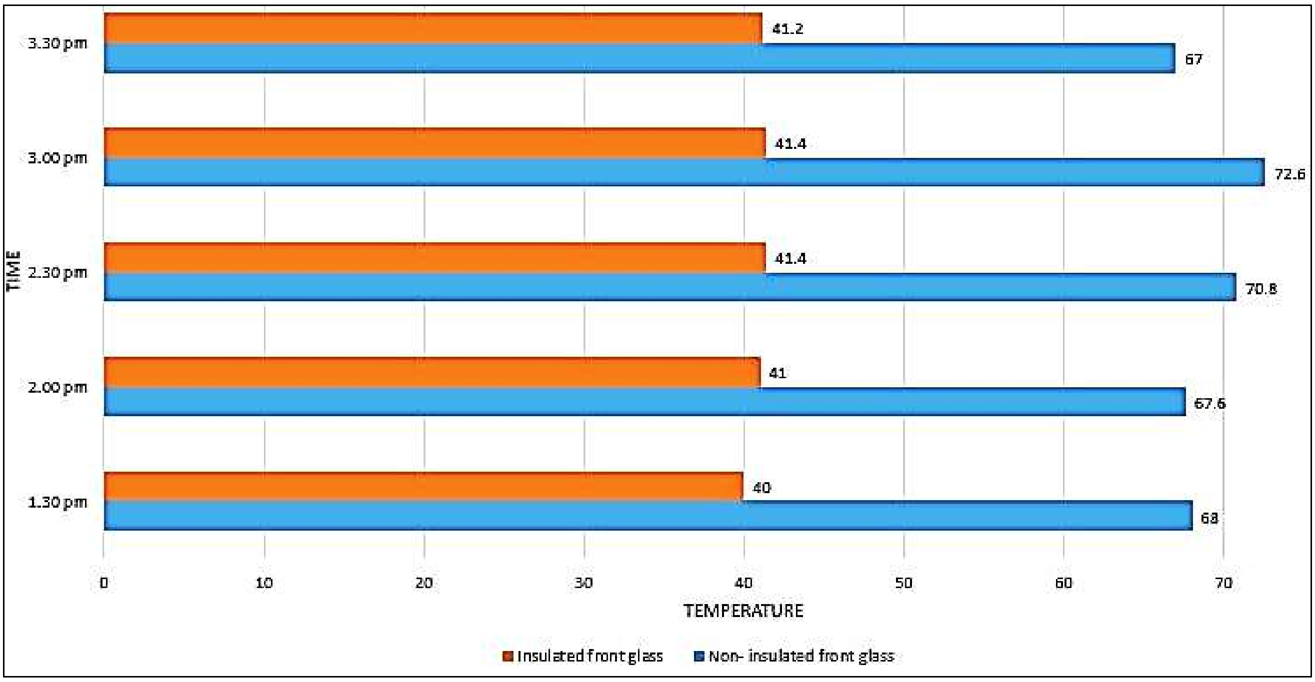


Fig 12: Comparison of temperature rise in dash boards through insulated and non-insulated front glasses

Here in this figure, the abscissa represents the time and the ordinate represents the temperature. The above graph is a comparison of temperature rise in dashboard through insulated and non-insulated front glass. The red bar graph represents insulated front graph. We can infer that temperature is reduced for insulated front glass.

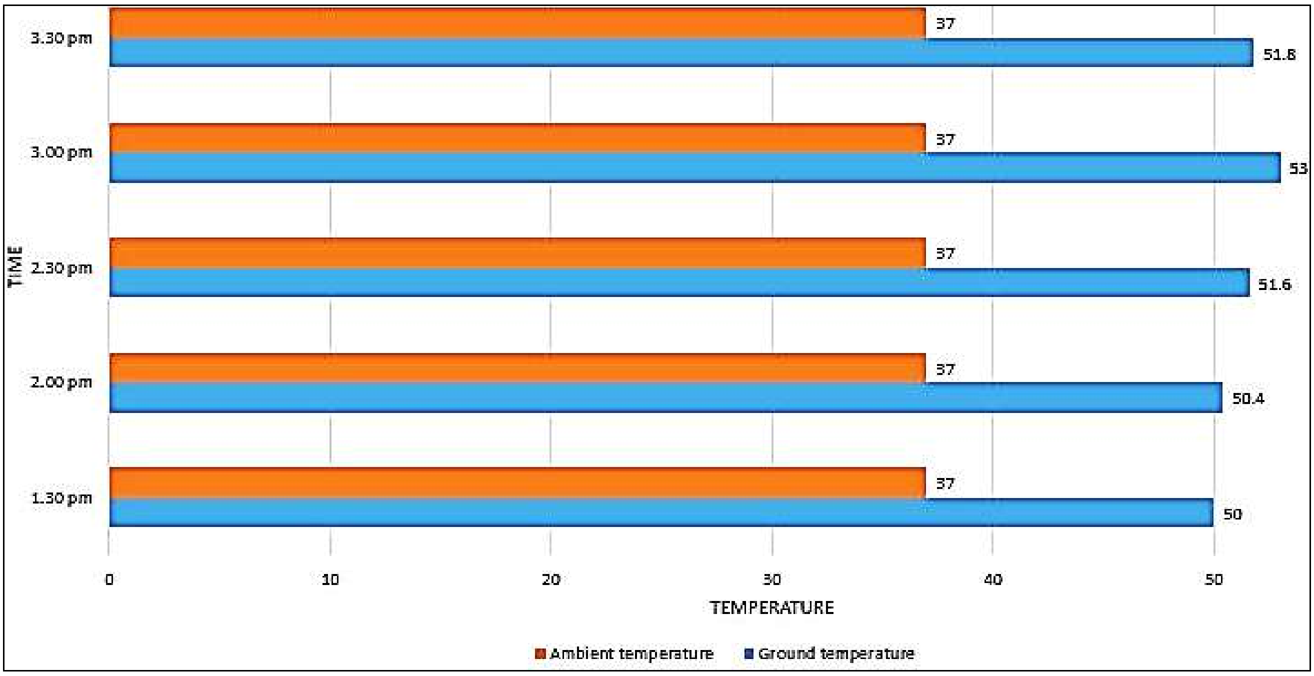


Fig 13: Comparison of temperature rise between ground and ambient conditions

Here in this figure, the abscissa represents the time and the ordinate represents the temperature. The ambient temperature measured during the time frame 1:30-3:30pm is 37 ^{o}C. The ground temperature at that time period varies from 50-53 ^{o}C. From this graph we can infer that when the car is parked, maximum heat enters into the car from the ground and not through the roof of the car. The temperature decreases as we move from ground level till the roof of the car.

Inferences

1. Colour and Reflectivity of a car body plays an important role in the temperature rise inside the cabin.
2. Lighter colour reflects more light than dark colours.
3. Front glasses of a dark painted automobile will experience higher temperatures.
4. Most temperature rise occurs through the front glass of an automobile.
5. Temperature for a parked car is maximum at its bottom, near to ground.
6. Temperature decreases from bottom to the top.
7. Temperature in a confined space will be greater than that of ambient conditions.
8. By insulating the glasses only we could attain a temperature reduction of around 30 degree Celsius.

B. Controlling the emission of toxic gases from dashboards using veneer stickers

Veneer stickers (Material pine wood) are used to cover the dashboard surfaces so that the dashboard is not exposed to high temperatures. This prevents the emission of harmful gases to a certain extent. In woodworking, veneer refers to thin slices of wood and sometimes bark, usually thinner than 3 mm (1/8 inch), that typically are glued onto core panels (typically, wood, particle board or medium-density fibreboard) to produce flat panels such as doors, tops and panels for cabinets, parquet floors and parts of furniture. Here in this process we are using veneer stickers of thickness 450 microns.

Fig 14: Veneer sticker

They are also used in marquetry. Plywood consists of more than three layers of veneer, each one is glued with its grain at 90^{0} to adjacent layers for strength. Veneer beading is a very thin layer of decorative edging placed around objects, such as jewellery boxes. Veneer is also a type of manufactured board.

Veneer is obtained either by “peeling” the trunk of a tree or by slicing large rectangular blocks of wood known as flitches. The appearance of the grain and figure in wood comes from slicing through the growth rings of a tree and depends upon the angle at which the wood is sliced.

Compared to wood, one of the important advantages of using veneer is stability. While solid wood may lead to warping and splitting, because veneer is made of thin layers of wood glued together, the chances of splitting or cracking are reduced.it would be impossible to construct certain projects using solid lumber due to contraction and expansion, it can be easily done with the help of venner stickers. Sustainability-furniture can be made with wood veneer which uses less wood than the same piece of furniture made with solid wood it is a great advantage. Further, it is easily available than solid wood as exotic hardwood lumber can be scarce and very expensive. The ecological characteristics include:

Recyclability and renewability: Wood has the least impact on total energy use, greenhouse gases, air and water pollution, solid waste and ecological resource use. Less energy is required in the use of wood compared with any other building materials with upto a reduction of 70%.

Sustainability: Using veneer extends the timber usage. The wood that might be used in one solid piece a few visible cm wide can cover a far greater area when used as a veneer.

Toxicity: It is Nontoxic as veneer stores carbon and also maximises the use of harvested wood.

8. Advantages

- Eliminates the cause of cancer, Kidney failures, Leukemia, Loss of blood cells.
- Overheating of cabin is removed.
- Dependency on Air conditioning system minimized.
- Load on air conditioners decreased.
- Energy is conserved.
- Suffocation is totally eliminated.
- Overheating of the Dash board is removed.

9. Features can be added

XLPE sheets consists of aluminum coating on both sides this reflects the heat entering the car on one side and the other side can be used to maintain the cool air inside. The dependency on air conditioning system can be reduced to a considerable amount once the XLPE sheets are coated and initiating intelligent A/C by allowing the A/C vents only at front glass which is commonly used for removing the fog and mist during rainy days. As the arrangement of these XLPE sheets are in parabolic fashion, it can evenly spread the cold air in to the cabin which in turn will reduce the loss of cold air. Thus by initiating the intelligent A/C, one can reduce the interior temperature to about 24 ^{o}C with the help of these XLPE sheets before entering in to the car.

10. Acknowledgement

The satisfaction and euphoria that accompany the successful completion of any task would be incomplete without mentioning the people who made it possible, whose constant guidance and encouragement crowned our effort with success.

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