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STUDY ON ACRYLONITRILE-BUTADIENE-STYRENE (ABS) DEGRADATION DUE TO WEATHERING AND ITS EFFECT ON VEHICLE SAFETY

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ABSTRACT

Plastics (polymers) are nowadays clearly a material of choice in all the application sectors including in Automobile sector. Automotive manufacturer have relived on new technology for vehicular accessories which are all made-up of different polymers like acrylonitrile-butadiene-styrene (ABS), Poly carbonates, Poly methyl methacrylate **(**PMMA), Acrylic, glass, resin etc. Although these components offer an impressive range of attractive properties, the effect of climatic conditions on the durability and performance of these materials is not fully understood. The durability, performance and rate of deterioration of these products are all significantly influenced by both the material composition, as well as the climatic conditions to which they are exposed. The degradation/ variation of the mechanical properties of the specimen treated at different environmental/ atmospheric conditions are a primary concern when recommending such a composite for particular use. This paper briefly examines the effects of the weathering on the performance and properties of well known polymers such as ABS products which are most commonly used materials in automobile sector. The use of accelerated weathering techniques to assist in assessing the durability of these product materials is also briefly discussed.

KEYWORDS: Plastics polymers, application sectors, acrylonitrilebutadienestyrene ABS, accelerated weathering techniques.

INTRODUCTION

The motor vehicle industries are one of the major pioneer activities for social and economic progress of any country. The production and use of motor vehicles is expanding at an enormous pace through out the world. Accordingly utilization of new technologies in different fields such as safety, reliability, comforts and environmental controls have to be considered as a paramount importance.

Plastics are nowadays clearly a material of choice in all application sectors. The relative growth of plastics in the last three decades compared to other materials has been phenomenal and the automotive industry has been no exception in contributing to this growth. End users always expects high performance vehicles with greater comfort, safety, fuel efficiency but lower prices. At the same time society as a whole expects lower pollution levels and increased recovery of cars at the end of life. To meet theses demands, plastics having unique combination of properties to provide technological innovation with cost efficiency and sustainability.[1]

Many types of polymer are used in more than 1000 different parts of all shapes and sizes. These vary from large applications such as all-plastics dashboards and fuel tanks to smaller items such as door handles and electrical components. Each polymer in turn can be adapted to meet the exact technical, safety, economic, environmental and aesthetic specifications required.[1] The figure 1 shows the list of different plastic components used in automobile.

Figure 1: Application of plastics in automobile.

Many components used in automobile applications are made of different types of materials like, acrylonitrile-butadiene-styrene (ABS), Polycarbonates, Poly methyl methacrylate (PMMA), Acrylic, glass, resin etc. Although these materials offer an impressive range of attractive properties such as functionality, light weight, safety, resource efficiency, integrated system, economics, recyclables, resistance to environmental impacts, high strength, etc, the effect of climatic conditions on the durability and performance of these accessories are not fully understood. The reason may be longer duration simulation to environmental, high cost, etc. The durability, performance and rate of deterioration of these products are all significantly influenced by both the material composition, as well as the climatic conditions to which they are exposed and finally affect the aesthetics and safety of the vehicle. Consumers spend more money to maintain products that inevitably degrade and to replace products that fail. Thus, weathering is a major concern for manufacturing industries. Materials that fail as a result of exposure to outdoor environments accounts for a significant portion of this total cost.[2]

The increase outdoor use of plastics in automobile has created a need for a better understanding of the effect of the environmental on these materials. The severity of damage depends largely on factors such as the nature of the environment, geographic location, type of polymeric material, and duration of exposure. The effect can be any where from a loss of colour or a slight crazing and cracking to a complete break down of a polymer structure. Any attempt to design plastic parts without a clear understanding of the degradation mechanisms induced by the environment would result in a premature failure of the product.[2]

Literature survey indicates that; available studies are mainly concentrating general applications of plastics, property of material, and a very limited study on effect of weathering.[3-7] Many regulations and standards are available to evaluate these components performance as mandatory requirements before launch of the vehicle by respective manufacturer.[8-16] Little studies are conducted to find out the material property change due exposure to climatic conditions. None of the studies directly involved to find out the automobile components degradation which are exposed to different atmospheric conditions and its effect on the automotive safety.

The studies conducted till date only based on the data of Florida and Arizona. The specifications using these studies are basically derived based on the data of the climatic conditions of Florida and Arizona. The Indian manufacturers have been using these specifications though these specifications may not be suitable for Indian climatic conditions. Many regulations / standards refer the requirements of weathering for the different automotive components.[8-13] Similarly many regulations / standards refer the requirements of energy absorbing material requirements during vehicular crash / impact.[13-16] These components need to meet the performance requirements as per national / international regulations not only when they are new but under different environmental conditions and even after exposure to such conditions for long duration.[8-16] Therefore, there is a need to revise these standards specification taking into consideration of Indian climatic conditions.

The above literature review indicates the possible prospects to carry out comprehensive further investigation on degradation of polymers used in automobile applications. Based on above, this investigation has been formulated as **"Study on ABS degradation due to weathering and its effect on vehicle safety".** Detailed study has been conducted to asses the effect of artificial weathering cycles on the ABS polymer used in automotive application. This journal briefly examines the effects of the weathering on the performance and properties of ABS polymer. The use of accelerated weathering techniques to assist in assessing the durability of these product materials is also briefly discussed. Also briefly explains the how these product failures are really effect on the vehicular safety requirements. This paper also attempts to evaluate the deterioration and premature product failure through weathering tests to assess a material durability. For product development, it is virtual to understand how to properly design to meet the safety standard to achieve the safety of the vehicle.

There are different types of failures expected in the polymers after weathering such as mechanical failure, thermal failure, Chemical failure and environmental failures. This journal briefs mechanical failure along with environmental failures.[3]

WEATHERING

Weathering is the adverse response of a material or product to climate, often causing unwanted and premature product failure. Consumers spend billions of dollars per year to maintain products that inevitably degrade and to replace products that fail. Materials fail as a result of exposure to outdoor environments account for a significant portion of this total cost.[4]

FACTORS OF WEATHERING

The three factors of weathering are solar radiation (light energy), temperature, and water (moisture). But it is just "how much" of each of these factors ultimately causes degradation to materials, because different types of solar radiation, different phases of moisture and temperature cycling have a significant effect on materials on exposure. These factors in conjunction with secondary effects such as airborne pollutants, biological phenomena and acid rain, act together to cause "weathering". Ultimately weathering causes of ageing results degradation of the materials. The Figure 1 shows the flow chart of the ageing process on the materials due to weathering.[4]

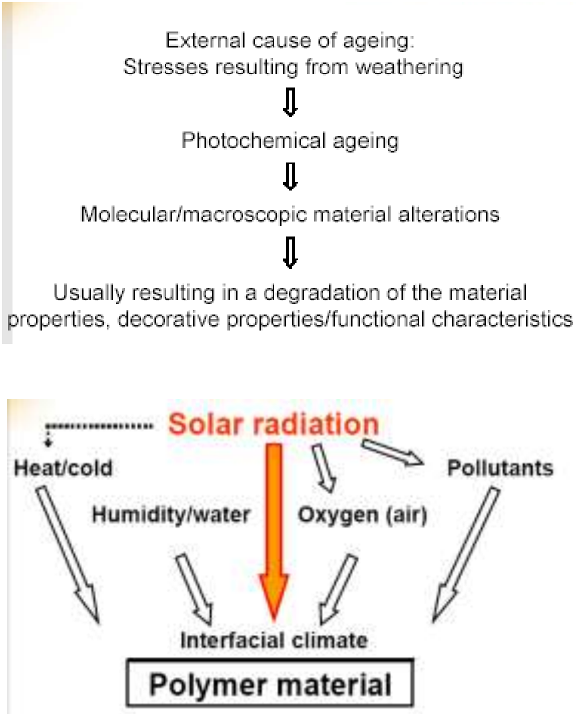

Figure 2: Flow chart of the ageing process on the materials due to weathering.

Solar Radiation

Solar irradiance on materials causes fading, color change, surface erosion, loss of gloss and numerous other deteriorations.

Radiant energy that comes from the sun is made up of photons that travel through space as waves. The energy (E) is proportional to their frequency (v) according to the following equation, where (h) is Planck's constant,(c) is the velocity of light in a vacuum , and (λ) is wave length.

$$E=hv=hc/\lambda$$

The solar radiation that reaches the earth's surface consists of wavelengths between 295 and 3000 nanometers. This terrestrial sunlight is commonly separated into three main wavelength ranges: ultraviolet (UV), visible (VIS), and infrared (IR). The distribution of total radiation of each range according to the wavelength is as shown in the Table I below.

Table 1: Distribution of total Radiation as per CIE pub 85.

Range Name	Wavelength Range	% of Total Solar
Ultraviolet (UV)	295 – 400 nm	6.8
Visible (VIS)	400 – 800 nm	55.4
Infrared (IR)	800 – 2450 nm	37.8

Reference Table in Accordance to CIE Pub. 85, Tab.4

The degradation characteristics of a material as a result of radiation is dependent on; the quality and quantity of radiant energy deposited onto the material, the wavelengths of radiation absorbed by the material and whether or not that absorbed radiation has enough energy to cause a chemical change, which could lead to material degradation.

Firstly solar radiation cause solar heating that will increase the internal temperature of an electrical component or assembly. Secondly the damage caused by solar radiation is colour fading and material breakdown etc.

TEMPERATURE

Temperature's effect on material weathering includes thermal oxidation degradations, subsequent reaction rates and accelerating other weathering reactions.

The temperature of material exposed to solar radiation has an influence on the effete of the radiation. Photochemical reactions are usually accelerated at elevated temperatures. In addition, temperature determines the rate of subsequent reaction steps. These secondary reactions can be qualified using the Arrhenius equation. A general rule of thumb assumes that reaction rates double with each 10 ° C rise. in material temperature.[4]

WATER (MOISTURE)

Water is one of the substances in our environment that is everywhere, whether in the form of humidity, rain, dew, snow, or hail. All materials used outdoors are exposed to these influences.

There are two ways in which water affects materials,. Water absorption by synthetic material and coatings from humidity and direct wetness are examples of physical effects. As the surface layers absorb moisture, a volume expansion is produced that places stress on the dry subsurface layers. Following a drying out period, or desorption of water, the surface layers will lead to a volume contraction. The hydrated inner layers resist this contraction, leading to surface stress cracking. This fluctuation between hydrated and dehydrated states may result in stress fractures.

The freeze-thaw cycle is another physical effect. Because water expands when it freezes, absorbed moisture in a material causes expansion and stresses that cause peeling, cracking, and flaking in coating. Rain, which periodically washes dirt and pollutants from the surface, has an effect on the long-term rate of deterioration that is determined more by its frequency than its amount. When rain strikes an exposed surface, evaporation processes cool the surface rapidly, which may cause physical degradation to a material. Frozen rain, or hail, may also cause physical degradation to a material because of the strong kinetic energy associated with its impact.[4]

TYPES OF WEATHERING TEST

NATURAL WEATHERING

Direct weathering, also known as out door or natural weathering is defined as an exposure to direct sunlight and other elements of weathering. Natural exposures are conducted under natural environmental conditions rather than inside a laboratory under artificial conditions. There are different types of natural weathering system depending on the type of sample mounting position /conditions namely fully system exposure, unbaked rack, backed rack, under glass, different sample orientation (90 south, 45 south, at latitude angle, variable angle etc.). This is typically accomplished by mounting the material on mounting exposure rack.

LABORATORY ACCELERATED WEATHERING

The goal of accelerated weathering tests is to provide a relatively rapid means of measuring the rate of property changes typical of those that occur in the long term tests. These tests are commonly designed from information obtained during the pre-tests. The intensity levels of the degradation factors during accelerated aging tests will normally be at or near worst case conditions as in the end use environment. If the initial accelerated methods do not induce mechanism representative of in-service degradation or if mechanism are induced that are not seen in the long-term tests ,the accelerated tests should be altered after reassessing the Information obtained during the problem definition and pre-testing analyses. Even if proper analysis has been done in the problem definition step, changing the level of a particular degradation factors may or may not affect the property change. The synergy of degradation factors should always be considered when developing these accelerated tests. This leads to more difficult interpretation of the results of the tests, especially when comparing the results of the long-term tests with the results of the accelerated tests.

EXPERIMENTATION

The objective of this paper is to provide a degradation effect ABS, PMMA and safety glass due to weathering and its effect on road safety by simulating the weathering conditions in the laboratory as a part of accelerated tests.

Many studies have been conducted on different polymer materials based on the weathering data of Florida and Arizona.[3,4] The existing regulation's specifications have been derived based on these data. These climatic data may not be really suitable for Indian climatic conditions.

The Indian manufacturers have been using these standards though these may not be particularly suitable for Indian conditions. Therefore there is a need to revise these standards taking into consideration the Indian climate and usage.

In this context, for this study, data of the Pune, India region consider as it represents the average Indian climate conditions and same was collected from Indian Meteorological Department, Pune, India. The average Pune region total (295 – 3000nm) irradiance per year is 6975.9 MJ/m^2. The test method is followed for this experiment is ISO SAE J 1960.[17] The equipment used for accelerating weathering is Atlas Ci 4000. The layout of the equipment is shown in the Figure No. 2 and 3 as below.

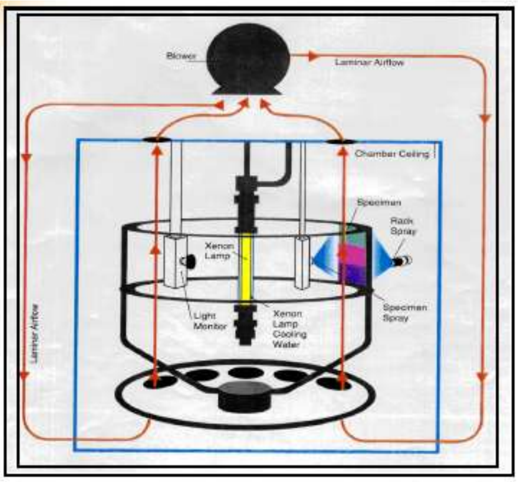

Figure 3: Layout of the water cooled Ci 4000 weather-Ometer.

Figure 4: Layout of the samples in side the weather-Ometer.

LIGHT SOURCE USED FOR EXPERIMENTS

The xenon long arc, when properly filtered, simulates UV and visible solar radiation more closely than any other artificial light source. The spectrum of xenon arc lamp versus day light over a range of 300 to 800 nm is shown in Figure 4. Xenon arc is a precision gas discharge lamp in a sealed quartz tube. The spectral power distribution is altered through filtering to simulate solar radiation. The weather-o-meter used in this experimentation is Ci 4000 water cooled.

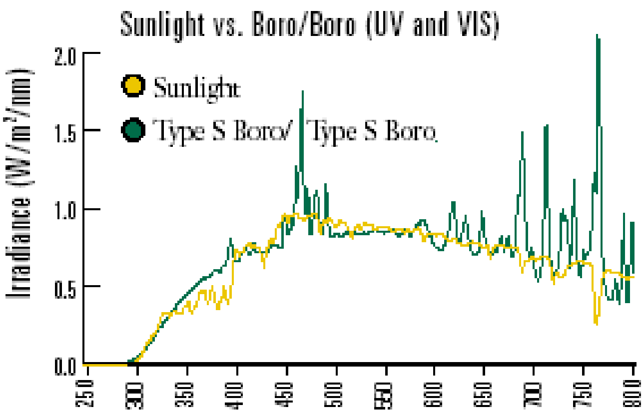

Figure 5: Spectrum of xenon arc lamp versus day light over a range of 300 to 800 nm.

SAMPLE PREPARATION AND TESTING

Most of plastic components used in automobile applications are basically derived from different grades of Acrylonitrile-butadiene-styrene (ABS), hence, for the experimental purpose, identified Acrylonitrile-butadiene-styrene (ABS) and same were procured in the form of granules. These granules are molded into test sample as per ASTM standards / ISO standards[18-23] to conduct different tests as mentioned below. The figure 6 shows the test specimen of ABS material as per ASTM standard.

Figure 6: Test samples as per ASTM standard.

For the better statistics, following number of test samples of each material was prepared and these samples are subjected to the following tests as per respective ASTM standards to find out the mechanical property changes due to weathering. Table 2 shows the list of tests, standard and number of samples used for the study.[18-23]

Table 2: List of tests, standard and number of samples used for the study.

Sr. No.	Test Details	ASTM Test	ABS
1.	Tensile	D638 –Type I	15
2.	Flexural	D790	15
3.	Impact (Izod)	D256 / ISO 180	15
4.	Hardness (Shore-D)	D2240 / ISO 178	15

Total there are 60 samples are exposed to accelerating weathering as per SAE J 1960[17] for the total radiant energy of 6356 MJ/m^2, which the total radiant energy is collected for one year at Pune region India, which is equal to around 3500 KJ/m^2 for 0.55W/m^2 at 340 nm.[4] Above mentioned tests are conducted at the intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2exposure weathering.

The different equipments such as Instron Universal Tester, Impact test machine and Shore Duro-meter equipment are used to measure the material properties after exposure to different radiant energy along with all other weather conditions, which are all having valid calibration and traceability to national / international laboratory. Also all these equipments are covered under ISO:17025 / NABL accreditation.[24]

RESULTS AND DISCUSSIONS

TENSILE STRENGTH TEST RESULTS OF ABS

Tensile strength retention during weathering was studied for most commonly-used material. Tables 3-8 shows the average tensile strength test results of three ABS samples after intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2 radiant exposure to weathering.

Table 3: Tensile Test Results on new sample before exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Tensile Strength (MPa)	Average Tensile strength (MPa)
1	0	12.96	3.94	40.08	40.81
2		12.98	3.89	42.55	
3		12.99	3.95	39.81	

Table 4: Tensile Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Tensile Strength (MPa)	Average Tensile strength (MPa)
1	875	13.48	3.87	38.05	38.63
2		13.02	3.93	38.53	
3		13.21	3.94	39.31	

Table 5: Tensile Test Results after 1750KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Tensile Strength (MPa)	Average Tensile strength (MPa)
1	1750	13.06	3.99	40.65	40.35
2		13.01	3.95	41.28	
3		13	3.95	39.13	

Table 6: Tensile Test Results after 2625KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Tensile Strength (MPa)	Average Tensile strength (MPa)
1	2625	13.06	3.96	39.44	38.42
2		13.25	3.97	38.83	
3		13.45	3.96	39.15	

Table 7: Tensile Test Results after 3500KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Tensile Strength (MPa)	Average Tensile strength (MPa)
1	3500	12.94	3.97	39.41	37.45
2		13.21	3.86	38.68	
3		13.54	3.91	38.98	

Table 8: Overall Tensile Test Results after each radiant exposure.

Sample set No.	Total radiant energy KJ/m^2	Average Tensile strength (MPa)
1	0	40.81
2	875	38.63
3	1750	40.35
4	2625	38.42
5	3500	37.45

The Fig.7 shows the Overall trend of Tensile Test with radiant exposure.

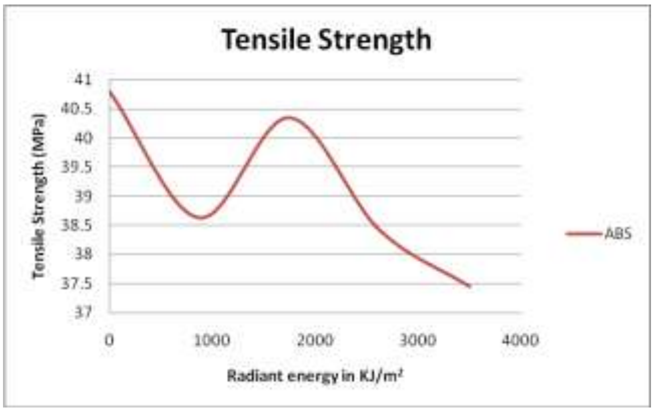

Figure 7: Overall trend of Tensile property of ABS after exposure to weathering.

The results shows that Tensile strength may either increase or decrease during initial weathering. However, after continues exposure to weathering, Tensile strength start decreasing. The variation coefficients of Tensile strength measurement for ABS specimen exposed from 0 to 3500 KJ/m^2 is around 8%.

IMPACT STRENGTH TEST RESULTS OF ABS

Impact strength retention during weathering was studied for most commonly-used material. Tables 9-14 shows the average Impact strength test results of three ABS samples after intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2 radiant exposure to weathering.

Table 9: Impact Test Results on new sample before exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Impact Strength (MPa)	Average Impact strength (MPa)
1	0	12.51	6.52	2.04	2.03
2		12.65	6.4	2	
3		12.73	6.45	2.04	

Table 10: Impact Test Results after 875KJ/m^2 radiant exposure Impact.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Impact Strength (MPa)	Average Impact strength (MPa)
1	875	12.78	6.36	1.56	1.56
2		12.6	6.56	1.56	
3		12.89	6.52	1.56	

Table 11: Impact Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Impact Strength (MPa)	Average Impact strength (MPa)
1	1750	10.21	6.26	1.48	1.49
2		10.73	6.51	1.48	
3		10.94	6.44	1.52	

Table 12: Impact Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Impact Strength (MPa)	Average Impact strength (MPa)
1	2625	10.84	6.54	1.48	1.48
2		10.5	6.49	1.48	
3		10.79	6.62	1.49	

Table 13: Impact Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Impact Strength (MPa)	Average Impact strength (MPa)
1	3500	12.93	6.54	1.11	1.13
2		12.58	6.29	1.14	
3		12.69	6.38	1.13	

Table 14: Overall Impact Test Results after each radiant exposure.

Sample set No.	Total radiant energy KJ/m^2	Average Impact strength (MPa)
1	0	2.03
2	875	1.56
3	1750	1.49
4	2625	1.48
5	3500	1.13

The Fig.8 shows the Overall trend of Impact Test with radiant exposure.

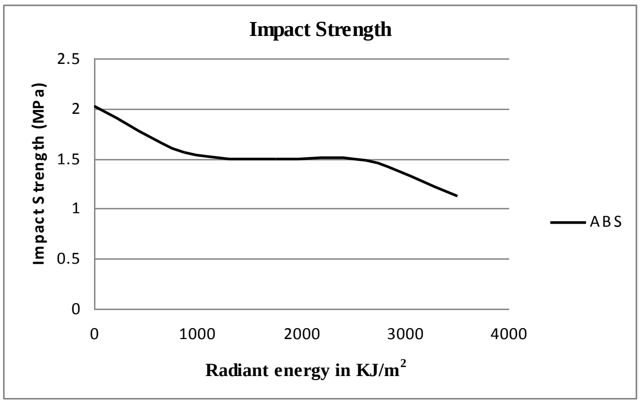

Figure 8: Overall trend of Impact property of ABS after exposure to weathering.

The results shows that Impact strength decreases after continues exposure to weathering and sometimes it rapidly drops. The variation coefficients of Impact strength measurement for ABS specimen exposed from 0 to 3500 KJ/m^2 is around 44%.

FLEXURAL STRENGTH TEST RESULTS OF ABS

Flexural strength retention during weathering was studied for most commonly-used material. Tables 15-20 shows the average Flexural strength test results of three ABS samples after intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2 radiant exposure to weathering.

Table 15: Flexural Test Results on new sample before exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Flexural Strength (MPa)	Average flexural strength (MPA)
1	0	12.43	6.49	59.69	58.21
2		12.66	6.48	56.32	
3		12.66	6.4	58.62	

Table 16: Flexural Test Results after 875KJ/m^2 radiant exposure Flexural.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Flexural Strength (MPa)	Average flexural strength (MPA)
1	875	12.63	6.46	65.88	65.25
2		12.55	6.41	64.58	
3		12.68	6.44	65.28	

Table 17: Flexural Test Results after 1750KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Flexural Strength (MPa)	Average flexural strength (MPA)
1	1750	12.66	6.43	66.86	67.47
2		12.72	6.43	69.85	
3		12.73	6.43	65.7	

Table 18: Flexural Test Results after 2625KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Flexural Strength (MPa)	Average flexural strength (MPA)
1	2625	12.71	6.41	67.75	68.61
2		12.51	6.45	69.33	
3		12.68	6.39	68.74	

Table 19: Flexural Test Results after 3500KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	Flexural Strength (MPa)	Average flexural strength (MPA)
1	3500	12.65	6.47	68.02	68.59
2		12.43	6.53	69.99	
3		12.01	6.42	67.77	

Table 20: Overall Flexural Test Results after each radiant exposure.

Sample set No.	Total radiant energy KJ/m^2	Average flexural strength (MPa)
1	0	58.21
2	875	65.25
3	1750	67.47
4	2625	68.61
5	3500	68.59

The Fig.9 shows the Overall trend of Flexural Test with radiant exposure.

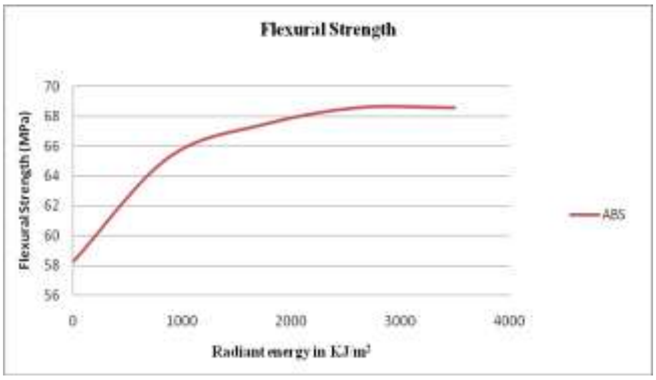

Figure 9: Overall trend of Flexural property of ABS after exposure to weathering.

The results shows that Flexural strength increase during initial weathering. However, after continues exposure to weathering, Flexural strength start stabiles till it failure. The variation coefficients of Flexural strength measurement for ABS specimen exposed from 0 to 3500 KJ/m^2 is around 17 %.

ELONGATION TEST RESULTS OF ABS

Elongation strength retention during weathering was studied for most commonly-used material. Tables 21-26 shows the average Elongation strength test results of three ABS samples after intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2 radiant exposure to weathering.

Table 21: Elongation Test Results on new sample before exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	% of Elongation	Average % of Elongation
1	0	12.96	3.94	17.79	17.95
2		12.98	3.89	18.54	
3		12.99	3.95	17.53	

Table 22: Elongation Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	% of Elongation	Average % of Elongation
1	875	13.48	3.87	7.19	9.15
2		13.02	3.93	12.53	
3		13.21	3.94	7.74	

Table 23: Elongation Test Results after 1750KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	% of Elongation	Average % of Elongation
1	1750	13.06	3.99	7.83	7.62
2		13.01	3.95	7.4	
3		13	3.95	7.615	

Table 24: Elongation Test Results after 2625KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	% of Elongation	Average % of Elongation
1	2625	13.06	3.96	5.7	4.22
2		13.25	3.97	2.74	
3		13.45	3.96	4.25	

Table 25: Elongation Test Results after 3500KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Width of the sample (mm)	Thickness of the sample (mm)	% of Elongation	Average % of Elongation
1	3500	12.94	3.97	2.07	2.10
2		13.21	3.86	2.125	
3		13.54	3.91	2.09	

Table 26: Overall Elongation Test Results after each radiant exposure.

Sample set No.	Total radiant energy KJ/m^2	Average % of Elongation
1	0	17.95
2	875	9.15
3	1750	7.62
4	2625	4.22
5	3500	2.10

The Fig.10 shows the Overall trend of Elongation Test with radiant exposure.

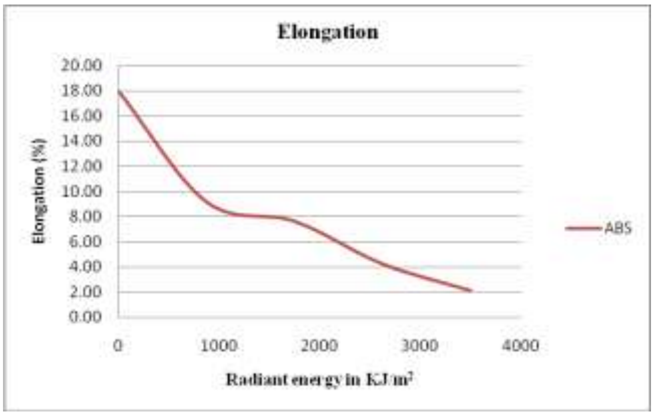

Figure 10: Overall trend of Elongation property of ABS after exposure to weathering.

The result shows that Elongation strength decrease continuously after continues exposure to weathering. The variation coefficients of Elongation strength measurement for ABS specimen exposed from 0 to 3500 KJ/m^2 is around 88%.

HARDNESS TEST RESULTS OF ABS

Hardness strength retention during weathering was studied for most commonly-used material. Table 27-32 shows the average Hardness strength test results of three ABS samples after intervals of 875 KJ/m^2, 1750 KJ/m^2, 2625 KJ/m^2 and 3500 KJ/m^2 radiant exposure to weathering.

Table 27: Hardness Test Results on new sample before exposure.

Sample No.	Total radiant energy KJ/m^2	Hardness shore D	Average Hardness shore D
1	0	73.95	73.36
2		72.18	
3		73.96	

Table 28: Hardness Test Results after 875KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Hardness shore D	Average Hardness shore D
1	875	74.8	75.37
2		75.5	
3		75.8	

Table 29: Hardness Test Results after 1750KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Hardness shore D	Average Hardness shore D
1	1750	74.9	74.97
2		74.8	
3		75.2	

Table 30: Hardness Test Results after 2625KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Hardness shore D	Average Hardness shore D
1	2625	72.3	74.47
2		75.6	
3		75.5	

Table 31: Hardness Test Results after 3500 KJ/m^2 radiant exposure.

Sample No.	Total radiant energy KJ/m^2	Hardness shore D	Average Hardness shore D
1	3500	76.1	73.53
2		71.6	
3		72.9	

Table 32: Overall trend of Hardness property of ABS after exposure to weathering.

Sample set No.	Total radiant energy KJ/m^2	Average Hardness shore D
1	0	73.36
2	875	75.37
3	1750	74.97
4	2625	74.47
5	3500	73.53

The Fig.11 shows the Overall trend of Hardness Test with radiant exposure.

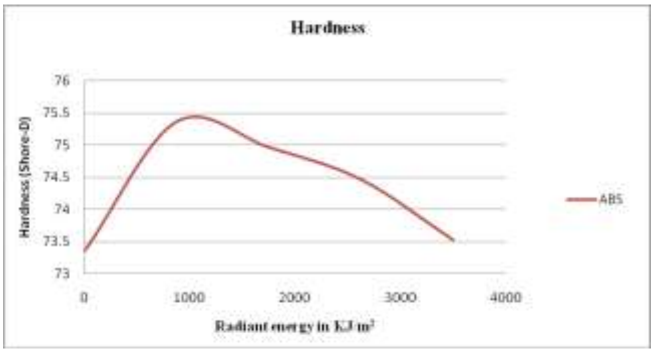

Figure 11: Overall Tensile Test Results after each radiant exposure.

The results show that Hardness strength may either increase or decrease during initial weathering. However, after continues exposure to weathering, Hardness strength start decreasing. The variation coefficients of Hardness strength measurement for ABS specimen exposed from 0 to 3500 KJ/m^2 is varies around 2%.

CONCLUSION

Overall, the study has shown that all the materials tested have generally maintained their mechanical properties with little change under one year accelerated weathering simulation. The rapid deterioration of the impact strength and percentage of elongation of ABS is of critical importance as the material is used for many frontal applications in the vehicle system. During the course of one year accelerated weathering exposure, some of the properties were not altered noticeably. But it is expected that on further exposure to weathering, these properties will undergo considerable changes. All materials have shown the surface effects of ageing eventually but further exposure is required to argue whether all the materials will meet fitness for vehicle component with respect to safety during crash / impacts, aesthetics and durability.

FUTURE WORK

A long term study should be undertaken with more number of samples so that they are exposed to radiation for substantial amount of time. This will help determine the exact relation between degradation and exposure.

Spectroscopic studies (E.g. FTIR) of the test materials should be carried out in order to determine the exact composition and changes in the same as a consequence of weathering. This will be useful in tracing the degradation mechanisms of the test materials.

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