World Journal of Engineering Research and Technology
WJERT
www.wjert.org SJIF Impact Factor: 5.218

FORMULATION OF INDIA SPECIFIC WEATHERING CYCLE REQUIRED FOR POLYMER TEST

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Article Received on 10/01/2018 Article Revised on 31/01/2018 Article Accepted on 21/02/2018

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ABSTRACT

Weathering is the adverse response of a material or product to climate, often causing unwanted and premature product failure. The factors responsible for weathering are; solar radiation (light energy), temperature and water (moisture).[1] The specifications of weathering cycles in Indian standards derived based on European regulations, American standards or Japanese standards; hence the entire weathering specifications based on the respective countries data. These specifications may not be suitable for Indian weathering climate as well as usage requirements. Any material design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity, and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions.[2] Hence, deriving the data for the standards as per Indian requirements is of prime importance. In this context, collected the Indian climatic data from five different regions considering India is one of the largest geographical areas and standardize India specific weathering test specification/cycle. Daily solar radiation (light energy), temperature, humidity and rainfall data collected from metrology department of different regions of India for the period 5 years are used to study the climatology and spatial and temporal characteristics of Indian weathering variations. Comparison of the Indian wreathing data with the Global weathering cycle shows a variation in each parameters. The India specific weathering data collected during the course of this study will prove to be of significant importance to automobile

manufacturers, testing agency and useful in development of Indian weathering standards. Also India specific weathering study of polymers helps Indian automobile manufacturer for selection of polymers as per Indian conditions.

KEYWORDS: Weathering, solar radiation, temperature, humidity, weathering cycle, polymers degradation.

BACK GROUND

Products which are exposed to a variety of climatic conditions must be studied initially to determine the influences of different weathering conditions. The specific conditions to which a material is exposed dictate the type of degradation which occurs. Weathering is the adverse response of a material or product to climate, often causing unwanted and premature product failure. The factors responsible for weathering are; solar radiation (light energy), temperature and water (moisture). Solar irradiance on materials causes fading, color change, surface erosion, loss of gloss etc. Temperature's effect on material weathering includes thermal oxidation degradations, and accelerating of other weathering reactions. The influence of moisture on materials causes expansion and stresses that result in peeling, cracking, stress fractures and flaking etc. These factors in conjunction with secondary effects such as airborne pollutants, biological phenomena and acid rain, act together to cause "weathering". However, the major challenge is to predict long term behavior from short term laboratory or field exposures.[1]

Few examples illustrate that

- Any essential weathering parameter may have a prevailing impact on the degradation of any given material.
- Even though it is possible to plot and correlate properties of materials with a single parameter, parameters of weathering work in combination producing a result which is specific to the unique set of parameters of a particular experiment.
- Changes occur in the materials not only because of a photochemical or a thermooxidation process but mechanodegradation also plays very prominent role.
- The morphology of the exposed material may be affected even by milder conditions (e.g., indoor environment) which may contribute to material changes.
- Samples not exposed to aggressive weathering conditions also change.

Experimental studies have told us that we need to know the weather conditions for a particular place or a particular experiment.

LITERATURE REVIEW

Literature available in this field is very much scarce. The literature survey gives briefs on various types of plastic materials used in different applications and, their characteristic, martial composition, usage and limited information on changes of properties due to weathering. It also gives a brief in-sight into technical papers and various studies conducted by different authors / Institutions in the field of weathering on plastic materials, paints etc.[5]

Vishnu Shah explains that environmental factors have significant detrimental effects on appearance and properties. He identified factors of weathering such as solar radiations, microorganisms, bacteria, fungus, mold, high humidity, Ozone, oxygen, water, thermal energy, pollution and its properties which will affect on the plastics. Different techniques of weathering testing used to evaluate degradation of plastics due to weathering are discussed. Finally he has concluded generically effect of these factors on plastics.[6]

Weathering Testing Guidebook by Atlas Material Testing Solutions,[3] explains the Factors responsible for weathering which includes what is weathering, factors of weathering, secondary effects, synergy, climate, measuring factors of weathering etc., It also explains the types of weathering test such as Natural testing and Laboratory testing, procedure, evaluation etc. Which also explains the weathering cycles simulates the different weathering conditions of natural weathering and their standards. This helps to researches to select the type of testing, cycles required for simulation etc.

George Wypych work provides comprehensive and current information on material weathering including brief information on effect of weathering on for over forty families of polymers.[4] It presents following topics discussions:

- Photophysics, or physics of light, encompasses all important for weathering ranges of electromagnetic radiation including UV, visible and infrared radiation. The scope of photophysics interest includes; the nature of radiation, the absorption of radiation by materials, the radiation wavelength versus excitation energy, the fate and utilization of absorbed energy, the process of energy transfer, the emission of electromagnetic radiation.

- Parameters of exposure like radiation, temperature, humidity, oxygen, rainfall & condensation moisture, particulate and gaseous contaminates and stress and measurement.
- Effects of weathering on material properties like mass loss, depth of degradation, mechanical properties, changes of colour and optical properties, surface changes, molecular weight, chemical composition of surface and buck, etc. However, these studies are for limited exposure and concluded in generally.

Donald V. Rosato etl. have studied the effects of temperature on the plastics. In his studies he has concentrated mainly on the temperature as parameter. He has conducted the experiments to find out the changes in the property of plastics due temperature effect. But a little study is reported effect of radiation, flammability etc.

SAE technical paper No.:2003-01-1192 titled “Highly Predictive Accelerated Weathering of Engineering Thermoplastics explains that the test methods prescribed by SAE J1960 and ASTM G26A do not reliably predict outdoor weathering in Florida across a variety of engineering thermoplastics. The problem with the tests seems to be two-fold. The unnaturally short wavelengths of light over-accelerate some polymers, particularly polycarbonate. Second, the frequent, misting water spray allows buildup of degraded polymer and pigment on the sample surface that does not occur outdoors. The new test conditions seem highly predictive across a broad range of resin types and colors. This shows importance of weathering data/cycle between geographical regions and requirements of country specific data.[7]

SAE technical paper No.:2003-01-1195 titled “Development of a Carbon/Epoxy Body for a High Performance Vehicle explains the three accelerated environmental degradation methods used at Lamborghini have been described and criteria for composite system selection for exterior applications reviewed.[8]

SAE technical paper No.:2003-01-1191 titled “Weathering of Black Plastics for Automotive Exteriors explains the ten mold-in-color black polymers were evaluated for exterior weathering in an attempt to improve the specifications for exterior mold-in-color plastics to meet five year durability for a 95th percentile sunbelt customer. Four different weathering methods were utilized including Arizona exposure, Florida exposure, and Xenon arc exposures per the GMNA and the GM Europe methods. Colorfastness, gloss retention and other material property changes due to weathering were measured and analyzed against two

GM durability standards. For the appearance attributes, correlations between actual exposure and accelerated exposure were attempted. Test results before and after polishing were also analyzed. Finally, in addition to comparing the performance of the ten polymers, the four weathering methods are compared and discussed with recommendations for the preferred testing regimen.[9]

Paper titled "Effect of stabilizer type on artificial weathering of rigid PVC. II†" Society of Plastics Engineers,[10] explains that the determination of the effectiveness of lead (Pb) and mercaptotin (MT) stabilizers on the useful service life of poly(vinyl chloride) PVC in outdoor applications, necessitates testing the mechanical properties of the polymer before and after weathering, to learn its behavior in the outdoor environment. Artificial weathering was used, and four mechanical tests were carried out, namely tensile, flexure, impact, and fracture toughness tests. The Pb stabilizer system used gave better fracture toughness and impact strength after exposure. The tensile strength and modulus of elasticity of MT-stabilized specimens increased significantly after exposure, unlike Pb-stabilized specimens. Brittleness in unplastisized PVC can be attributed to a number of factors, such as unsaturation, carbonyl group concentration, stabilized concentration, crystallinity, and extent of dehydrochlorination. The tensile strength and modulus of elasticity increase in tin mercaptide stabilizers significantly with increased UV exposure, while the increase in Pb specimens is less significant. There is a continuous diminution of the percent of elongation at break in both types of Pb or MT specimens, with increased exposure. The ductility of Pb may be accounted for by PbO and Pb stearate $(C_{17}H_{35}COO)_2Pb$. One of the possible causes for the brittleness of tin mercaptide stabilized specimens is antiplasticization.

Studied different National / International standards requirements used for evaluation of different types of automotive components under weathering effects for vehicle certification purpose.[11-21]

Different SAE and ISO standards specify the test procedure of weathering for different polymers, textiles, colour, painting etc. These standards also specify the indoor and outdoor weathering, equipments, light sources etc. along with evaluation procedure and requirements.[22-27]

Different ASTM standards specifies the Standard Test Method for Tensile Properties of Plastics, Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating

Materials, Tensile Properties of Thin Plastic Sheeting, Test Method for Rubber Property Durometer Hardness[28-31]

- The plastics are the material for the automobile due to their many inherent qualities.
- Limited 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.
- Studies not related to performance of polymers with different percentage of stabilizers which meets the performance requirements of automobile application.
- Due to non-availability of Indian weathering data, studies not available on polymer degradation use of Indian climatic data.

The continued research on both the theoretical and practical aspects of polymer light stabilization conducted as against Indian weathering data will provide the basis for the successful development of new UV-stabilized plastics applicable for automobile.

WEATHERING

Weather in a particular geographic location has a unique set of conditions which are difficult to reproduce exactly in any research setup. The exact weather data for a given geographic location are very important to relate weathering rates of laboratory equipment to the actual weathering rates. Providing the data requires separate treatment and a different medium (database or software).

In this journal these weather fundamentals are addressed:

- The general relationships between geographic locations and magnitudes of basic parameters of weathering.
- Selected weather data for some reference locations.
- Selected weather data for moderate and extreme conditions where products are most frequently used or may be used, respectively.

Although many weather parameters work in combination we may evaluate them in a fundamental way only one parameter at a time. Such information is very useful in planning weathering studies and interpreting their results.

It is not practical to determine the weathering characteristics of materials in all of the world's climates. Therefore, benchmark climates selected for exposure testing are based on their known severity for the weathering of materials and the anticipated market of the product to that country. The major marketing area of the material should be taken into consideration when selecting suitable climates and sites for weathering tests of that country.

How close we are to this dream? Certainly, the duplication of selected weather conditions in a single test is not impossible. Laboratory instruments are designed (or at least they should be) to simulate outdoor conditions as closely as the current technology permits. Such a design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity, and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions.

There are three problems which require solution:

- Weather variability
- Which part of the year should be simulated
- Which climatic conditions are to be selected for products used worldwide.

These issues raise serious complications in testing. Natural weather variability is the simplest to deal with. This is routinely done by weathering services which base their typical conditions for a location on averages of test results collected over many year.[2]

Over 480 standards have been issued by the European Standardization Committee (CEN), the International Commission on Illumination (CIE), the German Standards Organization (DIN), the International Standardization Organization (ISO), the Association of German Automotive Manufacturers (VDA), and the Association of German Engineers (VDI) which are directly relevant to weathering and their conditions. In North America, over 110 similarly relevant standards have been issued by the American Association of Textile Colorists and Chemists (AATCC), the American Society for Testing and Materials, and the Society of Automotive Engineers (SAE). These standards have been tailored to fit requirements of weathering studies in the United States of America. More than 130 standards have also been issued by various corporations (mainly automotive companies). These standards are relevant in assessment of weathering properties of their products. Many other national and international organizations have also issued standards on material weathering.[2]

These standards include information on material weathering that may be classified as follows:

- General procedures, standard practices, terminology, and reference materials
- Practice of operation of various instruments, including open flame carbon arc, enclosed carbon arc, fluorescent light, and xenon arc
- Material or industry specific standards
- Product specific standards or recommendations regarding weathering.

Standards for accelerated tests were intended to predict the service life of components, these can be an excellent starting point for anyone planning to develop a new method or improve an existing method of weathering. The terminology used in these publications and the reference materials will assist researchers and those writing standards.

As a first time daily solar radiation (light energy), temperature, humidity and rainfall data collected from metrology department of different regions of India for the period 5 years are used to study the climatology and spatial and temporal characteristics of Indian weathering variations. The purposes of this work are to study the solar radiation (light energy), temperature, humidity and rainfall climatology and to examine the temporal and spatial characteristics of these parameters over India.

Even though data collection includes daily, monthly, yearly data, for the purpose of compressing the data, reported only five year average data, comparison of all five region of India and comparison with the international data.

DATA COLLECTION

There is no Indian weathering data available to conduct the study / test on polymers, hence it was decided to collect data for total Solar Radiation (MJ/m^2), Ambient Temperature (ºC), Relative Humidity (%). In view of large area of India and anticipated variations in climatic conditions, the data was collected at five cities namely; Pune, Delhi, Kolkata, Nagpur, Chennai representing Western, Northern, Eastern, central and southern respectively. Five year daily raw data was procured from the respective Meteorology departments and applied statistical tool to make a standard cycle for Indian weathering.

TOTAL SOLAR RADIATION

Total (or global), diffuse and direct radiation measurements have been collected by meteo-rological stations for several decades. There are several important measurement of different types of radiation which includes:

- Global Solar Radiation is the total incoming shortwave (usually <3000 nm) solar radiation coming from the entire dome of the sky as received on a flat, horizontally-mounted thermopile surface.
- Sky Radiation is that portion of the total incoming radiation received on a flat, horizontally-mounted thermopile surface which is shielded from the direct rays of the sun by a shade ring.
- Reflected Radiation is that portion of the total radiation which has been reflected from the Earth's surface and received on a flat, horizontally-mounted, downward-faced thermopile surface.
- Net Radiation is the net difference between incoming and outgoing radiation.

For the purpose of computation of weathering cycle, only total global solar radiation (MJ/m^2) (usually <3000 nm) was procured for 5 years data and same will be statistically derived.

The Tables 1 to 5 shows the total global solar radiation (MJ/m^2) data of India-Chennai (southern region), India-Delhi (Northern region). India-Kolkata (Eastern region), India-Pune (Western region) and India- Nagpur (central region) respectively. These tables also represents the total radiation of monthly for the five years for all the above referred regions. These data was derived from adding each day of total radiation for respective month. Table 6 shows the total global solar radiation (MJ/m^2) data of all India.

Table 1 compares the total solar radiation of India-Chennai (southern region) data. In this region gets more radiation in the month of March-May and less in the month of November-December, however there is not much difference in the rest of the months of the respective years.

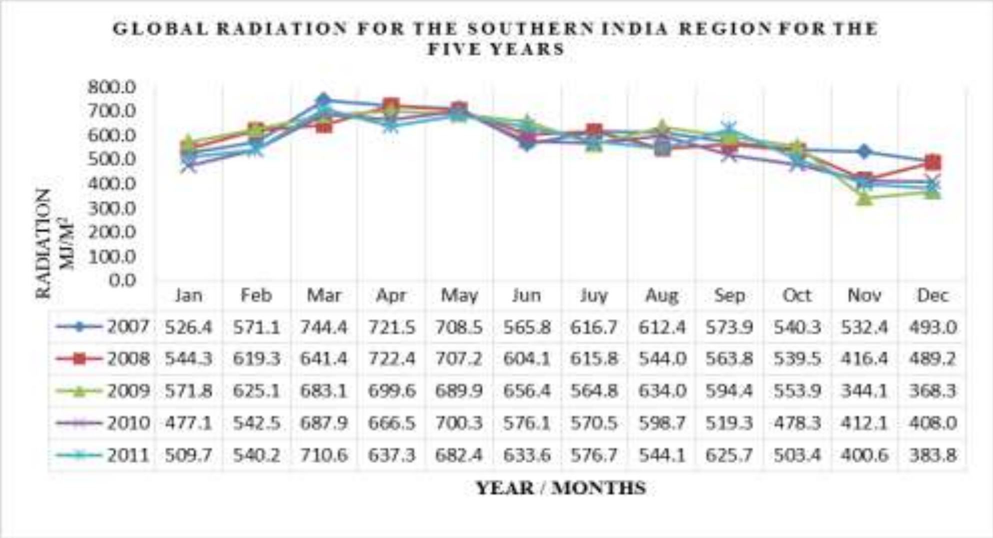

Table 1: Global radiation for the Southern India region for the five years.

Total Global Radiation for 5 years for Southern India	34584.4
Ave. global radiation for 5 years for Southern India	6916.9

Table 2 compares the total solar radiation of India-Delhi (Northern region) data. In this region gets more radiation in the month of April –May-June and less in the month of November-December-January, however there is not much difference in the rest of the months of the respective years.

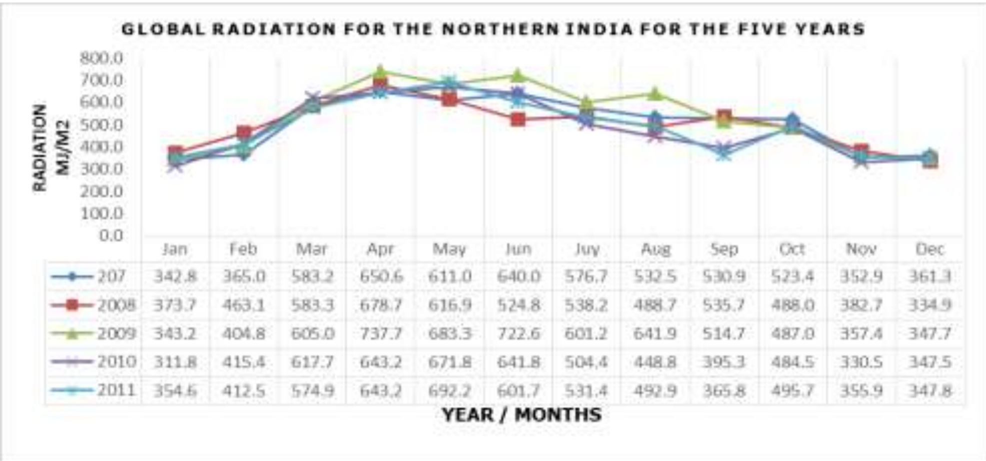

Table 2: Global radiation for the Northern region for the five years.

Total Global Radiation for 5 years for Northern India	30206.4
Ave. global radiation for 5 years for Northern India	6041.3

Table 3 compares the total solar radiation of India-Kolkata (Eastern region) data. In this region gets more radiation in the month of April –May-November – December and alomost same amount in all these months. However there is not much difference in the rest of the months of the respective years.

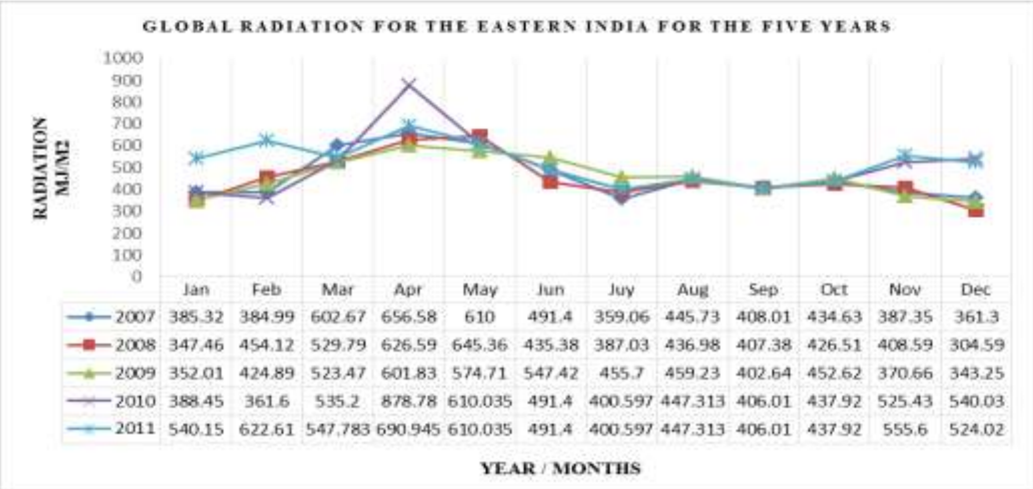

Table 3: Global radiation for the Eastern India for the five years.

Global radiation for the Eastern India for the five years	28742.4
Ave. global radiation for 5 years for Eastern India	5748.5

Table 4 compares the total solar radiation of India-Pune (Western region) data. In this region gets more radiation in the month of May and less in the month of November-December-January. Generally the radiations gradually start increasing from February till May and decreases in June and stable will be upto October. The figure also shows that in the month of October always slight increase.

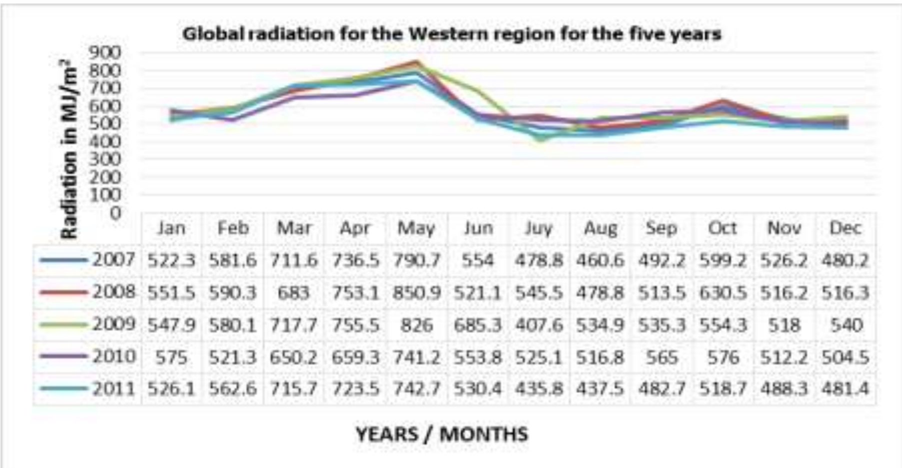

Table 4: Global radiation for the Western region for the five years.

Total Global Radiation for 5 years for western India	34832
Ave. global radiation for 5 years for western India	6966

Table 5 compares the total solar radiation of India-Nagpur (Central region) data. In this region gets more radiation in the month of May and less in the month of December-January. Generally the radiations gradually start increasing from March till May and decreases in June and stable will be upto October. The figure also shows that in the month of October always increase. However there is not much difference in the rest of the months of the respective years.

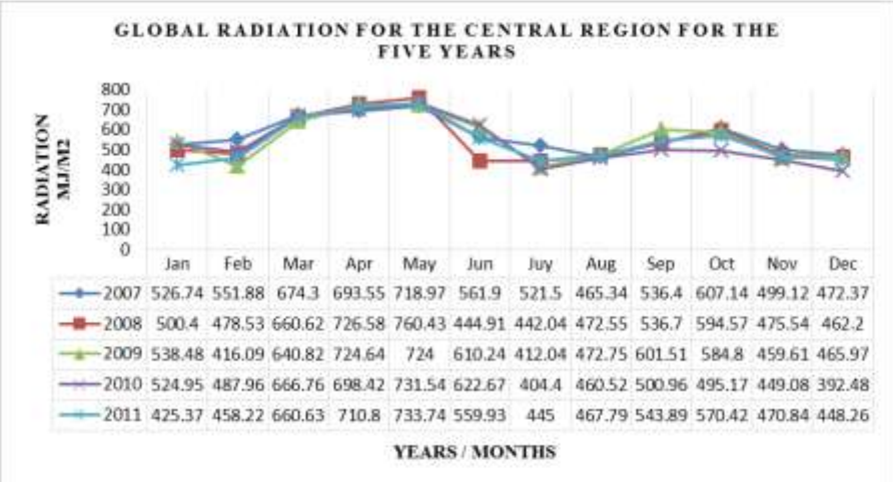

Table 5: Global radiation for the central India for the five years.

Total Global Radiation for 5 years for central India	32565.0
Ave. global radiation for 5 years for Central India	6513.0

Table 6 shows the total global solar radiation (MJ/m²) data of all India. The comparison shows that Southern India gets more global radiation followed by western region and eastern region India gets lesser radiations followed by Northern region. Central region gets average of all India data. Generally in Northern India gets maximum radiation in the month of May – June however it is reverse cycle in the month of December-January compared to all India.

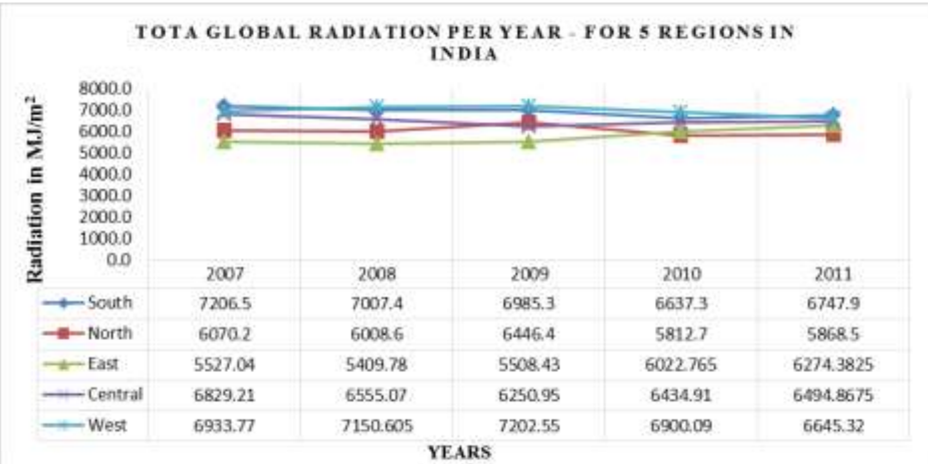

Table 6 shows the total global solar radiation (MJ/m²) data of all India.

Table 7 shows the comparison of total global solar radiation (MJ/m²) data of all India versus Miami-Florida, Phoenix-Arizona, Sanary surMer, France, Hoek van Holland and The Netherlands. The comparison shows that, average all India global radiations very close to the Miami-Florida and Sanary surMer, France. However observed major variation compared to all other countries data.

Table 7: Comparison of total Global radiation of all India versus Miami, Florida, Phoenix, Arizona, Sanary sur Mer, France, Hoek van Holland and The Netherlands.

Comparison of Global radiation MJ/m^2										
Year	**South India**	**North India**	**East India**	**Central India**	**West India**	**Avg. India**	**Miami, Florida**	**Phoenix, Arizona**	**Sanary sur Mer, France**	**Hoek van Holland, The Netherlands**
2007	7206	6070	5527	6829	6934	**6513**	6474	7974	6497	4129
2008	7007	6009	5410	6555	7151	**6426**	6310	8163	6497	4129
2009	6985	6446	5508	6251	7203	**6479**	6495	8111	6318	4172
2010	6637	5813	6023	6435	6900	**6362**	6288	7847	6293	4018
2011	6748	5868	6274	6495	6645	**6406**	6540	8278	6499	4267
Total for 5 years	34584	30206	28742	32565	34832	**32186**	32108	40373	32103	20715
Avg. for 5 years	6917	6041	5748	6513	6966	**6437**	6422	8075	6421	4143

TEMPERATURE

Temperature's effect on material weathering includes thermal oxidation degradations, and accelerating of other weathering reactions. "Rule of Thumb" is that 10°C increase in temperature doubles Rate of chemical reaction. Also solar radiation plus high temperature equals increased Rate of Degradation.

There is a substantial difference between temperatures reported by meteorological stations and temperatures recorded in weathering investigations. However temperature measurement in World Meteorological Organization (WMO) stations is in all probability the most precise measurement. In meteorological stations, air temperature is recorded with an instrument that is not exposed to or affected by radiation. Air does not absorb a lot of heat energy from infrared radiation thus the temperature measurements are lower than the temperature developed on a solid surface exposed to sun. Three types of measurements are performed: minimum temperature, maximum temperature and average temperature, all in specified time intervals. Like solar radiation data reported above, temperature and humidity is not reported in details even though all the data was available. However the average, maximum and minimum temperature compiled using each day data collected.

Table 8 shows the comparison of maximum temperature of all India versus Miami-Florida, Phoenix-Arizona, Sanary surMer, France, Hoek van Holland and The Netherlands. The comparison shows that, maximum average temperature with in India is in central India region. Also the comparison shows that, average all India maximum temperature does not matches with any other available data such as the Miami-Florida and Sanary surMer, France.

Table 8: Comparison of maximum temperature of all India versus Miami, Florida, Phoenix, Arizona, Sanary sur Mer, France, Hoek van Holland and The Netherlands.

Comparison of Temperature (^{0}C) - Maximum										
Year	**South India**	**North India**	**East India**	**Central India**	**West India**	**Avg. India**	**Miami, Florida**	**Phoenix, Arizona**	**Sanary sur Mer, France**	**Hoek van Holland, The Netherlands**
2007	33.4	31.68	31.85	34.62	32.2	32.8	30	30	22	14
2008	33.7	--	--	34.31	32.1	33.4	30	29	20	14
2009	35.5	31.97	--	35.42	32.6	33.9	30	30	20	14
2010	33.5	31.24	--	34.55	--	33.1	29	29	21	13
2011	34.2	31.06	--	33.61	--	33.0	31	29	21	14
Avg. for 5 years	34.1	31.49	36.34	34.50	32.3	33.7	30	29.4	20.8	13.8

Table 9 shows the comparison of minimum temperature of all India versus Miami-Florida, Phoenix-Arizona, Sanary surMer, France, Hoek van Holland and The Netherlands. The comparison shows that, minimum average temperature with in India is in western India region. Generally in the winter Northern region shows extreme coldest weather in December – February, however average statistical data shows western region is having minimum temperature. Also the comparison shows that, average all India minimum temperature does not matches with any other available data such as the Miami-Florida and Sanary surMer, France.

Table 9: Comparison of minimum temperature of all India versus Miami, Florida, Phoenix, Arizona, Sanary sur Mer, France, Hoek van Holland and The Netherlands.

Comparison of Temperature (^{0}C) – Minimum										
Year	**South India**	**North India**	**East India**	**Central India**	**West India**	**Avg. India**	**Miami, Florida**	**Phoenix, Arizona**	**Sanary sur Mer, France**	**Hoek van Holland, The Netherlands**
2007	24.6	19.10	24.56	20.72	18.6	21.5	19	16	13	9
2008	24.9	--	--	20.59	18.2	21.2	19	16	12	8
2009	24.5	19.33	--	21.30	19.6	21.2	19	16	12	8
2010	24.9	19.59	--	21.48	--	22.0	18	15	11	7
2011	24.1	18.89	--	20.23	--	21.1	19	15	12	9
Avg. for 5 years	24.6	19.23	24.56	20.86	18.8	20.9	18.8	15.6	12	8.2

Table 10 shows the comparison of maximum humidity of all India versus Miami-Florida, Phoenix-Arizona, Sanary surMer, France, Hoek van Holland and The Netherlands. The comparison shows that, maximum average humidity with in India is in southern India region. Also the comparison shows that, average all India maximum humidity does not matches with any other available data such as the Miami-Florida and Sanary surMer, France.

Table 10: Comparison of maximum humidity of all India versus Miami, Florida, Phoenix, Arizona, Sanary sur Mer, France, Hoek van Holland and The Netherlands.

Comparison of Humidity (%) - Maximum										
Year	**South India**	**North India**	**East India**	**Central India**	**West India**	**Avg. India**	**Miami, Florida**	**Phoenix, Arizona**	**Sanary sur Mer, France**	**Hoek van Holland, The Netherlands**
2007	75.73	74.28	76.2	64.03	74.41	72.93	93	41	80	88
2008	74.87	73.69	--	62.29	73.00	70.96	92	45	93	87
2009	70.84	70.57	--	62.97	72.44	69.20	91	45	81	91
2010	78.30	74.48	--	63.53	--	72.10	95	57	83	92
2011	72.72	75.36	--	64.82	--	70.96	94	44	81	90
Avg. for 5 years	74.5	73.7	76.2	63.5	73.3	72.2	93	46.4	83.6	89.6

Table 11 shows the comparison of maximum humidity of all India versus Miami-Florida, Phoenix-Arizona, Sanary surMer, France, Hoek van Holland and The Netherlands. The comparison shows that, minimum average humidity for the North India, Central India and West India is comparable. Also the comparison shows that, average all India minimum humidity does not matches with any other available data such as the Miami-Florida and Sanary surMer, France.

Table 11: Comparison of maximum humidity of all India versus Miami, Florida, Phoenix, Arizona, Sanary sur Mer, France, Hoek van Holland and The Netherlands.

Comparison of Humidity (%) - Minimum										
Year	**South India**	**North India**	**East India**	**Central India**	**West India**	**Avg. India**	**Miami, Florida**	**Phoenix, Arizona**	**Sanary sur Mer, France**	**Hoek van Holland, The Netherlands**
2007	67.2	49.0	69.0	48.8	48.3	56.5	53	15	39	62
2008	63.6	50.4	--	49.1	46.9	52.5	53	16	43	60
2009	58.8	46.6	--	47.5	27.2	45.0	47	16	43	62
2010	70.2	52.8	--	48.6		57.2	51	21	44	64
2011	63.8	53.3	--	49.0	--	55.4	49	17	42	63
Avg. for 5 years	64.7	50.4	69.0	48.6	40.8	54.7	50.6	17	42.2	62.2

DERIVATION OF INDIA WEATHERING CYCLE

Laboratory instruments are designed (or at least they should be) to simulate outdoor conditions as closely as the current technology permits. Such a design should permit the independent selection of the major degrading forces such as UV radiation, temperature, humidity and rain. Thus the selection of the right combination for a particular location and time of year should be easy and should give a cycle that truly simulates natural conditions.

Products which are exposed to a variety of climatic conditions (e.g., worldwide) must be studied initially to determine the influences of different climatic conditions. Depending on the product, an initial study may result in the selection of one set of the most accelerating conditions (as in the previous paragraph) or several conditions which must be separately addressed (by testing and formulation) to sustain material performance in adverse climatic conditions.(HB-CH8).

Table 12 shows the weathering cycle followed by different standards. These standards include information on material weathering that may be classified the test conditions which includes equipment used, type light source (xenon/carbon arc/UV/fluorescent light etc), cycle (light/dark), temperature(Black panel / chamber), humidity etc. The total Irradiance dosage (W m-2 nm-1) of the complete cycle is depending on the test requirements, type of sample, application, agreement between the buyer and seller of the product, hence it will varies from test to test.

The operation parameters contained in the standards, listed in Table 12, usually differed from standard to standard. The conditions specified in these product specific standards vary quite widely. For example, the black-panel temperature varies from 24 to 63^{0}C, with 60^{0}C the most frequently used. Water spray temperature ranges from 7 to 45^{0}C. Dry/wet cycle time is often 51/9 or 102/18, but 1/1 and 18/6 are also suggested. Some standards suggest a day and night cycle (D822 - 18/6 h; D3361 -1/1 h; D4028-5/2 days; D4303- 8/4 h). Generally, there is a freedom of choice. There is no a logical relation between the conditions of material performance and the ability to withstand environmental condition. The selection of test conditions seems to depend on the opinion of a particular standard committee on what is possible to achieve and test in existing equipment.

Table 12: Comparison of weathering cycle followed by different standards.

Standard	Filters	Cycle	Irradiance $W/m^2 .nm$	RH%	Temperature (BP)	Chamber Temperature	Spray
SAE J1885	Inner - quartz, Outer - Type S	Light 228	0.55 @ 340	50±5	89±3	--	no
		Dark 60	0	95±5	38±2	--	no
SAE J1960	Inner - quartz, Outer - Type S	Light 40	0.55 @ 340	50±5	70±2	--	no
		Light 20	0.55 @ 340	50±5	70±2	--	yes face
		Light 60	0.55 @ 340	50±5	70±2	--	no
		Dark 60	0	95±5	38±2	--	yes back
SAE J2212	Suprax to match CIE 85 (1989)	Light 228	80 @ 300-400	50±5	97±3	--	no
		Dark 60	0	95±5	38±2	--	no
ISO 4892-2-A	Day light filters	Light 102	0.51 @ 340	50±5	65±3		no
		Dark 18	0.51 @ 340	--	--		yes
ASTM D 4956	Day light filters	Light 102	0.51 @ 340	50±5	65±3	38±2	no
		Dark 18	0.51 @ 340	--	--		yes
ISO 105 B -04	Day light filters	Light 29	0.35 @ 340	30±2	-	40±2	no
		Light1	0.35 @ 340	--			yes

Generally there are three problems which require solution namely weather variability, which part of the year should be simulated and which climatic conditions are to be selected for products used worldwide. These issues raise serious complications in testing. Natural weather variability is the simplest to deal with.

To deal with above problems, derived India specific weathering cycle based on the above data. Table 13 shows three different weathering cycle derived from three basic standards generally followed in India in different applications.

Individual manufacturer may be select different parameters specific to region if required based on above data. Similar results are also available for the extreme conditions in a particular location.

Table 13: Indian weathering cycle derived based on five year Indian data collection.

Standard	Filters	Cycle	Irradiance W/m^2 .nm	RH%	Temperature (BP)	Chamber Temperature	Spray
India Cycle 1 - Derived based on ISO 105 B -04	Day light filters	Light 29	0.35 @ 340	70±2	-	35±2	no
		Light1	0.35 @ 340	95±5	-	--	yes
India Cycle 2 - Derived based on SAE J1960	Inner - quartz, Outer - Type S	Light 40	0.55 @ 340	70±2	-	35±2	no
		Light 20	0.55 @ 340	70±2	-	35±2	yes face
		Light 60	0.55 @ 340	70±2	-	35±2	no
		Dark 60	0	95±5	-	--	yes back
India Cycle 3 - Derived based on SAE J1885	Inner - quartz, Outer - Type S	Light 228	0.55 @ 340	70±2	-	35±2	no
		Dark 60	0	95±5	-	35±2	no

CONCLUSION

- In the absence of Indian weathering data to conduct the study / test polymers, five year data was collected which includes total Solar Radiation (MJ/m^2), Ambient Temperature (ºC), Relative Humidity (%).
- Data was collected at five cities namely; Pune, Delhi, Kolkata, Nagpur, Chennai representing Western, Northern, Eastern, central and southern respectively and applied statistical tool to make a standard cycle for Indian weathering.
- Analysed and presented the general relationships between geographic locations and magnitudes of basic parameters of weathering
- Comparison was made with international weathering data with Indian data
- Derived three India specific weathering cycle based on the five years data

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