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A Conceptual Review of Weathering Testing Using Malaysian Tropical Timber

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Abstract

History of accelerated weathering testing as a tool to explain the nature of weathering with a faster outcome has been documented since the 1940s. There are various method applied as accelerated weathering testing, i.e., cyclic boil-dry test, automatic boil test and QUV instrument. One of the recently conducted worldwide in accelerated weathering testing was QUV accelerated weathering. QUV instrument gives information about how materials degrade to the extended exposure environment within a reasonable time frame. Furthermore, QUV instrument employs the wavelength simulating with real-life solar radiation. Thus, applications of accelerated weathering testing in timber industry really give fast response to manufacturer in improving their timber product for long term usage. The conceptual review has studied on the application of QUV instrument in the accelerated weathering testing since 1997 till 2014. Accelerated weathering testing as a simulation of natural weathering was used in determining the long-term serviceability of Malaysian tropical timber in the extended environmental exposure.

Keywords: Accelerated weathering testing; QUV instrument; Malaysian tropical timber; extended environment exposure

Abstrak

Sejarah berkaitan ujian luluhawa dipercepat sebagai alat untuk menjelaskan sifat luluhawa semulajadi dengan hasil yang lebih cepat telah direkodkan sejak tahun 1940-an. Pelbagai kaedah kajian yang wujud dalam ujian luluhawa dipercepat, seperti contoh, kitaran didih-kering, automatic didih dan alat QUV. Salah satu kaedah kajian yang dijalankan secara meluas dalam ujian luluhawa dipercepat adalah dengan menggunakan alat QUV. Alat QUV ini memberikan maklumat tentang cara sesuatu bahan menjadi rosak selepas terdedah kepada persekitaran lanjutan dalam kerangka masa yang ditetapkan. Tambahan pula, alat QUV ini menggunakan pengsimulasian panjang gelombang dengan sinaran suria yang sebenar. Oleh itu, penggunaan ujian luluhawa dipercepat dalam industri kayu menyediakan pengujian yang pantas untuk meningkatkan produk kayu bagi kegunaan jangka panjang. Kajian ini akan mengulas secara terperinci terhadap konsep penggunaan alat QUV dalam bidang penyelidikan ujian luluhawa dipercepat sejak tahun 1997 hingga 2014. Penggunaan ujian luluhawa dipercepat sebagai simulasi kepada luluhawa semulajadi adalah penting dalam menentukan kebolehkhidmatan jangka panjang terhadap kayu tropical Malaysia yang terdedah kepada persekitaran lanjutan.

Kata kunci: Ujian luluhawa dipercepat; alat QUV; Kayu tropical Malaysia; pendedahan kepada persekitaran lanjutan

1.0 INTRODUCTION

In the last decades, the increased utilizations of timber for structural applications have been significantly contributed to the rapid increase in the amount of research in the timber industries. As timber manufacturing is aiming to produce a structural product for long term usage, there is a need for the research on timber weathering in order to enhance the proper selection of timber, advance in timber protection, and offer valuable timber end-products.

Weathering occurs due to slow degradation in a complex combination of chemical, mechanical and light energy of exposed timber [1, 2]. Many studies have been done on the factors that contribute to the timber weathering. In general, light, high temperature and moisture contribute to timber weathering. Timber when used as structural components needs to possess good ability to withstand environmental effects when exposed to outdoor environment or in air-conditioned room as well as in high humidity condition. When timber is exposed to outdoor environment, this will contribute to the photo-oxidative or photochemical degradation of its surface in natural weathering [2].

Other than surface degradation, weathering will result in mechanical stress and physical changes [3, 4]. Williams [2] reported the effects of ultraviolet (UV) portion of the solar spectrum on timber properties, such as mildew growth, checking, splitting and warping as shown in Figure 1.

Since the 1940s, analysis on timber weathering that has been conducted for a century has rapidly evolved from natural weathering testing to the acceptance of artificial weathering testing, or better known as accelerated weathering testing [4]. Even though natural weathering testing provides real life exposure and ultimately delivers realistic results of timber weathering with inexpensive cost, the development of analysis of natural weathering testing into accelerated weathering testing is due to the fact that natural weathering testing can be time consuming.

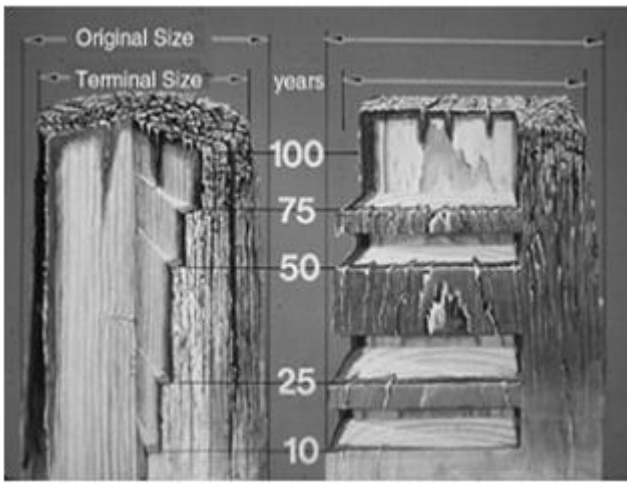

Figure 1 Simulation of 100 years of weathering of posts showing checking and erosion of the surface.

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In order to determine the life span of Malaysian tropical timber product, the timbers need to be exposed to the extended environment. There are many accelerated weathering testing methods specified in standards for evaluating the physical and mechanical performance of wood-based panels such as cyclic boil–dry (CBD) in ASTM D 1037-93 [5], automatic boil test in ASTM D 3434-2006 [6] and operating fluorescent ultraviolet (UV) lamp apparatus or betterknown as QUV instrument in ASTM G154 [7]. Therefore, in this study, QUV instrument will be reviews in details due to recently used worldwide and availability of the equipment.

2.0 LITERATURE REVIEWS

2.1 Durability: Accelerated Weathering Testing

Bontz and Wonneberger [8] explain that design parameters need to cover weathering testing that can possibly contribute to dangerous performance and result in the structural components becoming less durable. Durability is defined as the ability of a material to withstand environmental stress over an extended period of time [9]. The durability of a building, assembly, component, product, element, or construction can be thought of as the capability of that object to provide and sustain acceptable performance over a specified time under designed operating conditions.

Accelerated weathering testing maximizes the effects of weathering factors such as heat and moisture on shrinkage and swelling stresses, which influence physical and mechanical changes of the product. Accelerated weathering testing is carried out for three major purposes. Firstly, to establish in a conveniently short time the relative ranking of materials with respect to their physical and mechanical durability. Secondly, to estimate the potential long-term serviceability of material systems under expected use condition. Thirdly, accelerated weathering testing has ability to speed up the processes of deterioration in the laboratory [10].

Lee, Pourdeyhimi and Martin [11] have studied standard weathering test methods have shown that precise understanding of morphological changes of exposed material is crucial. This evaluation is important in preventing misinterpretation of weathering effects and material's durability.

Sanberg and Soderstrom [12] have reviewed enormous research work which focuses on six aspects of weathering effects. The weathering effects are color change, wood erosion [13], influence of free

radicals, wettability, anatomical changes and strength performance. In addition, Rowell [13] reveals weathering effects of his experimental work on ultraviolet radiation and weathering resistance. It has been discovered that weathering effects of weight loss, erosion rate and depth of penetration occur after 700 hours of accelerated weathering for acetylated aspen [13].

Furthermore, three factors that influence material durability are precise monitoring, analysis of appearance and surface defects [11]. Table 1 summarises selected timber species from Malaysian tropical timber useful for further study on artificial weathering testing due to their specifications of not being naturally durable and requiring treatment [14]. A study by Williams shows the importance of the parameter for timber density which results in the depth of penetration of UV radiation into denser wood shown to be lower [2].

Table 1 List Of durability of malaysian tropical timber [14]

Durability	Timber	Strength Class	Density (kg/m^2)
Not naturally durable and requiring treatment	**Pauh Kijang**	SG3	1100
	Kapur	SG4	780
	Merpauh	SG4	780
	Bintangor	SG5	710
	Mengkulang	SG5	800
	Keruing	SG5	830
	Jelutong	SG6	480
	Light Red Meranti	SG6	500
	Sesendok	SG7	550

2.2 QUV Instrument Simulate The Natural Weathering

In their study, Russo, Acierno, Marinucci, Greco and Frigione [15] have proposed that accelerated weathering as simulation of natural weathering in one or more weather-like conditions achieves greater levels than those occurring naturally.

Thus, QUV instrument manufactured from Q-Panel Supplier list out 11 factors that influence the relationship between tester exposure and outdoor exposure as comparative data, namely, variable on geographical latitude, level of altitude, local geographical features, variations in the weather from different years, seasonal weather variations, sample placement, different degrees of degradation of insulated sample that degrade 50% faster than uninsulated samples, standardized procedure of cycle of operation, standardized procedure of temperature applied in the operation, variations of the sample and degree of spectral power distribution(SPD) of the UV lamps.

Table 2 explains in details about preferred exposure condition when selecting programs of UV exposure in accelerated weathering testing. Moreover, the exposure cycle was determined based on type of UV-lamp used in each instrument, namely, UVA-340 and UVB-313. These types of UV-lamps are categorized based on short wavelength that simulate solar wavelength. UVA-type built with short wavelength closely simulate solar cut off, meanwhile UVB-type short wavelength is below the solar cut-off, which result in unrealistic outcomes [16].

Variance of typical irradiance was control by the inherent spectral stability of its fluorescent UV lamps. Overall, exposure cycles are based on 12 hour cycle of exposure condition. They are divided into UV lamps exposure, which vary from 8 hours to 20 hours, and condensation exposure (mainly for 4 hours).

2.3 Application of QUV Instrument

Patel, Tikhtman, Lee and Scott [17] have carried out experimental work on accelerated weathering testing. Repeatability and reproducibility of the instrument are important measurement in Patel et al., study. The ability to duplicate results from one test to another is referred to repeatability measurement, while reproducibility can be described as the ability of instrument of the same model to duplicate test results.

Acceptance of QUV instrument in accelerated weathering testing has begun in the early 1970s by application of UV-emitting fluorescent lamps [18]. Moreover, many researchers have been developed weathering analysis in a short time-frame to provide improved results to the manufacturers [19]. Hence, accelerated weathering testing becomes commonly used nowadays in timber weathering analysis.

The applications of QUV weather tester in a simulation of the natural weathering by replicating the short wave UV spectral region cause most weathering damages.

Previous study done using artificial accelerated weathering had listed out seven stages in QUV weather tester that followed the ASTM designation [4]. In detailed analysis, each cycle of 0, 1, 2, 4, 8, 16, and 32 cycles consisted of 4 hours of fluorescent ultraviolet light (UV-B, 313/280nm) at 60°C, and 4 hours of condensation at 40°C, to accelerate the deterioration caused by ultraviolet light and water.

The American Standard of Testing Material [7] has summarized nonmetallic materials testing according to specific UV exposure cycle conditions, such as:

1. Cycles 1 for coatings and plastics;
2. Cycles 2 for coatings;
4. Cycles 3 and 4 for exterior automotive materials;
5. Cycles 5 for roofing materials;
6. Cycles 6 for high irradiance exposures of coatings and plastics; and,
7. Cycles 7 for thermal shock and for erosion testing of coatings for wood.

Mitra, Athire and Malik [3] have used exposure conditions of Cycle 2 that are specifically designed for erosion testing of coating material. Meanwhile, some modifications in methodology need to be considered

when using different types of QUV instrument. For instance, Rajkovic, Bogner, and Radovan [1] have used cycle 6 in QUV instrument type UV-A. This cycle has been designed for high irradiance exposure of coatings and plastics. The experiment was conducted with 24-hour cycle

Table 2 Exposure Conditions Astm G154 [7]

Cycle	Lamp	Typical Irradiance	Approximate Wavelength	Exposure Cycle
1	UVA-340	0.89W/m²/nm	340 nm	8 h UV at 60 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
2	UVB-313	0.71 W/m²/nm	310 nm	4 h UV at 60 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
3	UVB-313	0.49 W/m²/nm	310 nm	8 h UV at 70 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
4	UVA-340	1.55 W/m²/nm	340 nm	20 h UV at 80 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
5	UVB-313	0.62 W/m²/nm	310 nm	8 h UV at 60 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
6	UVA-340	1.55 W/m²/nm	340 nm	8 h UV at 60 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature
7	UVA-340	1.55 W/m²/nm	340 nm	8 h UV at 60 (±3)°C Black Panel Temperature; 0.25 h water spray(no light), temperature not controlled; 3.75 h Condensation at 50 (±3)°C Black Panel Temperature
8	UVB-313	28 W/m²/nm	270 to 700 nm	8 h UV at 70 (±3)°C Black Panel Temperature; 4 h Condensation at 50 (±3)°C Black Panel Temperature

consisted of eight hours of UV radiation with the UVA-340 lamps at 60°C and followed by four hours of condensation at 50°C. These cycles would be repeated and the samples were withdrawn after 1, 4, 8, 12 and 16 weeks.

In accelerated weathering testing with timber sample, the QUV instrument need to be modified in order to allow the maximum UV-lamp exposure conditions. Commonly, it is recommended to make some modification at the door attached to main QUV instrument, as shown in FIGURE 2.

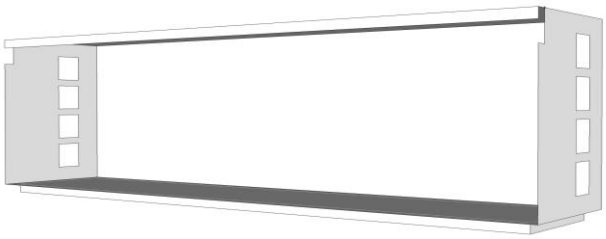

Figure 2 Modification At door of quv instrument for timber sample in accelerated weathering testing.

2.4 Color Changes

There were also studies which had investigated color changes. After accelerated weathering testing was conducted, exposed timber specimens were evaluated by Baur, Easteal, Edmonds, Waddingham, Jones and Devendra based on color values [20]. Parameter for evaluation based on color changes is also supported by another research conducted by Williams on accelerated weathering testing [2].

Rowell, Susott, De Groot and Shafizadeh [21] carried out experimental studies on bonding fire retardants on wood. Rowell, *et al.*, [21] concluded that degradation mainly occurred in the lignin component, which contributed to color changes.

Lignin as an adhesive component in the cell wall plays a role in holding together the cellulose fibers which will result in the cellulose becoming less susceptible after rapid degradation of lignin [22]. Thus, accelerated weathering testing provides evidence in the process of exposed timber surface becoming rough and resulting in a change in color.

Therefore, a study on the color changes of Malaysian Tropical Timber need to be evaluated when conducting accelerated weathering testing. Surface

colors of some Malaysian Tropical Timber are summarise in Figure 3

Figure 3 Surface color of malaysian tropical timber

2.5 Strength Performance

Yildiz, Tomal, Yildiz, and Ustaomer [23] carried out experimental studies on the effect of artificial weathering testing on timber strength performance. Data collected showed that sample exposed to artificial weathering testing for 1600 h achieved maximum strength losses. Furthermore, experimental work done by Yildiz *et al*., [23] concluded that mechanical performance in hardwood species was better than softwood species after being exposed to artificial weathering testing.

Thus, grading of the timber is important before permitted in the structural member. Timber is graded using visual strength grading rule for hardwood structural grade (HSG) based on Malaysian Standard MS1714 [24] to select the quality timbers for making glulam beams. The grader will be examined and grade the timber according to the established rules (FIGURE 3)

Figure 3 Visual grading process; a) measuring the specimen, b) identifyingthe species of the specimen, c) checking the defects, d) checking moisture content, e) grading the sample

The defects that might exist in timber are sloping grade, curvature, holes, borer, knots (Figure 5), decay wood (

Figure **5**6), sound sapwood, wane (FIGURE 6), end splits, twist, brittle heart, open shakes, surface checks and end checks. Decay wood needs to be discarded due to reduction of strength performance of the timber tested [9].

The strength performances were determined statistically in four- point bending under loading at a constant rate until the test specimens failed. There were two main properties of the test specimens which were evaluated, namely, modulus of elasticity (MOE) and modulus of rupture (MOR).

MOE is defined as the ratio of stress strain up to the proportional limit while MOR is a measure of ultimate strength based on the maximum load carrying capacity of the test member.

Commonly four-point bending test was designed in accordance with ASTM D198 [25] with the span-to-depth ratio of 18. The test was carried out in a universal testing machine (UTM) equipped with a 2500kN load cell as shown in FIGURE 7. The test was conducted to fail between 5 to 10 minutes with a loading rate of 0.05mm/min. The data acquisition was collected through the data loggers

3.0 CONCLUSION

QUV instrument used in accelerated weathering testing has become one of the techniques widely used for assessment in quality control and certification of materials used. It is theoretically accepted that QUV instrument have employ the wavelength simulating with real-life solar radiation. Furthermore, QUV instrument provides information about how materials degrade due to the environmental exposure within a reasonable time frame and accepted as a qualitative indicator. Thus, this conceptual reviews paper comes to a conclusion that timber weathering using QUV instrument will give significant reproducible result of data beneficial for manufacturers that need fast screening improvement of timber products.

Figure 4 Knot

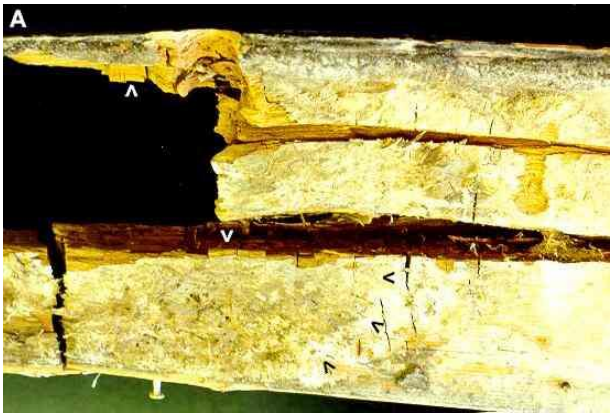

Figure 5 Decay wood

Figure 6 Wane

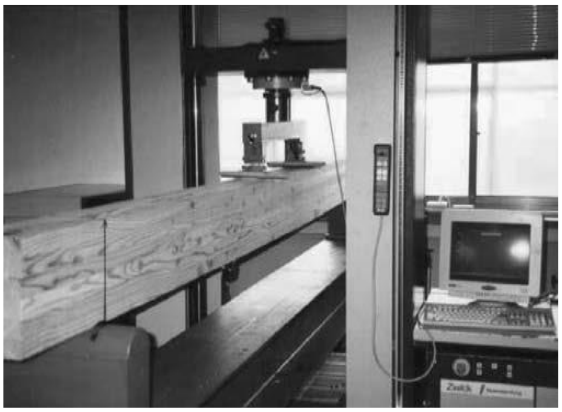

Figure 7 Full-scale four-point bending test setup

4.0 MANAGEMENT IMPLICATION

The conceptual reviews paper on applications of accelerated weathering in timber products since the 1940s for long term usage, especially accelerated weathering testing using QUV instrument. Future studies need to be done on development and modifications of conditions using QUV instrument to achieve real-life environment for timber weathering. Evaluation of timber after accelerated weathering testing needs to be precisely done, mainly on the morphological changes because timber is built from a complex component.

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