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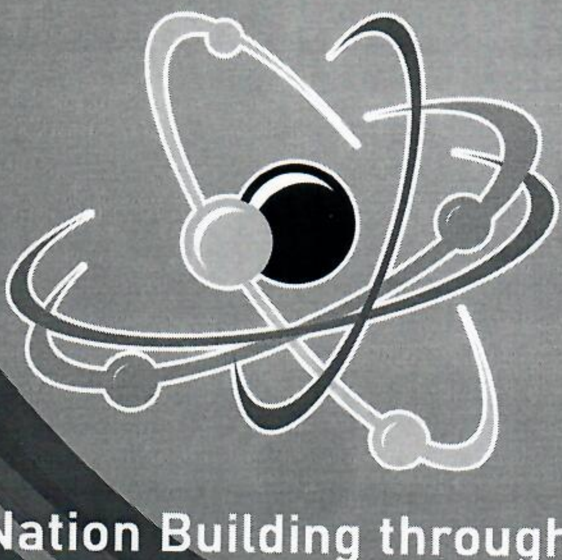

Nation Building through

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24th–25th May, 2019, University of Yangon

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The Studies on the Changes of Properties of a Myanmar Lesser_used Timber Species Following Gamma Irradiation

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Abstract— **The irradiation processing of polymeric materials is a main step in certain modern technologies. On the other hand, polymeric materials included in parts of irradiation facilities or in nuclear plants are subjected to the action of ionizing radiation in the presence of air. These facts explain the high interest in the study of radiation effects on polymers. Timber is a polymeric material and also it is successfully employed as a structural or decorative material in a wide variety of application. In Myanmar, timber is extensively employed as a structural and decorative material in a wide variety of applications as well as being a major export commodity. In fact, the commercially important timber species will become scarce due to the development of wood- based industries and increased domestic and international trade. Thus, the Forest Department has considered that commercially important timber should be substituted by other appropriate woody species or by some lesser-used timber species (LUS). In collaboration with International Tropical Timber Organization (ITTO), the Forest Department has undertaken a project on "Introducing Myanmar's Lesser-Used Timber Species to the World Market". The radiation techniques for the improvement of the quality of these LUS are new to us. In this project, the changes in physical properties such as dimensional changes and specific gravity, and mechanical properties such as static bending test, compression tests and hardness tests of Leza, a lesser used Myanmar timber species, following radiation processing with 10kGy gamma radiation has been studied. The timber samples were obtained from Timber Physical Section and Timber Mechanical Section, Forest Research Institute (F.R.I), Yezin and these samples were informed to be collected from Kabaung Reserve Forest of Taunggu Forest Division. The results for these tests were analyzed at 95 percent confidence level by using Statistical Analysis System. The results revealed that although the physical properties of Leza are not significantly changes at 95 percent confidence level, the results for strength properties of Leza are significantly changed at 95 percent confidence level after gamma radiation.**

Keywords: **Gamma Radiation, Irradiation, Timber, Leza, Strength Properties, Physical Properties**

I. Introduction

Radiation technology is commonly used for radiation processing, tracer technology, nuclear control system, non-destructive testing and nuclear analytical techniques, etc. The general advantages include reliability and simplicity of process control, reduction or complete elimination of industrial pollutant, and superior of even unique quality of product. Radiation processing is to upgrade the quality of the products by using ionizing radiation. It essentially involve absorption of large quantities of ionizing radiation energy from the radiation source into substrates, resulting in useful modifications in the material properties rendering them more useful or enhancing their commercial value. There are two main radiation-initiated polymerization methods used to cure monomer in wood; Gamma radiation and electron beam.

When gamma-radiation passes through a material such as wood or a vinyl monomer it leaves behind a series of ions and excited states as the energy of the γ-ray is absorbed through photoelectric, Compton and pair production collisions. (Co-60 produce tow γ-ray of 1.17 and 1.33 MeV. Approximately 30eV is required to rupture a covalent bond and to cause ionization). The ions and excited states generated in the absorbing material immediately rearrange to form free radicals, which in turn initiate the polymerization process.

$$(\text{Monomer}) \rightarrow R + H^{*}$$

The free radicals usually consist of H* and the radical monomer. Once the free radical is generated, the polymerization reaction is the same as that of the above normal free-radical catalyzed, vinyl monomer bulk polymerization [14].

With the gamma radiation, polymerization rate and extent of polymerization within wood pores are depend on the type of monomer, other chemical additives, wood species and radiation dose rate. An example of radiation polymerization of the vinyl type monomer, MMA using Co-60 γ-ray dose rate of 56,30, and 9 rad/s produce exotherms at 120 C, 90C, and 70C, respectively, with reaction times of 5,7,and 12h, respectively, produced 0-8-% wood weight gain. A 1.5-2.5 Mrad dose of gamma irradiation from a Co-60 souce is isotope activity 20,000 Ci can be used to polymerize MMA in wood. Polymerization rate of vinyl compounds in wood, by gamma-ray irradiation decreases in the presence of oxygen giving 50-90% conversion for styrene, methyl-, ethyl-, propyl-, and butyl methacrylates, and 4-8% conversion of vinyl acetate. Radiation polymerization of the vinyl monomers butyl methacrylate and styrene in different wood species, using cobalt 60- γ-ray radiation at various doses at a dose rate of 100 rad/s exotherms with different monomer concentrations, produced 5-140%polymer retention [3]. The radiation dose required for complete conversion during polymerization in an inert atmosphere was 1.5-2 Mrad for spruce and 20-25 Mrad for pine, polar and beech [3].

Wood as a mixer of high-molecular-weight polymer, when exposure to high-energy radiation, it will depolymerize the polymers by creating free radicals along the C-C backbone to initiate polymerization. If two free radicals are created on separate chains in close proximity, corss-linking will take place. Thus, when radiation exposure reaches 1.0

Mrad, some slight increase in mechanical properties and a decrease in hygroscopicity normally take place. If the free radical is created near a reactive or functional group, other type of reactions, not cross-linking reaction, normally take place. When the free radical is on a tertiary carbon, dis- proportionation will occur with chain scission. The effect on wood properties was negligible up to a dose of 10.0 Mrad, but higher radiation does led to strength and toughness losses (Simunkova et al. 1983). When radiation doses achieve 3 x 108 rd, the wood will be completely soluble [14]. Consequently, the theoretical radiation doses for polymerization of monomers and graft of wood consequents are normally below 10 Mrad.

However, as the vinyl monomers are normally non-polar and the wood's cell wall structure is not swollen by the monomers, there is little opportunity for the monomer to reach the free-radical sites, generated by the γ-radiation on the cellulose, to from vinyl polymer branch, and there is little if any interaction with the hydroxyl groups attached to the cellulose molecule. Consequently, in general, most vinyl polymers simply bulk the wood structure by filling the capillaries, vessels and other voids within wood.

Tables are not prescribed, although the various table text styles are provided. The formatter will need to create these components, incorporating the applicable criteria that follow.

The radiation processing of polymeric materials is a main step in certain modern technologies [35]. Irradiation of polymer results in several structural changes owing to radiation induced physical and chemical process [7]. In Myanmar, radiation applications have already been made in sterilizing human tissue-grafts at Kyee-Myint-Dine Orthopedic Hospital, Yangon. Research and development of radiation cross-linking of natural rubber latex has been introduced by Mar Mar Oo [16, 17]. On the other hand polymeric materials included in parts of irradiation facilities or in nuclear plants are subjected to the action of ionizing radiation in the presence of air. These facts explain the high interest in the study of radiation effects on Polymers.

Timber is a polymeric material. Timber is a successfully employed as a structural or decorative material in a wide variety of applications. Development of useful polymer-wood combinations followed extensive research on the effects of radiation on wood and the lignin –carbohydrate complex of which it consists. Changes in mechanical properties of irradiated wood are caused by radiation-chemical processes. These result in higher solubility in water, mainly as a consequence of breaking polysaccharide micro molecules into products of smaller molecular weight.

In Myanmar, timber is extensively employed as a structural and decorative material in a wide variety of applications as well as being a major export commodity. In fact, the commercially important timber species will become scarce due to the development of wood-based industries and increased domestic and international trade. Thus, the Forest Department has considered that commercially important timber should be substituted by other appropriate woody species ir by some lesser-used timber species (LUS). In collaboration with International Typical Timber Organization (ITTO), the Forest Department has undertaken a project on "Introducing Myanmar's Lesser_Used Timber Species to the world market". At present, the Forest Department is exploring the use of fifty four lesser-used timber species. By acquiring better knowledge of such species and techniques to improve their quality at the Forest Research Institute (FRI), Yezin [39]. The radiation techniques for the improvement of the quality of these of the quality of these LUS are new to us.

Exposure to 10kGY gives slight increase in mechanical properties. Above this level cellulose is degraded and mechanical properties decrease rapidly. Low exposure lead to temporarily inhibit growth of fungi [14]

So far, the objective of this study id to investigate the changes in physical and mechanical properties of Myanmar lesser-used timber species following radiation processing with 10 kGy gamma radiation.

II. MATERIAL AND METHODS

A. *Material*

Leza [Lagerstroemia tomentosa Presl], which is one of the lesser-used timber species (LUS) of Myanmar, has been selected for this study. The wood samples were obtained from timber physical Section and Timber Mechanical Section, Forest Research Institute (F.R.I), Yezin. The wood samples were informed to be collected from Kabaung Reserve Forest of Taunggu Forest Division. Authentication of plant species and identification of wood samples were done in the Herbarium Section and Wood Anatomy Section in F.R.I, Yezin.

B. Sample Preparation

Some physical properties such as dimensional changes and specific gravity, and some mechanical properties such as static bending, compression and hardness tests were carried out in this study. The test samples were prepared to the procedure described in ASTM designation D143-83 developed by American Society for Testing and Materials (ASTM). Measurements of the test specimens had been made to an accuracy of not less than ±0.3%. Care was taken that each and every samples was free from defects such as knots, decay and drying. All the tested samples were prepared at the F.R.I Wood workshop.

The size and the number of samples tested for each of the physical properties are given in Table 1 and for each of the mechanical properties are also given in Table 2. To know the mechanical properties of one particular timber species, green test (above FSP) and air-dry-test (at 12%) are usually performed. In this study only air-dry test which is more applicable than green test were carried out because of the limit number of sample obtained from FRI.

Table 1
Size and Number of Sample for Physical Properties Test

Name of Test	Size of Sample	Number of sample
Radial Shrinkage	1 in x 1 in x 4 in	8
Tangential Shrinkage	1 in x 1 in x 4 in	8
Specific Gravity & Volumetric Shrinkage	2 in x 2 in x 6 in	12

Table 2
Size and Number of Sample for Physical Properties Test

Name of Test	Size of Sample	Number of sample
Static Bending	20mm x 20mm x 300mm	60
Compression Parallel	2 in x 2 in x 8 in	60
Compression Parpendicular	2 in x 2 in x 6 in	60
Hardness	2 in x 2 in x 6 in	60

C. Methodology

Physical Properties Measurement carried out on the Samples. The principle tests made on both unirradiated wood samples and irradiated samples and the physical properties evaluated are: Radial shrinkage, Tangential Shrinkage, Volumetric Shrinkage and Specific gravity.

Out of the samples, 4 samples for radial shrinkage, 4 samples for tangential shrinkage and 6 samples for volumetric shrinkage and specific gravity were then irradiated with 10kGy gamma radiation by using a gamma chamber from Department of Atomic Energy. The activity of this chamber is 12000Ci and irradiated volume is 5000cc approximately. The diameter of the sample chamber is 17.2cm and the height is 20.5cm. Irradiation time was 1 hour as its dose rate was 10kGy per hour at that time of test.

To determine the radial shrinkage and tangential shrinkage, green dimension of the tested sample were measured by slide clipper and for volumetric shrinkage and specific gravity, the green volume was obtained by using the water displacement method as designated in ASTM D-143. After these measurements, the tested samples were put in an oven, which has the temperature at 103±2 C, till the constant weight i.e., oven-dry (OD) weight is obtained. Then OD dimensions of each of the tested samples were measured as before.

Based on the green dimensions and OD dimensions, radial shrinkage and tangential shrinkage from green to OD condition were computed by using equation as mentioned in Equation. Similarly volumetric shrinkage from green to OD condition and green specific gravity and oven-dry specific gravity were computed based on the green volume, OD volume and OD weight. All the above mentioned tests were conducted at the Timber Physics Laboratory, F.R.I, Yezin.

The tests conducted here are the most important tests in determining the strength properties of wood. The principle tests made on both unirradiated wood samples and irradiated samples and mechanical properties evaluated are: (i) static bending test: modulus of elasticity (MOE), modulus of rupture (MOR) (ii) compression perpendicular to the grain test: fiber stress at proportional limit (FS@PL), Maximum crushing strength (MCS) (iii) compression perpendicular to the grain test: fiber stress at proportional limit (FS@PL) (iv) hardness test: tangential, radial, end

The sample boards obtained were said to be air-dried at FRI, since May, 1998. After one year of air-drying, the MC of the sample boards were said to be about 13% to 14%. To reduce the MC of the tested samples down to 12%MC, they were usually placed in a conditioning chamber. However, the samples were tested as it is because of the lack of a conditioning chamber at the Timber Mechanic Lab, FRI. To know the MC of the tested samples at the time of test, MC sections were cut immediately after the test. The initial weight, OD weight were measured and then MC of each of the tested samples were computed by using following equation.

$$MC\ (\%) = \frac{\text{Weight of water in wood}}{\text{Oven Dry Weight of wood}}\ x\ 100$$

For the static bending test, out of the samples, 30 samples for static bending test were irradiated with 10 kGy gamma radiation at SINA GAMMA PLANT in Malaysia Institute for Nuclear Technology Research Department (MINT) and Shimadzu Universal Testing machine at Forest Research Institute of Malaysia (FRIM) and Shimadzu Software were used.

Center loading and a span length of 280 mm was used. Both supporting knife edges were provided with the bearing plates and rollers of such thickness that the distance from the point of support to the central plane is not greater than the depth of the specimen.

The tested sample was placed so that the load was applied through the bearing block to the tangential surface nearest to pith. And the load was applied continuously throughout the test at a rate of motion of the movable crosshead of 6.6 milli meter per minute. The load-deflection curve were taken to the maximum load for all static bending tests. From this curve, load at proportional limit and deflection at proportional limit were obtained.

The following common properties were computed from the test results. (i) Dimension of test piece such as breath b in millimeter, depth d in millimeter, gauge length l in millimeter, and span L is 20 millimeter were measured. And then Maximum load P in Newton could be derived, load at proportional limit P' in N, deflection at mid length at limit of proportionality δ in mm are derived from Load-deflection curve. Properties computed for static bending test are as following:

(i) Modulus of Rupture

$$MOR = \frac{1.5\,PL}{b\,d^2}$$

(ii) Modulus of Elasticity

$$MOE = \frac{P'L^3}{4\delta b d^3}$$

(ii) Compression Parallel to the Grain Test

For this test, Out of the samples for this test, 30 samples were irradiated with 10 kGy gamma radiation and the Avery Universal Timber Testing Machine (type 7102 CCH and capacity 60,000lg) was used. The speed of load depend on the type of the test and it should not be varied by more than 25% from the specified value for given test.

Special care was taken in preparing the compressing parallel to grain test samples to ensure that the end grain surface will be parallel to each other and at right angles to the longitudinal axis. The load was applied continuously throughout the test at a rate of motion of the movable rosshead of 0.003 inch per inch of specimen length per minutes.

The following common properties were computed from the test results. For dimension of test species such as cross-sectional area A in square inches, guage length L in inch and draw Load-compressing curve from which are derived, the load of proportional limit P' in lb, Maximum crushing load P in lb and Deflection at limit of proportionality δ in inch. Following properties computed for compression parallel to the grain test are Maximum crushing strength MCS = P/A.

And the Fiber stress at proportional limit could be calculated by using this equation.

$$FS@PL = \frac{P'}{A}$$

For the Compression Perpendicular to the Grain Test, out of the samples for this test, 30 samples were irradiated with 10kGy gamma radiation by using a gamma chamber from Department of Atomic Energy. And the load was applied through a metal bearing plate 2 inches in width placed across the upper surface of the specimen at equal distance from the ends and at right angle to the length. The specimen was placed so that the load will be applied through the bearing plate to a radial surface. And then the load was applied continuously throughout the test at the rate of motion of the movable crosshead of 0.012 inches per minutes. The dimension of test pieces and cross-sectional area A in square inches and gauge length L in inch were measured. Direction of load were either radial or tangential directional. And drew load-compressing curves from which is derived the load at proportional limit P' in lb. The compression perpendicular test, the fiber stress at proportional limit was calculated by using this equational.

$$FS@PL = \frac{P'}{A}$$

For Hardness Tests, for this tes, 30 samples out of the samples were irradiated with 10 kGy gamma radiation. The modified ball test with a ball of 0.444inches in diameter was used. Recorded the load at which the ball has penetrated to one half its diameters, as determined by the tightening of the collar against the specimen. One penetration was made on each tangential surface, one on each radial surface and one on each end. The choice between the two radial and between the two tangential surfaces shall be such as to give a fair average of the piece. The penetration was for enough from the edge to prevent splitting or chipping.The load was applied continuously throughout the test at a rate of motion of the movable crosshead of 0.25 inch per minute.

III. RESULTS AND DISCUSSION

A. Irradiation Effects on the Physical Properties of Leza

The physical properties such radial shrinkage, tangential shrinkage, volumetric shrinkage and specific gravity of un-irradiated and irradiated samples are reported in Table III.

The values of radial shrinkage, tangential shrinkage and volumetric shrinkage were calculated from green to ovendry state. Specific gravity at green and oven-dry states were also calculated based on the oven-dry weight.

Table III. Mean Value of Some Physical Properties of LEZA with Standard Division

Name of Test	Un-irradiated Wood	Irradiated Wood
Radial Shrinkage (%)	4.8±0.2	5.0±0.2
Tangential Shrinkage (%)	6.8±0.1	7.1±0.1
Volumetric Shrinkage(%)	11.6±0.4	12.1±0.4
Specific gravity		
Green	0.62±0.22	0.62±0.22
Air- Dry	0.661±0.02	0.663±0.02

In order to clearly reveal the difference between unirradiated and irradiated sample, statistical analysis was carried out by using Statistical Analysis System. From the analysis, all the physical properties of irradiated Leza are not significantly different to those of unirradiated Leza at 95% confidence level.

B. Irradiation Effects on the Mechanical Properties of Leza

The mechanical properties of unirradiated and irradiated Leza together with the moisture content at the time of test are given Table IV.

To get a comparison between unirradiated and irradiated Leza, the mechanical properties in each test are adjusted to 12%MC by applying the factor given in Table 6 . The adjusted properties at 12%MC are represented in Table 4. In order to clearly reveal the difference between unirradiated and irradiated samples, statistical analysis was carried out by using Statistical Analysis System. From the above analysis, all the mechanical properties of irradiated Leza are significantly different to those of unirradiated Leza at 95% confidence level. It can be seen that after irradiation, the mechanical strength properties of irradiated Leza become higher than those of unirradiated Leza.

Table IV. Mean Value of some Mechanical Properties of Leza (at the time of test) with the Standard Deviation

Name of Test	Unirradiated Wood MC (%)	Unirradiated Wood Properties ($N\ mm^{-2}$)	Irradiated Wood MC (%)	Irradiated Wood Properties ($N\ mm^{-2}$)
Static Bending				
MOR	13.5	116.5±12	13.5	118.5±11
MOE	13.5	11964±1070	13.5	12233±1120
Compression Parallel				
FS @ PL	13.4	32.0±4.0	14.6	34.0±4.1
MCS	13.4	42.0±4.4	14.6	44.0±5.0
Compression Perpendicular				
FS @ PL	13.5	12.0±1.0	14.4	13.0±1.1

Table V. Mean Value of Hardness Properties of Leza (at the time of test) with the Standard Deviation

Name of Test	Unirradiated Wood MC (%)	Unirradiated Wood Properties (Kg)	Irradiated Wood MC (%)	Irradiated Wood Properties (Kg)
Hardness				
Tangential	13.5	514.0±30.0	14.7	545.0±28.2
Radial	13.5	550.0±30.5	14.7	555.0±29.5
End	13.5	701±32.5	14.7	705.0±30.5

Table VI. Mean Value of some Mechanical Properties of Leza (at 12% MC)

Name of Test	Unirradiated Wood Properties ($N\ mm^{-2}$)	Irradiated Wood Properties ($N\ mm^{-2}$)
Static Bending		
MOR	121	125
MOE	12322	12600
Compression Parallel		
FS @ PL	34	39
MCS	46	51
Compression Perpendicular		
FS @ PL	13	15

Table VII. Mean Value of Hardness Properties of Leza (at 12%MC)

Name of Test	Unirradiated Wood Properties (Kg)	Irradiated Wood MC (%)	Irradiated Wood Properties (Kg)
Hardness			
Tangential	532		581
Radial	570		591
End	742		780

IV. CONCLUSION AND RECOMMENDATION

The findings can be summarized as follow: Physical properties of irradiated Leza such as radial shrinkage, tangential shrinkage, volumetric shrinkage and specific gravity are not significantly different from those of unirradiated Leza at 95% confidence level.

Mechanical properties such as modulus of elasticity (MOE) and modulus of rupture (MOR) in static bending test, fiber stress at proportional limit (FS@PL) and maximum crushing strength (MCS) in compression parallel to the grain test, fiber stress at proportional limit (FS@PL) in compression perpendicular to the grain test and harness of radial, tangential and end surface were carried out for this study. The result reveal that all the strength properties of Leza are improved by irradiation.

This is may be the first application of radiation technology in timber processing. The results suggest that irradiation improves properties of Leza. Whether such improvement could be obtained with other species need to be investigated widely before radiation could be considered to have commercial feasibility. It is noted that commercial irradiation is a simple matter using either cobalt-60 industrial gamma irradiation facilities or electron beams available in many countries.

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