THE USE OF RESISTANCE-TYPE MOISTURE METERS AND THE CORRECTION FIGURES FOR PHILIPPINE WOODS[1]

Two methods are commonly used in determining the moisture content of wood in wood-seasoning operations such as air-drying, predrying and kiln-drying, and in wood processing in manufacturing plants and wood-working factories. They are: (1) the oven-drying method and (2) the electric-moisture-meter technique.

1. *Oven-drying method.* — The moisture content of the wood is calculated from weight values before and after the specimen is dried to constant weight in an electric oven. This method, however, has certain disadvantages. First, it involves the cutting of specimens from representative pieces of wood randomly selected from the stock and, therefore, a time consuming. Second, it has limited accuracy when testing wood that contains volatile extractives and wood that had been treated with wood preservatives. Third, it requires the use of laboratory facilities such as an oven that can be maintained at a temperature of 103±2°C. (217.4 ±3.16°F.), an accurate thermometer to check the temperature inside the oven, a sensitive balance, and some carpentry tools to prepare the specimens. Despite these disadvantages, this method is the most universally accepted for determining moisture content, even in research and for purposes already enumerated. It is comprehensively discussed in F.P.R.I. Technical Note No. 19.

2. *Electric-moisture-meter method.* — The use of electrical devices is rapid and does not involve the cutting of wood. However, it is not as accurate as the oven-drying method. Its use has gained popular acceptance among local wood producers and wood users because electrical moisture meters are designed to provide a quick, easy and non-destructive quantitative test for moisture in wood. Instruments now available are being used satisfactorily for approximating the moisture content of wood in the lumber, veneer and plywood industries, and in plants manufacturing wood products.

Electrical instruments used in determining the moisture content of wood can be classified into two main groups: (a) Those that are based on the relation of the moisture content to the electrical resistance of the wood (resistance-type) and (b) those that are using radio-frequency power-loss type (capacity-type meters). Although both types of electric moisture meters are found in wood-using industries, the resistance-type is more commonly used. The following discussions concern mainly the use of the resistance-type moisture meter.

In wood-using industries, the resistance-type moisture meter is commonly used. This type uses the relation between moisture content and the direct-current electrical resistance of wood. Although it is generally known that oven-dry wood is an extremely good electrical insulator, its electrical resistance falls rapidly as the moisture content increases, until a moisture content of about 25 to 30 percent is reached. Above this range, the decrease in resistance is relatively small.

The most reliable range for resistance-type moisture meters for lumber is between 7 to 30 percent moisture content. Within this range, the accuracy of the resistance-type meter, when properly calibrated and correctly used, approximates within ±1 percent. Some instruments are calibrated for moisture values from 4 to 120 percent, but it is not expected that readings above 30 percent will be as accurate as those in the lower range.

Correction figures for the resistance-type electrical moisture meter, calibrated for Douglas fir (*Pseudotsuga menziessii*)[2], have been prepared and studied by the Forest Products Research Institute for different Philippine wood species. The accompanying table presents the results so far obtained in this study. This table does not apply to meters calibrated for other species and should not be used with capacity-type moisture meter. Resistance-type moisture meter, manufactured in Australia and the USA, are generally calibrated for Douglas fir, while those of European origin are usually calibrated for beech. (*Fagus sylvatica*).

ASTM (D2016-62T) suggests the following procedures in the use of resistance-type moisture meters. These are general and should not supersede the instructions supplied by the instrument manufacturer.[3]

[1] This is Technical Note No. 56 of the Forest Products Research Institute, College, Laguna.

[2] Formerly *P. taxifolia* (Lamb.).

[3] Suggested procedures in the use of Power-Loss-Type meters, see ASTM (D2016-62T) 11(b) p. 101.

1. Test suitable specimens for moisture content according to the instructions for the particular meter being used. Use insulated needles if they can be obtained. Drive the needles into the wood oriented so that the current flows parallel to the grain.

2. If the reading drifts toward a lower moisture content, take the reading immediately after the needle electrodes are driven into the specimen.

3. When the meter is being used with uninsulated needles, note the moisture indication when the point of the needle just pricks the surface and as the needles are driven into the wood. If the meter reading at the time the needles just prick the surface is as high as when the needles penetrate 1/4 of the thickness of the specimen, that specimen may have a wet surface and the accuracy of the reading is doubtful. If the meter reading increases progressively as the needles are driven deeper, the specimen does not have a wet surface. In this case, uninsulated needles will give correct indications.

4. Wood or rectangular cross-section, that has been drying under reasonably constant equilibrium conditions, generally has a moisture distribution across its thickness such that, at a depth below the surface of 1/4 to 1/5 of the thickness, the moisture content is equal to the average for the entire piece. Correspondingly, for wood of circular cross-section, the average moisture content occurs at a depth below the surface of about 1/6 to 1/7 of the diameter. Therefore, to measure the average moisture content with resistance-type meter, drive the electrode needles to a depth of about 1/4 to 1/5 of the thickness of specimens with rectangular cross-section, and to about 1/6 to 1/7 of the diameter of cylindrical specimens. If the regular electrode needles are too short to reach the specified depth, use nails or other substitute electrodes. Drive the substitute electrodes to the proper depth and about the same distance apart as the needles on the standard electrode. The reading may then be obtained by touching the regular electrode needles to the exposed ends of the substitute electrode needles.

Therefore, to obtain the maximum benefit from the use of an electric moisture meter, the user should study the instructions furnished with the instrument and should be thoroughly familiar with its operation.

As a guide to the proper use and handling of these direct-reading instruments, some of the possible sources of errors are enumerated below:

1. *Species.* — Electrical resistance of wood at any moisture content varies between species; hence, a need for applying correction factors for different species. For example, in testing tañgile, if the meter reading is 9 percent, the approximate moisture content as given in the table is 10 percent.

2. *Temperature.* — As the temperature of the wood increases, the electrical resistance decreases. Meter readings will be too high if the lumber being tested is hot. Most resistance-type meters are calibrated to test at 70°F. (21.1°C.). For any variation of 20°F. (6.6°C.) above or below this temperature, there is an error of 1 percent in moisture-content reading. This point is of importance when using a resistance-type meter for testing lumber that is fresh from the kiln. For example, when testing sample board taken from a kiln with a temperature of 150°F. (65.5°C.), the meter reading must be reduced by 4 percent because there is a 1 percent decrease in moisture content for every increase of 20°F. (6.6°C.) above 70°F. (21.1°C.). This correction must be made if the temperature of the wood is different from the temperature at which the meter was calibrated. Correction figures for different temperatures are usually provided by the manufacturer. Together with the species correction, it should be used in correcting the readings of the instruments.

3. *Maintenance.* — The maintenance of a moisture meter consists largely of replacement of exhausted or broken components. Periodic inspections will minimize the probability of the moisture meter while in use.

4. *Testing of treated wood.* — Wood, treated with salts for preservative or fire-retarding purposes, becomes more conductive. Consequently, it may indicate in the electrical moisture meter a moisture content that is greater than the correct value. The hygrometric method as mentioned on page 96 of ASTM (D2016), is better adopted for this particular test.

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SOME PRACTICAL POINTERS IN SAWING PHILIPPINE HARDWOOD LOGS[1]

Almost all sawmills in the Philippines today are sawing logs of inferior quality. The better-quality logs are either exported or absorbed by local veneer and plywood plants. Such situation therefore calls for the sawmillers to improve their sawing methods and techniques in order to obtain the most out of the defective logs.

Log defects commonly found in Philippine commercial hardwoods, affecting lumber yield, may be classified into three general categories, namely: (1) interior or center defects, (2) side or surface defects, and (3) crook and sweep. The first group comprises of brash center, heart or ring shake, heart checks, center rot, and butt rot. The second category includes catface, season checks or split, rotten knot, wormy and unsound sap. The last group comprises of those logs that are not straight.

Sawing Logs with Interior or Center Defects

Logs with center rot, heart shake, and brash center. — The point of concentration of these defects, usually at the end of the log, is an important indication of how to open up the log on the headsaw. If these defects are confined within the center of the log, sound lumber is sawed around, i.e., by boxing the defective heart of the log. However, if these defects are restricted in the outer zone, thus affecting only one face, the better faces should be sawed first, confining the defects to the last face to be cut. If the rot is elliptical in shape, the sawcut should run parallel to the long axis of the rot. In case of incomplete heart shakes, the sawcut should be parallel to a line connecting the two ends of the arc of the shake.

Logs with heart checks. — Heart checks usually occur in apitong, guijo, yakal and other denser species. They appear as short radial cracks emanating from the pith, affecting sometimes the entire length of the log. In a log with well-center heart, this defect has no influence upon the manner in which the log is to be divided into cutting faces and the sequence of cutting them.

Sawing is done around the log for the purpose of obtaining wood lumber. The heart is then boxed into square timbers. Off-centered logs with heart checks should be sawed with the longest radius perpendicular to one of the cutting faces. The best faces are sawed first and the affected face is sawed last by boxing the heart.

Logs with butt rot. — This defect occurs in the butt log. It narrows abruptly from the butt end to the top or small end of the log. In sawing, this log should be taper-sawed with the sawcut parallel to the long axis of the rot. The small end of the log should be set out with the aid of a taper off-setting device until the entire log length is parallel to the sawline. All the merchantable materials are taper-sawed from the four faces. It is necessary to remove the taper upon reaching the central defective portion of the log.

Sawing Logs with Side or Surface Defects

Logs with catface. — If the catface is shallow, it should be removed in the first cutting face by sawing parallel to the defect. Sawing the remaining good faces can be better planned after the catface has been removed. However, if the catface is too deep, this should be the last face to be sawn.

Logs with season checks and splits. — The direction of split or crack in the log with respect to the saw line is an important factor to be considered before making the first cut. The split should almost or exactly be parallel with the sawcut and must be the first face to be cut. The log is sawed on this side until the split is reached or passed by the saw. If the split extends very close to the heart or center of the log, the defect should be parallel with the last side to be sawn.

Logs with rotten knot. — If the effect of the rotten knot is confined to one cutting face, only the slab is removed during the first cutting. The log is turned for successive cutting of better faces until sawing is completed on the defective side.

Knotty logs should be oriented on the carriage so that the knots, rotten or sound, would appear at the edges or corners of the sawed boards to facilitate edging them out. If this is not possible, the knots should be confined to one or two faces only, leaving the other faces free of knots.

[1] This is Technical Note No. 57 of the Forest Products Research Institute, College, Laguna.

Logs with wormy and/or unsound sap. — Usually these defects occur only in the sapwood. Faces affected by either of these defects should be slabbed first to determine the extent of the damage, after which the faces without defect are sawed to include all the good lumber. The slabbed face or faces are sawed last. If slabbing reveals that the heartwood is attacked by grub worms, the affected face should be sawed in such a way as to concentrate the holes at the edges of the boards.

Sawing Crooked Logs

In sawing crooked log, the crook must not be above or below the boltster but should face the saw. Short boards can be obtained from the sawed face until a full-length flat surface is attained. This flat surface is placed against the knees (log turned 180°) or laid down the bolster (log turned 90°). The faces beside or adjacent to the belly of the crook should be sawed deep to recover much of the full-length boards.

Other Important Points in Sawing Hardwood Logs

1. Big sound logs should be cut such that the high-grade lumber from all the four faces are obtained.
2. Generally, lumber thicker than 4/4 inch should not be sawn immediately after the slab is made in order to minimize the loss of good edging material.
3. The log should be turned to the next cutting face when this face will produce higher-quality material than the face being sawn.
4. Low-grade faces should be sawed as rapidly as possible in order to recover the low-priced lumber with the least cost.
5. Very inferior grade logs should be sawn "through-and-through" without such attention to turning. Slabs are usually cut from two sides, after which the log is turned 90° in either direction before sawing "through-and-through" to produce square boards on the headsaw.
6. Taper-sawing should be applied on high-grade faces while the poor faces should be sawed by the conventional method.

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CHEMICAL TREATMENT OF WOOD WITH BORON COMPOUNDS[1]

Extensive tests and experience in other countries have shown that boron compounds used in wood preservation are highly toxic to various species of fungi and insects. The minimum toxic load against fungi was found ranging from 0.4 to 3.0 kg. per cubic meter (0.025 to 0.187 lb/cu.ft.) of wood, depending on the method of tests, the species of fungi and the wood used. In Australia and New Zealand, boron treatment of wood at a minimum core concentration of 0.2 per cent boric acid equivalent (calculated as per cent of the oven-dry weight of the wood) has proven completely effective in the prevention of powder-post-bettle infestation in building timbers. As regards termites, boron concentration of 1.0 per cent of the oven-dry weight of the wood has also been found effective against certain termite species which depend on intestinal protozoa for the digestion of their food materials.

Boron compounds, used in wood preservation, compare favorably in properties with most water-borne preservatives now in use. They are very cheap and relatively harmless to human beings. Furthermore, they can be applied on green wood which reduces drying time and handling costs to a minimum, whereas, treatment of wood with water-borne preservatives usually requires the drying of the wood before treatment and before delivery to the end-user. The main disadvantage with boron compounds is their low resistance to leaching. However, in building timbers, plywood, and other wood products protected from rain and not in contact with the ground, high leaching resistance is not an essential requirement.

Boron compounds may be applied to wood by pressure or non-pressure methods. The most popular method in commercial use is by diffusion. The essential steps in diffusion treatment are (a) application of the preservative to the surfaces of the green wood, and (b) storing of the treated wood

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[1] This is Technical Note No. 58 of the Forest Products Research Institute, College, Laguna.

under retarded drying condition. The former may be accomplished by soaking, dipping or spraying but, the latter, either by placing the treated wood within a shed where moisture movement is restricted or by covering the blockstacked lumber tightly with moisture-proof material or its equivalent, to prevent moisture loss. The difference in the concentration of the chemicals outside the green wood and the water in the wood tends to move the dissolved chemicals into the wood. It is, therefore, essential for the wood to be in the green condition because surface-dry timber will not permit diffusion to commence.

In Australia and New Zealand, commercial diffusion treatment is done either by steam heating the green wood, then immediately quenching in cold preservative solution, or by heating and cooling the green wood in the solution. Another method is by passing the lumber individually through a spray tunnel or a trough on a conveyor. In all of these methods, the treated timbers are placed under diffusion storage to complete the treatment. Where heating is used, 3 to 6 per cent toxic-acid-equivalent solution is usually applied. In momentary treatment, a srtonger solution (20 to 40 per cent boric acid equivalent) is used.

In developing boron compounds as wood preservatives, flourides, arsenic, and chromates have been used as additives to provide increased effectiveness against decay and insect attack. In mixtures, they have been found effective against termite infestation in building timbers in New Guinea. With sapstain fungi, it was reported that borax, added to chlorinated phenates, gives better or equal protection at lower costs than the use of chlorinated phenates alone. The recommended mixture for sapstain control in tropical countries is 9 kg. (19.8 lb) borax, 9 kg. sodium pentachlorophenate, and 34 kg. (74.8 lb) benzine hexachloride dispersable powder in 450 kg. (990.0 lb) water. Benzine hexachloride in the mixture is effective for the prevention of pinhole-borer infestation.

From the foregoing information, boron compounds appear to have some potential applicability in the Philippines as a wood preservative, particularly in the treatment of building timbers, plywood, and other wood products used where leaching conditions are not severe. They appear to be most suitable for powder-post-beetle control. However, they do not seem to be suited for subterranean termite control. They would rather require a high retention even with certain termite species which have been found susceptible to them. Under Philippine conditions, the addition of arsenic and flourides to borates may be necessary for increased effectiveness against decay and termite attack.

A major drawback in the development of the wood-preserving industry in the Philippines is the high cost of the treated wood. Boron compounds and the equipment required for treatment are very cheap and should be able to fill this gap.

The condition of use and the service required of the treated wood usually determine the choice of a preservative. As long as the preservative properties and their limitations are clearly understood, and the essential requirements of a good treatment are observed (adequate retention and deep penetration), there should be no problem in insuring a long service life. There are now many good wood preservatives commercially available, but a preservative is only good depending on how well it is applied. Most often, failure to recognize this point is the cause of many untimely failures of treated wood in service.

For more details about this subject matter, write to the Director, Forest Products Research Institute, College, Laguna, Philippines.

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NAILING AND NAIL-HOLDING QUALITIES OF WOOD[1]

Everyone who has used wood may have realized the problems of connecting two or more pieces, whether simply to hold them together or join them for the purposes of transmitting loads from one member to another. Of the many types of mechanical fasteners already developed for wood joints, nails are still most commonly used in wood construction, from the simple and crude boxes or crates to engineered structures of novel design.

The ease with which nails can be driven into and withdrawn from wood and, apparently, the strength and efficiency of a nailed joint may vary considerably. Such variation is influenced by a number of factors, the most important of which are *the species of wood, the kind of nail* and *the conditions of use*. The development of an efficient nailed joint would, therefore, require an understanding of the effects of these factors on the nail-holding qualities of wood.

Generally, there are two ways a nailed joint can be made to sustain external forces. When one member tends to slide over an adjacent one because of the loads acting on it, the strength of the joint depends mainly on the lateral resistance of the nails. On the other hand, when nails are used to resist forces tending to cause direct separation of the joined members, the strength is dependent on the wood's ability to resist direct withdrawal of the nails. In this case, the nails are subject to tension under loads acting parallel to their shank. This latter type of joint is not recommended for structural purposes, but there are instances when it could not be avoided. It is more often used in the construction of wooden boxes and crates for packaging, and sometimes in millwork and furniture manufacture.

Nail Withdrawal Resistance

The ability of wood to resist the force required to withdraw or to start withdrawal of a nail by pulling along its shank is known as the withdrawal resistance. Like the other strength properties of wood, it is closely related to specific gravity of the wood.

In general, the dense, heavy species have greater nail-holding power and offer more resistance to nail penetration than the softer woods. The less dense species, however, are sometimes preferred in spite of their low holding-power because of their greater ease in nailing. Furthermore, they do not split so readily as do the heavier woods and therefore allow the use of additional or larger nails to provide the required strength.

The nail-holding power also depends upon the amount of wood substance in contact with the nail shank. For common wire nails, it varies directly with the depth of penetration and diameter of the nail.

Tests at the U.S. Forest Products Laboratory showed that the force required to withdraw common wire nails from the side grain of seasoned wood immediately after driving is obtained by the following formula:

$$P = 6900\ G^{5/2}\ D$$

where P = load in pounds per inch of penetration

G = specific gravity of the wood on weight and volume when ovendry.

D = diameter of the nail in inches

Partial results of tests conducted, so far, at the Forest Products Research Institute, University of the Philippines, College, Laguna, indicate that for sixpenny (2" long) and eightpenny (2½" long) nails, the U.S. FPL formula aforementioned is more conservative for wood with a specific gravity not greater than 0.60

In designing nailed construction, an over-all reduction factor of about 6 is generally applied to the theoretical withdrawal load P.

Moisture Conditions

The seasoning condition of the wood has some effect on its nailing characteristic. For instance, it is easier to drive a nail into wet wood than into dry wood. Splits due to nailing are also less likely to occur in green than in seasoned wood.

Generally, the force required to pull nails immediatley after driving is about the same for both green and seasoned wood. However, if any seasoning takes place after the nails are driven or when driven into dry wood that is subsequently subjected to repeated cycles of wetting and drying, there is considerable loss in the wood's resistance to direct withdrawal. For seasoned wood that undergoes moisture changes due to normal atmospheric variations, the holding power of nails also diminishes with lapse of time.

Direction of Nailing

Wood offers its greatest resistance to withdrawal when nails are driven perpendicular to its grain (side grain, either radial or tangential), and the least resistance to withdrawal when nails are driven to its end grain. Thus, in designing struc-

[1] This is Technical Note No. 59 of the Forest Products Research Institute, College, Laguna.

tural assembles, it is a common practice not to subject nails to direct withdrawal loads from the end grain.

Studies in Canada on the effect of slant driving on the holding power of nails showed that nails driven vertically have higher withdrawal resistance over those driven at an angle. However, when driven into wet wood that is seasoned before the nails are pulled out, the slant-driven nails have greater withdrawn resistance than the nails driven in a direction perpendicular to the surface.

Character of Nail Shank, Point and Head

The nail-holding power of wood can be improved by various means. One method is to increase the area of the nail shank in contact with the wood without increasing the weight of the nail. Nails are therefore manufactured with different types of shanks such as square, triangular, barbed, and longitudinally or spirally grooved. Another method is to change the surface condition of the nail by employing various kinds of nail coating, or by subjecting the nail shank to special treatments. Cement coating increases the friction between the nail shank and the wood fibers, thereby augmenting the holding power of the nails especially when used with softer woods. After a month or so, however, only about one-half of the initial increase remains. Because of this particular behavior, cement-coated nails have been extensively used in boxes which are usually constructed for short-time service. Zinc-coated nails are used under conditions favorable to corrosion.

In general, nails with long sharp points have a higher holding power than those with the common diamond points. But when used with the harder species they are likely to cause splitting. A blunt-pointed nail reduces splitting but its resistance to withdrawal is less than that of the common nail.

The most common nail heads generally used in carpentry and joinery work are the flat head, the finishing head and the large flat head. An example of the latter type is the roofing nail.

Boring holes slightly less than the diameter of the nail shank not only reduces splitting but also increases the nail-holding power. Splitting of the wood may be reduced by staggering the nails. Another way to overcome splitting is to use nails of smaller diameter, increasing the number, if necessary, to give the required strength.

Nails which are clinched one-eigth to one-fourth inch at right angles to their shanks will obviously increase the holding power.

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