ME 8883 Paper Physical Property Measurements

Instructor:

Dr. Roman E. Popil (Ph.D. 1984, Plasma Physics, UBC) office: 333, ph 404 894 9722, e-mail: roman.popil@ipst.edu

Senior Research Scientist

Institute of Paper Science and Technology

Tuesdays and Thursdays, 1:35 to 2:55 pm
Paper Property Measurements

• Principles of measurements, significance to paper quality issues
• Hands-on demonstrations in the lab, pragmatics of instrument maintenance and calibration, emphasis will be on standard Tappi methods, some discussion of specialized methods
• How to use physical property measurements to solve paper quality and manufacturing problems
Paper is a complex orthotropic, anisototropic and hygroscopic mess – (no surprise)

Recent laser confocal shot of a softwood lab handsheet 40X mag. A conglomerate of fibers, each fiber is different than the next

What does that mean to you? – Paper is lumpy, bumpy, fuzzy stuff!!

• Be aware that there is a lot of variability in all properties between samples and within a sample – all measurements must consist of at 6 or more repeats

• there are 3 directions to machine made paper: MD (x, 1, 11) CD (y, 2, 22) ZD (z, 3, 33), mechanical properties in these three directions are all different

• paper retains moisture and "remembers" its moisture history – mechanical properties are dependent on paper moisture in a non-linear fashion!
Paper Physical Property Measurements

Topics:
1. basis weight, moisture density
2. Caliper, hard and soft
3. Tensile strength, stretch to break, TEA, Instron and L&W methods
4. tear, burst, ZDT, fold, zero span tensile
5. Ultrasonic stiffness, stiffness orientation plot
6. Hygroexpansivity
7. Roughness: air leak and profilometry, 3D shadow Moire, gloss
8. Formation: optical transmission, electrography
9. Opacity, brightness
10. Color
11. Bending stiffness, 2 point L&W, Taber and L&W 4 point
12. Linerboard: Ring crush and STFI
13. Corrugated Board: ECT, BCT, creep, Concora crush
14. Water absorption: water drop, contact angle, Cobb, WVTTR, size tester
Grading

• 3 lab sessions are in the plan – using the techniques demonstrated and learned, produce a cohesive set of measurements on a sample set to produce a complete description of paper properties and their interrelationships

• Final closed book exam – check of retention of recollection of the basics
Paper consists of 50 to 30% air and a network of bonded fibers aligned predominantly along the MD - machine direction.
Moisture Hysteresis Curve of Paper

Wink from IPST produced a curve of the moisture content of paper versus relative humidity quoted in textbooks, “going up the curve is not the same as going down”

Paper once wet, is never the same again.

If you put paper in a high humidity environment e.g. 90% RH it will absorb moisture to have a moisture content (i.e. wet – dry weight/wet weight) of 11%, take it back down to 50% it will have a moisture content of maybe 9%

But, if you take paper to 20% RH, then up to 50% RH, it will likely have a moisture content of 7% RH repeatably

- Do you know where your sample has been? Your sample knows!

Tappi method 404 – condition paper samples at 20% RH for 24 hrs, then condition samples for 50% RH for 24 hours prior to any measurements
Moisture Control in 351 and 352

• Adjoining 351 is room 352 – this is the dry room, maintained at 20% RH and 73 deg C. Note the circular chart on the wall new samples to be tested stay here on the racks for 24 hours make sure air can get to the surfaces of your samples by hanging them up on the racks

• after 24 hours in the dry room, hang your samples on the racks to condition in 351 lab maintained at 50%RH 73 deg C,

-Make sure you have you samples labeled with name, phone number and date, the racks are for conditioning samples, not storage, samples left on the racks are periodically discarded without notice!

- After your samples have finished the conditioning sequence, store them in sealed plastic bags, the conditions in lab 351 are subject to fluctuation and upsets by outside weather!!

- If your samples are ever subjected to humidity above 5% RH, they must re-conditioned: 24 hours at 20% RH followed by 24 hours at 50% RH
Tappi test methods

• most of the testing methods we will discuss are industry standardized methods decided and reviewed by Tappi committees that meet at regular Tappi conferences.

• this ensures universal quality standards that characterize paper as a commercial product.

• each method is designated as T- #### - letter suffix, 400 – 500 is Paper ands Paperboard testing, 800’s are Containerboard tests, - om designates an official method, - pm provisional method.

• Let’s look at the first one:

T 400 sp-97

Sampling and accepting a single lot of paper, paperboard, containerboard, or related product.
1.1 This method describes procedures for obtaining a sample for testing. It should be recognized that in an ideal situation the samples selected should represent a lot of paper or paperboard, container board, or related product, including converted paper products (all hereafter referred to as “paper”). However, in some situations the sample may be as small as a single sheet of paper that has been provided to the laboratory for testing and may not represent the lot from which it is obtained.

3.1 Lot, a quantity of paper of a single type, grade, grammage, thickness, and composition, about which it is desired to make a judgment (usually as to conformance to specification) by examining or testing a small fraction called the sample.

3.2 Sample, a specified number of test units selected according to a prescribed procedure to represent the lot. It should also be recognized that in some situations the sample to be tested may consist of a limited quantity, or as small as one sheet of paper.

3.3 Test unit, an area of paper sufficient to obtain a single adequate set of test results for all the properties to be measured.

3.4 Test specimen, a test unit, or a portion of a test unit, upon which (for a specified property) a single test determination is to be made.

3.5 Test determination, (1) the process of carrying out the series of operations specified in the test method whereby one or more readings (observations) are made on a test specimen and the observations combined to obtain the value of a property of the test specimen, or (2) the value obtained by the process.

3.6 Test result, the value obtained for one test unit of the sample by carrying out the complete protocol of the test method, the value being (as specified in the test method) either a single test determination or a specified combination of a number of test determinations.

3.7 Test strip, cross machine strip, continuous strip of paper that represents the width of either a roll or reel as specified by the buyer/seller. Machine direction strip - continuous strip of paper of a length and machine position to reflect the measurement of interest.
Paper is highly variable, non-uniform, how many samples and measurements do you need to take to characterize a paper property?

A sample is associated with a certain grade, process parameters, each sample will have several specimens or replicates.

5.3.2 When taking a test unit from a skid or roll that may not be opened at the time of sampling, cut a window 300 by 450 mm (12 x 18 in.) or larger if larger test specimens are required. Cut the window with its longer side parallel to the machine direction when this is known, or if not known, cut the window at least 450 by 450 mm (18 x 18 in.) with...
Paper from a paper machine has a variation in the MD and the CD, CD variation arises from drying profiles, headbox edge flows, MD are high frequency variations, focs, wire marks, etc.
Most measurements are made with several repeats (6 or more) on several specimens from a sample.
T 402 om-93

Standard conditioning and testing atmospheres for paper, board, pulp handsheets, and related products

2. Significance

2.1 The physical properties of a sample at 50% RH depend on whether the sample was brought to 50% from higher or lower relative humidities; this "humidity hysteresis effect" is 5-25% of the test value for many physical properties. For example, a hysteresis effect of 1.5% moisture content (or 25% of the test value of 6% moisture content) is typical. Preconditioning on the dry side within the range specified will avoid most of the hysteresis effect and result in the moisture content of a given sample being established within 0.15% when the sample is later conditioned to 50% RH and 23°C. Conditioning down to 50% gives most papers a moisture content very nearly the same as conditioning up to 60%.

2.2 Both temperature and relative humidity have significant effects on the physical properties of paper and board (1, 2.) For some properties of paper and board (e.g., MD tensile and CD stretch) a change of 1°C may have nearly as much effect as a change of 2% RH. For synthetic fibers and plastic laminates, the temperature effect may be greater than the RH effect.
Samples for mechanical property testing have to be placed in a conditioned room: 24 hours at 20% RH followed with 24 hours in 50% RH.

5.3 Expose the sample sheets or specimens to the preconditioning atmosphere so that both surfaces of single sheets and exterior surfaces of laminated products or sealed containers are freely exposed. This is best achieved by suspending them from overhead or supporting them on a wire grid or rack.

5.4 Precondition the sample sheets or specimens by exposing them as specified above (5.3) to the preconditioning atmosphere. Precondition for a minimum of 24 h, unless a lesser time has been found to give satisfactory results. If the sample is to be stored for time after preconditioning, store at a temperature below 25°C (77°F) and a relative humidity below 40%, but not below 10%.

NOTE 4: For preconditioning apparatus of ample capacity and air circulation, the following preconditioning times have usually been found satisfactory: single sheets of paper, less than 1 h; linerboard, corrugating medium, chipboard, boxboard, 1-2 h; corrugated and solid fiberboard in sheet form, 5-10 h; sealed boxes and shipping containers, 12-16 h; specially treated water vapor resistant papers and boards, 24 h and more.

% moisture, weight or other moisture dependent property

1 hr for single sheets
5 hr of corrugated board sheets

Time
Condition sample at 20% RH, its % m will be 4%.

Bring a sample from 20% to 50% RH then % m is 7%.

The same sample from a humid environment conditioned at 50% RH will have % m of 8%.

Fig. 1. Typical moisture sorption isotherms for pulp and paper.
An example of the effect of moisture

Excerpted from Popil and Schaepe, August 2005 Tappi Journal

Studies at IPST have shown that RC, or similarly the short span compression strength STFI dependence on moisture can be described by the empirical relation:

\[
STFI(m), RC(m) = STFI_0, RC_0 1.89 e^{-0.09(M)}
\]

where, \(M\) is the percent moisture content by weight of the linerboard and the 0 subscript denotes the values of RC or STFI for samples equilibrated at 50% RH Tappi Standard testing conditions [26]. Exposure to high humidity conditions can increase the moisture content of liner to 11% lowering the strength properties according to Equation 3 and, consequently, Equation 1 by 30 percent. Therefore, keeping box components dry as possible is important in maintaining corrugated board strength.

[27] Tappi test method T402 “Standard conditioning and testing atmospheres for paper, board, pulp handsheets, and related products”.

ME 8883 # 1: intro, sampling, moisture, basis weight
 Moisture in pulp, paper and paperboard

Use a drying oven at 105 deg C, dessicator chamber and sample tins

5.2 For small specimens (2 g).
5.2.1 Weigh the specimen in the tared weighing bottle to the nearest milligram, place it in the drying oven, remove the stopper and heat for about 30 min; for grammages greater than 224 g/m², heat for 1 h.
5.2.2 Restopper the bottle, remove it from the oven, cool to room temperature in a desiccator, loosen the stopper momentarily to allow air to enter, and reweigh. Carry out this weighing step within 30 min after removal of the bottle from the oven to prevent reabsorption of water vapor by the specimen.

Calculate the moisture for each specimen as the percentage loss of the original weight of the specimen, to the nearest 0.1%.

Percent moisture content = \frac{(W_1 - W_2)}{W_1} \times 100 \quad (100)

where:

$W_1 = \text{initial weight specimen, g}$

$W_2 = \text{dry weight specimen, g}$

Report as moisture the average of the values for the two specimens. Any variations from the recommended method should be stated in the report.
Repeatability (within a laboratory), 0.35% moisture content.

Reproducibility between laboratories is variable depending on how well the procedure is followed, differences as great as 1.5% moisture content.

7.2 The precision and accuracy of test results will be affected by: (a) variations in moisture content throughout a reel; (b) handling and atmospheric exposure; and (c) the ambient relative humidity of the drying oven. A difference of up to 0.3% moisture content in bleached paperboard has been noted between cases where the oven has been located in a low relative humidity (less than 15%) or at standard (50%) humidities. Where possible, it is suggested to locate the oven in the test laboratory environment of 50% R.H.
Air tight jar with dessicant on bottom

Place sample in air tight sample can
1) Place samples inside of oven kept at 105 deg C for two hours,

2) Put can covers on using heat resistant gloves,

3) Put cans into dessicant jar, weigh to 4 places when cooled
IR methods for moisture

Using a filter wheel or several detectors, a difference method may be used to determine the moisture content in paper, calibration is required for different grades due to different optical effects.

Microwave absorption is also used in some sensors, more applicable to thick substrates.
Grammage of paper and paperboard (weight per unit area)

3. Significance

Most paper is bought and sold in accordance with its mass per unit area, and therefore the grammage has great significance both to the consumer and the producer in defining price. The values of many physical properties such as bursting strength, thickness, and bulk are interpreted and specified with regard to grammage.

4.2 Cutting device, such as a “four square” cutter, circular cutter, precise puncher or other device for ensuring parallelism of the opposite edges, normally capable of repeatedly cutting out test specimens whose area, in at least 95 instances out of 100, falls within \( \pm 0.5\% \) of a known area, as determined by the method specified in 5.2.1.

6.2 After conditioning each test unit of the sample, cut a sufficient number of representative sheets for a total area per test unit of at least 5000 cm\(^2\) (800 in.\(^2\)). The dimensions and hence the area of each sheet will depend on the sheet cutting device available. If a template is used, a minimum dimension of 20.0 \( \times \) 25.0 cm (8 \( \times \) 10 in.) is recommended.

\[
G = \frac{K \times M}{A}
\]

\( K = 1 \), for \( M = g \), \( A = \text{cm}^2 \) most commonly used

\( K = 4.882 \) to convert to lb/1000 ft\(^2\)

Q: what are the basis weights of common copy paper, AJC newspaper, household aluminum foil, plastic transparency film?

To what degree of accuracy can you measure?