Effect of Relative Humidity on Paper Strength

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INTRODUCTION

Paper and paper board are used in a great variety of forms, distinguished by a vide range of properties to satisfy many different use requirements. Most of the properties that determine the usefulness of paper are physical absolutes. Tensile strength is an important property of bag and wrapping papers. Folding test is the best means of measuring quality of papers which are required to resist considerable handing and folding in use. It is generally recognized that paper is affected more or less by the moisture in the atmosphere. The moisture content of paper affects strength, permanence and dimensional stability. The obvious importance of these changes in papers to be used in printing, charting, mapping, photography, blue printing and the like need not be overstressed.

Although it has been realised for a long time that physical testing is affected by humidity, there is relatively little experimental data to show its significance. Owing to incompleteness of data on the subject one research project was initiated at the PAPRI to undertake studies so as to evaluate quantitatively the impact of %RH on the physical properties of paper & board. Further it is felt a consolidated discussion of test results will represent a significant contribution to literature.

LITERATURE REVIEW

Fundamental factors that are responsible for paper strength are :

(i) Average fibre strength and flexibility of individual fibres.

(ii) Adherence and bondage ability of fibres surface both in terms of bonded area and strength per unit area of bonded surface.

Strength of individual fibres, have been evaluated by different researchers from time to time, and reported as follows:

TABLE-I

Material		Tensile Strength kgf/mm²
Cotton fibre	—	34.3–37.6
Linen fibre	—	35.2–36.0
Hemp fibre	—	45.0–78.0
Wood (coniferous) fibre	—	31.0
Steel, cold Molled	—	28.1–42.2
Steel, structural	—	38.7–46.7
Wrought Iron	—	34.0–37.0
Copper wire	—	34.5–47.5
Brass	—	20.4–52.8

It is observed from Table-I, that, cellulosic fibre compare quite favourably in strength with metals.

Strength of paper in the direction of its greatest strength amounts to 10–15% of strength of fibres. It is evident that the strength of paper is largely determined by the degree to which the fibres are made to adhere to one another.

Extensive studies have been made in the past to determine the sorption characteristics of cellulosic materials ([2,3,4,5]) which affects physical properties of paper considerably.

Significant amount of strength variation under fluctuating % RH is reported by various researchers for different grades of paper and board.

Wink[6] reported pronounced effect of hysteresis phenomenon on stretch, tensile and tearing resistance of paper. It was pointed out that within the temperature change from 69°F to 76.5°F, tensile and stretch properties could be changed to the extent of 3–8 percent in case of kraft papers.

Based on the critical appraisal of the literature information, it was thought desirable to initiate systematic studies on the qualitative as well as quantitative evaluation of physical properties of paper under fluctuating environmental conditions of % RH and temperature.

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An attempt has been made in this work, to study the impact of %RH on strength properties of different grades of paper.

PLAN OF THE WORK

Experimental investigations were planned in three phases:

PART-I

In determining the most advantageous means of presenting the data the question arises as to whether the moisture content and physical qualities of paper are expressible as a function of the actual amount of moisture present per unit volume of air, i.e., the absolute humidity or as a function of the percentage relative humidity, that is the ratio of partial pressure of the vapor to the vapor pressure of liquid at the actual temperature. There are evidences in literature which indicates, that, physical qualities are determined by %RH rather than by absolute humidity. Unfortunately humidifier manufacturers' charts indicate only the % humidity that is the quantity of water present in unit weight of vapor free air divided by the quantity required to saturate unit weight of vapor free air at the temperature under consideration on percent basis. Furthermore at all humidities other than 0 or 100%, the percentage humidity is less than the %RH. It can be shown that papers that are incorrectly graded at one particular RH would be much better if tested at different humidity. For these reasons, it was thought desirable to evaluate % RH directly from the reading of air temperature (dry bulb) and the wet bulb at barometric pressure. This work was taken up in the first part.

PART-II

In order to evaluate quantitatively the interstitial substances present in the paper, chemical analysis is carried out for various grades of paper in the 2nd part. It is proposed to carry out investigations to study the effect of different degrees of sizing on papers of the same fibre furnish with paper strength under varying % RH. This constitutes a seperate project and will be taken up in the near future.

PART-III

The 3rd part presents the effect of %RH on paper strength. This is the heart of the project and is discussed in great detail. It is most advantageous to present data as % variations from some convenient reference point. 65 % RH has been chosen for this, since;

(i) It is relatively easy to produce the conditions.

(ii) It is an atmospheric condition in which it is not uncomfortable to work.

(iii) The conditions are apparently approximately midway in the increasing and decreasing curves of strength due to variations of % RH.

(iv) Most of the laboratories which control testing conditions have addopted 70°F and 65%RH as their standard and have collected data.

(v) Bureau of standards have adopted and recommended 65% RH at 70°F as the standard conditions under which testing of paper should be conducted.

(vi) ISI standards for paper testing is fixed at 65±2 % RH.

Twenty different grades of paper & Board having substance range variation from 30-300 gsm, were conditioned at a particular % RH for 18 hours, and conditioned paper samples were tested with reference to the following:

a) Moisture Content
b) Ream weight
c) Expansion & contraction of sheet
d) Breaking length under tensile
e) Folding endurance
f) Tearing resistance
g) Bursting strength
h) Thickness
i) Gsm

The paper samples were conditioned and tested within the range of 30–95% RH.

RESULT AND DISCUSSIONS

The tests result show:

(i) Moisture content increases (at varying rates) with increase of RH.

(ii) Ream weight and thickness behave in a manner similar to moisture content.

(iii) Expansion & Contraction with humidity variation is greater in the cross than in the machine direction and the magnitude of the effect depends on the grade of paper.

(iv) Tensile strength and bursting strength increase upto the range of 35 to 45 % RH and decrease above this range. The amount of change for breaking length (tensile strength) is practically the same for machine and cross directions.

(v) Elongation increases continuously with moisture content.

(vi) Folding endurance increase over the observed humidity range. There is little concordence of results in machine and cross directions.

(vii) Tearing resistance increases with RH are

practically the entire range of humidity changes and its behaviour depends on the grade of paper tested.

(viii) Of strength qualities considered bursting strength is least affected by humidity changes, breaking strength and tearing resistance assume an intermediate position while folding endurance is influenced most.

The strength of fiber is attributed to the net effect of two independent factors, the strength and flexibility of individual fibers and the mutual adherence of the fibers. Emphasis is placed on the surface friction of fibers.

EFFECT OF RH ON INDIVIDUAL FIBER

Cellulosic fibers have the property of gaining strength and flexibility with increasing moisture content. These fibres exhibit the phenomena of absorption and smelling in humid atmosphere. The capillary theory of absorption advanced by Patrick fully explains this behaviour. In a very small capillary the vapor pressure of liquid must be less than that of same liquid outside. When the vapor pressure of liquid is very small indeed water which exists as vapor in the air would immediately condense upon entering the ultra microscopic structures of the walls of the cellulose fiber. This condensed or absorbed water due to its surface tension causes the fiber to swell. Some of the local deformations thus disappear or become less pronounced and the fiber gains in strength. While this accounts in part for the considerable increase in strength of a moistured fibre it is probable that another contributing factor in this increase is the tensile strength of minute water columns themselves. For if a small column of water is confined in such a manner that its cross section cannot be reduced except by rupture, it exhibits considerable tensile strength.

EFFECT OF HUMIDITY ON FIBER FRICTION

The surface friction of fibers results from superficial irregularities such as creases, projecting edges and protruding fibrillac resulting from the cooking and heating of the pulp. Also sizing materials in the paper are very important cause of surface friction. Moisture absorbed by fiber tends to reduce the irregularity of its surface. While the strength of fiber is thus increased its surface friction is obviously decreased for the smoother surface which is less effective in interlocking with irregularities of contiguous fibres. Of most important is the moisture on the surface of fibers, which acting as a lubricant appears to be largely responsible for the decrease of surface friction and hence facilitates the slipping over one another.

It follows, therfore the tensile strength of paper can increase as the fibres increase in strength with humidity, provided the change in the friction of the surfaces of the fibres is slight. For no matter how long the fibres may be, the strength of paper is limited by the effectiveness of the bond between them.

Since standard paper testing conditions according to TAPPI and ISI Standards are significantly different to each other, paper strength properties are expected to be different under TAPPI and ISI Standard conditions, as depicted in the following Table -II

TABLE—II
PAPER TESTING CONDITIONS

	ISI	TAPPI
% RH :	65±2	50±2
Temperature :	27±2°C	20±1°C

Sl. No.	Paper Quality	GSM	Percent variation of properties				
			Grammage	BF	BL	TF	DF
1.	Offset	60	+1.50	—10.0	—12.0	+ 8.0	+30.0
2.	White printing	60	+1.58	— 7.0	— 7.0	+36.0	+25.0
3.	S.S. Maplitho	60	+1.20	—12.0	—15.0	+ 4.0	+18.5
4.	Bond	58	+1.48	— 5.0	+ 5.5	+11.2	+20.5
5.	M.F.W. Tissue	21	+1.90	—10.0	+ 7.0	+12.3	+20.0
6.	White Airmail	30	+1.80	—15.0	+20.0	+ 8.4	—
7.	Pulp Board	185	+1.83	— 9.0	+ 3.0	+ 7.0	—

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