

A Simplified Guide for Forensic Analysis of Paper as Evidence

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***Abstract-** Paper is a versatile material with many uses such as writing, printing, packaging, painting, cleaning etc. Physical evidence from paper based material have great forensic value and forensic analysis of their physical properties, optical properties, electrical properties, strength properties and microscopic structure of fiber reflect the intrinsic chemistry, morphology and structure of individual fiber which assist the investigator to detect the document fraud, link particular suspect material with original document and other samples of the paper associated with the crime. The goal of this research is to examine the properties of paper by nondestructive and destructive technique under forensically sound condition.*

Keyword- Physical evidence, Physical property, Chemical property, Optical property, Electrical property, Strength property

Introduction- Paper is an aqueous deposit made by pressing any vegetable fibers in sheet form. Paper is mainly used for writing, packaging, cleaning such as tissue paper and particularly in the Asian culture it is used as food ingredients. The word "paper" is etymologically derived from *Papyrus* plant abundantly found in Egypt was used for making paper by ancient Egyptians. China was the first to introduce the paper in second century from tree bark. In that year historical record show that the invention of paper is reported to the Eastern Han Emperor Ho-Di by Ts' ailun an official of the imperial court.

The main constituents of paper are vegetable fibers mainly derived from wood pulp. Some plants other than wood pulp such as Bamboo, Cotton, Flax, Jute, Esparta, Straw, Hemp, Manila are also suitable for paper making. The process of paper manufacturing is simple one- Cook the vegetable fiber with hot water and a chemical is added such as lye which softens the fiber. Pass this hot mixture from a head box and forming table where dewatering and forming of the sheets are carried out. Let the water drip off from the paper until it is left with approximate 5% humidity and a sheet of paper is left behind. A flow chart of paper making is shown below in figure: 1.

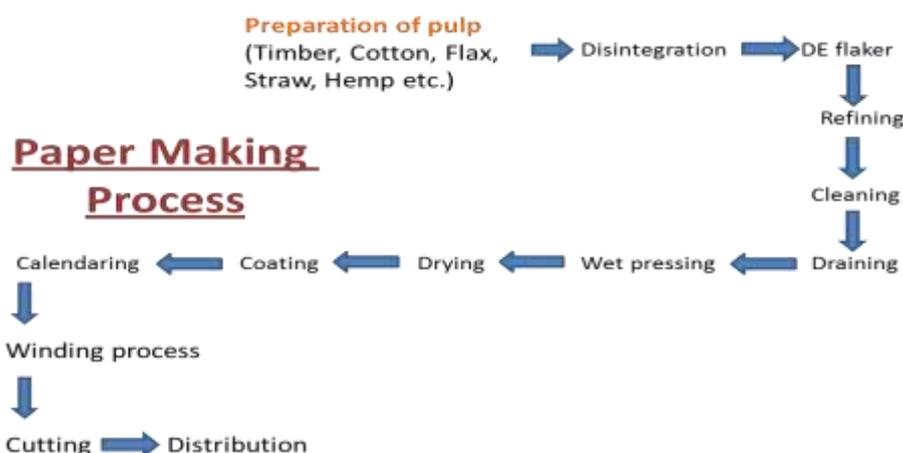


Figure: 1 Paper Making Process

Properties of paper- Paper is classified in a number of ways. Here is a classification which defines properties of paper in terms of the kind of property to be measured.

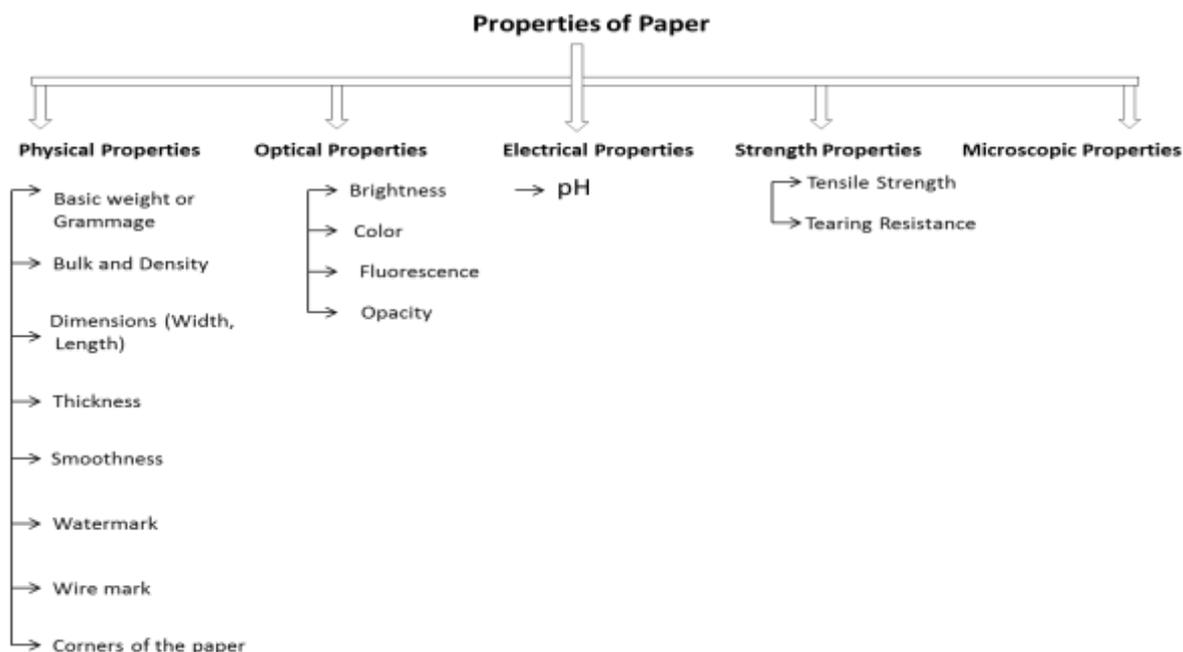


Figure: 2 Classification of Paper

Composition and structure of fibers- The main constituents of paper manufacturing are vegetable fibers. Permanency and durability of the paper depends upon the quality of fiber. All major compositions of fiber are mentioned below in following table: 1.

Carbohydrate	Cellulose 40%	α-cellulose
	Hemicellulose	β-cellulose γ-cellulose
Lignin (25%)		
Resins		
Tannins		
Mineral Material (0.2-1%)		

Fibers are made up of different layers with a thickness of 10-40 μm depend upon the species of wood. The shape of the pulp fiber is tubular. The cell wall of the fiber is formed by the primary and secondary wall. Secondary wall is further divided into three types of layer i.e. External secondary wall, Middle wall and Inner secondary wall. Primary wall is made up of macro fibrils (built from combination of micro fibrils) with 0.1-0.3μm thickness. Secondary layer is made up of micro fibrils.

Primary layer-Filaments of this layer crossed each other and lying almost perpendicular to the fiber shaft.

Secondary Layer- This layer consists of three different layers.

- a) External Secondary wall- This wall is made up of micro fibrils with a thickness of 0.1-0.2 μm. These micro fibrils are aligned in opposite directions.
- b) Middle layer- It is also made up of micro fibrils with a thickness of 1-7 μm. The micro fibrils of middle layer are aligned almost parallel to the fiber shot.
- c) Inner secondary layer- This layer is very fine 0.1μm thickness.

A simplified fiber structure is shown in figure: 3.

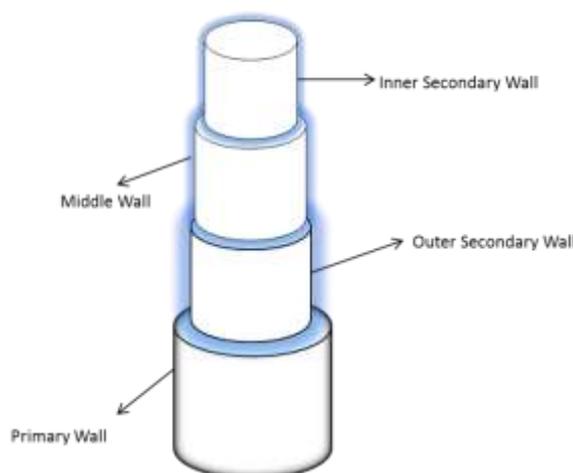


Figure: 3- Simplified Fiber Structure

Due to the versatile nature, paper founds on various types of crime scenes. Forensic examination of these evidences helps to the investigator to detect document fraud, link particular suspect evidence with other original documents.

Testing Requirements-

Specimen- The study is conducted on three different types of paper. Each paper is individually examined for 15 parameters, in which some test are nondestructive and some are destructive.

Due to the involvement of judiciary system we prefer the nondestructive techniques to maintain the originality and authenticity of the evidence.

The entire test is performed under the forensically sound condition by using forensic grade instruments. Tests which are performed for forensic analysis of paper are mentioned below in table: 2.

Nondestructive Analysis		Destructive Analysis
1) Basic weight or Grammage	8) Color	1) Microscopic examination
2) Bulk and Density	9) Fluorescence	
3)Dimensions(Length, Width)	10) Thickness	
4)Smoothness	11) Ph	
5) Watermark		
6) Wire mark		
7) Corners of the paper		

Table: 2- Paper testing Parameters

Equipments- Instruments which are required for the paper analysis are mentioned in table: 3.

Light Source	Micrometer
Digital grammage	Linear measuring device (Scale, Calipers)
Stereomicroscope, Compound Microscope	Paper cutter
Magnifier	pH meter
Transmitted light box	VSC
UV light source	

Table: 3- List of instruments

The entire instruments are calibrated and forensically reliable.

Analysis and Result-

A) Nondestructive methods-

- 1) Basic weight or grammage- It is the weight per unit area expressed as the weight in gram per square meter (g/m^2), pound per 100 Sq.ft. or weight in Kg or pounds per ream (500 sheets) of specific size. By using digital grammage all three paper was measured respectively.



Figure: 4- Digital grammage

- 2) Bulk and density- It is a term used to indicate volume or thickness in relation to weight. Thickness and weight is calculated by using caliper and basic weight. By using following formula we calculate bulk.
 $Bulk = \text{Thickness (mm)} \times 1000 / \text{Basic weight (g/m}^2\text{)}$
Density is measured by using following formula-
 $Density = \text{Basic weight (g/m}^2\text{)} / \text{Thickness (mm)} \times 1000$
- 3) Dimensions- Length and width of the paper is measured by using scale in cm, inch, feet and meter.
- 4) Smoothness- Smooth surface have irregularities of the order of 0.0005 to 0.010 which cannot visualized by naked eye. By using magnifying lens or stereomicroscope we can examine the smoothness of the paper. Sometime at low angle illumination we can also examine smoothness from naked eye.
- 5) Watermark- Watermark is any type of impression which is produced by water coated metal stamp or dandy roll onto the paper during manufacturing process. Forensically watermarks have great value. It is visualized when paper is examined under UV light chamber or by using VSC (Video Spectral Comparator).
- 6) Wire-mark- During manufacturing process a metal thin strip is pressed between the paper fibers. It is visualized by the naked eye.
- 7) Corner of the paper- By using magnifying glass notice the shape of the corner either it is round, square or curved finish.
- 8) Color- Color of the paper is observed under natural light with naked eye.
- 9) Fluorescence- Security feature such as luminescent fiber or other fluorescent whitening agent which present in the paper are noticed by using UV chamber or VSC.
- 10) Thickness- By using digital micrometer measure the thickness of the paper.



Figure: 5- Micrometer

pH is a measurement of the acidity or basicity of aqueous solution. pH of the paper can give an appropriate idea about the life-span of the document. Paper with low pH levels (acidic) start to deteriorate after 25 years. pH is measured either by making the aqueous solution of paper or by placing the wet electrode on the paper.

Results of all destructive analysis are as mentioned below in table: 4.

Sr. No.	Testing parameter	Paper 1	Paper 2	Paper 3
1	Basic weight or grammage	68.9 g/m ²	76.3 g/m ²	74.3 g/m ²
2	Bulk	0.820029	0.6947575	0.72960969
3	Density	12194 g/m ²	14377 g/m ²	13705 g/m ²
4	Dimension	8.27"x11.69"	11.69"x16.54"	11.69"x16.54"
5	Smoothness	Surface is smooth	Presence of small beads on the paper surface	Smooth
6	Watermark	Absent	Absent	Absent
7	Wire-mark	Absent	Absent	Absent
8	Corner of the paper	Square	Square	Square
9	Brightness	80.27	81.22	81.07
10	Color	White	-----	-----
11	Fluorescence	Presence of luminescence fiber	Absence	Presence of luminescence fiber
12	Thickness	0.0565 mm	0.05301 mm	0.05421 mm
13	pH	7.2	7.1	7.6

B) Destructive method-

Microscopic examination- The procedure of microscopic examination of paper can be done in following manner-

Take the paper which is to be examined. Cut it into small pieces and dip them into the boiling water. Boil the paper until a thick slurry paste will form. After the slurry formation take the bit of slurry formed papers with the help of forceps and place it on the slide for examination. Put some glycerine on it and place the coverslip properly so that no bubbles will form. After that we stain it with saffranin dye for better results.

Now observe it under the microscope having resolution of 30X or 40X. The microscopic structures of paper which are observed under the microscope along with their sketches are shown below in the figure 6, 7 & 8 respectively.



Figure: 6



Figure: 7

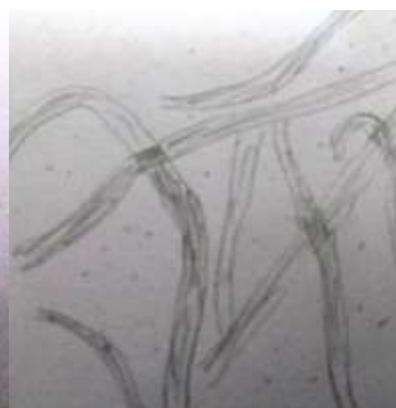


Figure: 8

Fig: Microscopic structure of paper

Conclusion- Paper as a document plays a vital role in investigation process. Physical evidence from paper based material along with their physical properties has great forensic value. In this research paper we examine the physical properties of three different types of papers by non-destructive and destructive techniques under forensically sound condition. In the examination of physical properties of paper we analyze that all the three papers have different basic weight, bulk, density and dimensions as well, in which second type paper has the highest value among all the three types.

pH of the paper can give an appropriate idea about the life span of the document. Hence paper with low pH level (acidic) starts to deteriorate first i.e. approx. after 25 years. Among these three types of papers, type second paper has acidic pH, whereas other two are slightly basic in nature. Luminescent fiber is present in 1st and 3rd type paper and absent in type 2nd paper.

Similarly, in destructive method we examine the microscopic structures of all the three types of papers, which help to study the individual structure of fibers. Hence, it is concluded that all the different physical and microscopic properties which reflect the intrinsic chemistry, morphology and structure of individual fiber assists the investigators to link particular suspect material with original document and other samples of the paper associated with the crime. Further work and maximizing the no. of subject (paper) types involves in the study can help for the better results as well as forensic investigation process.

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Wiremark available at, <http://www.merriam-webster.com/dictionary/wire%20mark>

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