Measuring Moisture Levels and Strength Variations in Corrugated Boxes: Comparative Analysis of Cobb Values at 30 and 40

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Abstract. Corrugated boxes are essential for packaging products, demanding high quality to meet client expectations. Manufacturers prioritize quality control, with humidity content being crucial for box quality. This paper addresses moisture control challenges by adjusting Kraft paper's Cobb value. Comparing boxes with Cobb values of 30 and 40, the study measures moisture content and conducts compression and bursting strength tests. Results show that boxes made with Cobb value 30 Kraft paper exhibit better quality and lower humidity content. This approach offers insights into improving corrugated box quality by managing moisture levels and enhancing overall packaging performance.

Keywords: Corrugated box, Cobb value, Compression strength, Bursting strength, moisture

1 Introduction

In recent years, corrugated board manufacturers have been focusing significantly on controlling the moisture content in corrugated boxes. Although these boxes are highly versatile in modern packaging, ensuring high-quality standards is of utmost importance. Sonam emphasizes the importance of producing high-quality corrugated boards that meet the changing demands of customers. It specifically focuses on the effects of moisture content on manufacturing and printing processes. According to findings from Janus Packaging Pvt. Ltd. in Baddi, an optimal moisture content of 8-12% is recommended [1]. Among all the variables that can influence quality, moisture content is the most crucial factor. It can impact both during and after the production process, leading to issues like warping, decreased strength, and reduced durability. Singh et al. analysed how compression strength in corrugated containers is affected by the size, shape, and placement of ventilation and hand holes, crucial for handling ergonomics and perishable shelf life. Experimental findings reveal a strength loss of 10% to 40%, exceeding prior reports [2]. To ensure that the boxes remain in good condition, maintaining stable humidity levels is a significant challenge for the entire corrugating industry. Kaplan et al., explored four drying methods for water-damaged corrugated boxes, reflecting the diverse nature of materials in archives. Criteria included packing efficiency, record-keeping, security, costs, and final product quality. Effective communication and resource estimation are crucial for project success, guiding decisions on in-house treatment versus outsourcing. These findings assist in selecting suitable recovery options for corrugated box archives [3].

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As a result, advanced moisture control methods are being explored to replace conventional approaches. These new methods are expected to improve the quality of corrugated boxes, making them more reliable and durable. Although packaging technology and humidity control have advanced significantly, achieving standardized and optimized practices has proven difficult. While modern technologies offer several advantages, they also present challenges such as high initial investments, environmental impacts, recurring maintenance costs, and the risk of over-drying. Furthermore, reliance on skilled labour and increased power consumption further complicate the adoption of these technologies.

The purpose of this study is to propose a new system that can regulate moisture levels in corrugated boxes and improve the quality of the corrugated boxes used by reducing its Cobb value. The Cobb value is a measure of a paper material's water absorbency and face wettability. Lower Cobb values indicate lower moisture absorbency, which can improve the paper's resistance to humidity. By opting for Kraft paper with lower Cobb values, manufacturers can enhance the moisture resistance of corrugated boxes and thereby improve their quality.

2 Manufacturing

Fluting medium and liner boards are two of the unique layers used to make corrugated boards.Steam at high pressure is used to humidify paper in traditional corrugators. The purpose of the moisture is to soften the paper fiber, easing the flute conformation and, as a result, the smooth glueing process. The papers absorb a significant amount of water during the process. Drying is needed to exclude this moisture once the board has formed. Hot plates are used to heat the recently created corrugated sheet as shown below (Fig. 1). Large coils of it are transferred to the corrugators. It's hotted, wet, and shaped into a fluted pattern on the geared rollers at the single facer. To produce a single face board, this has stuck to a flat liner board using glue. An additional flat liner board is fastened to the opposite side of the fluted medium at the double backer to create a single-wall corrugated board.

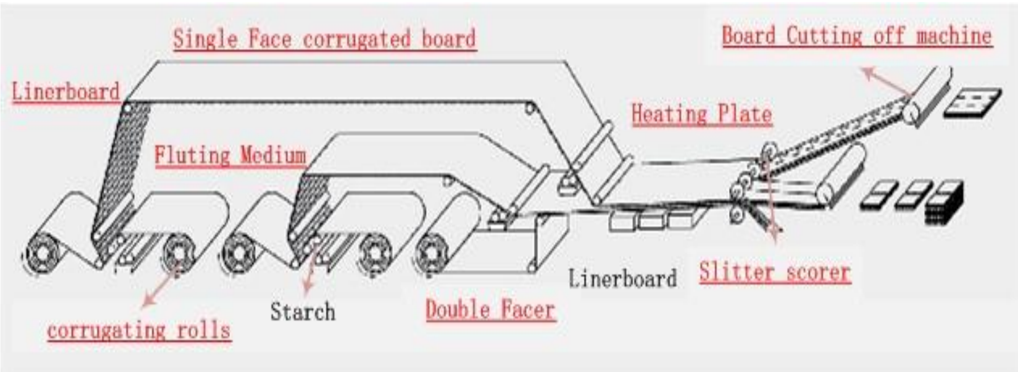

Fig. 1. Manufacturing of corrugated box

Because the paper is hygroscopic, moisture, temperature, and adhesive level all affect adsorption. However, one drawback of corrugated board is that moisture affects the material's strength and quality. By measuring the humidity of the paper or board that will be utilized, quality should be inspected at every stage of the manufacturing process.Common flutes are" A"," B"," C"," E" and" F" which are shown in Fig. 2.

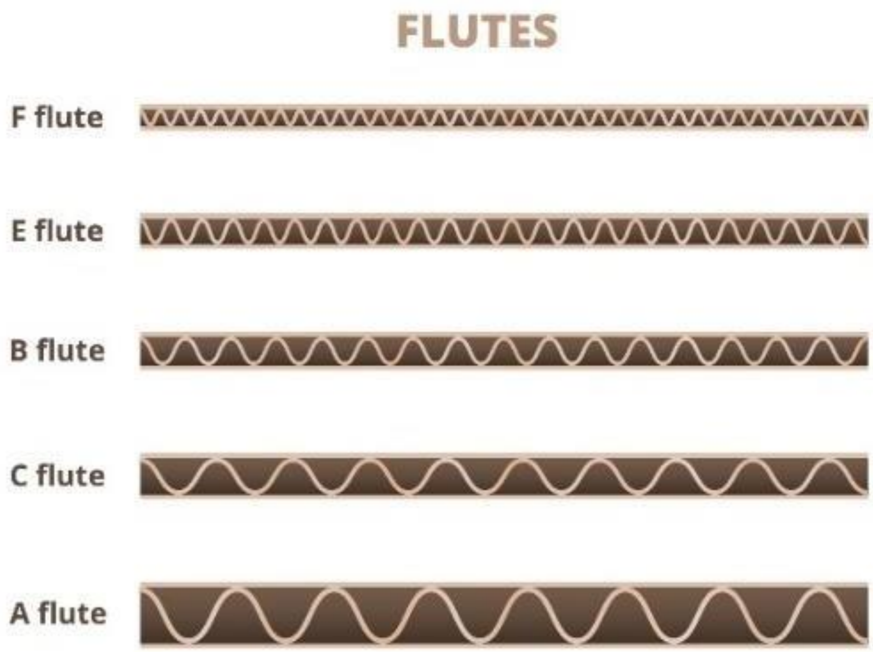

Fig.2. Types of corrugated flutes

3 The Raw Material Required for Manufacturing of Corrugated Sheet Boxes

3.1 Paper Reel

Reels of liner and flute weighing from 200 kg to 300 kg and cobb value of 30 and 40 are imported from “Kovai Maruthi Papers & Boards (P) Ltd.” And “SBM MILLS”.

3.2 Pasting Gum

Starch-based gum powder is mixed with water in a ratio of 1:4.

3.3 Stitching Coil

Steel rust-proof stitching coils are brought from “ADVANCED TECHNO WIRE LTD.”

3.4 Printing Paint

Gloss-based solvent ink is used for printing.

4 Methodology

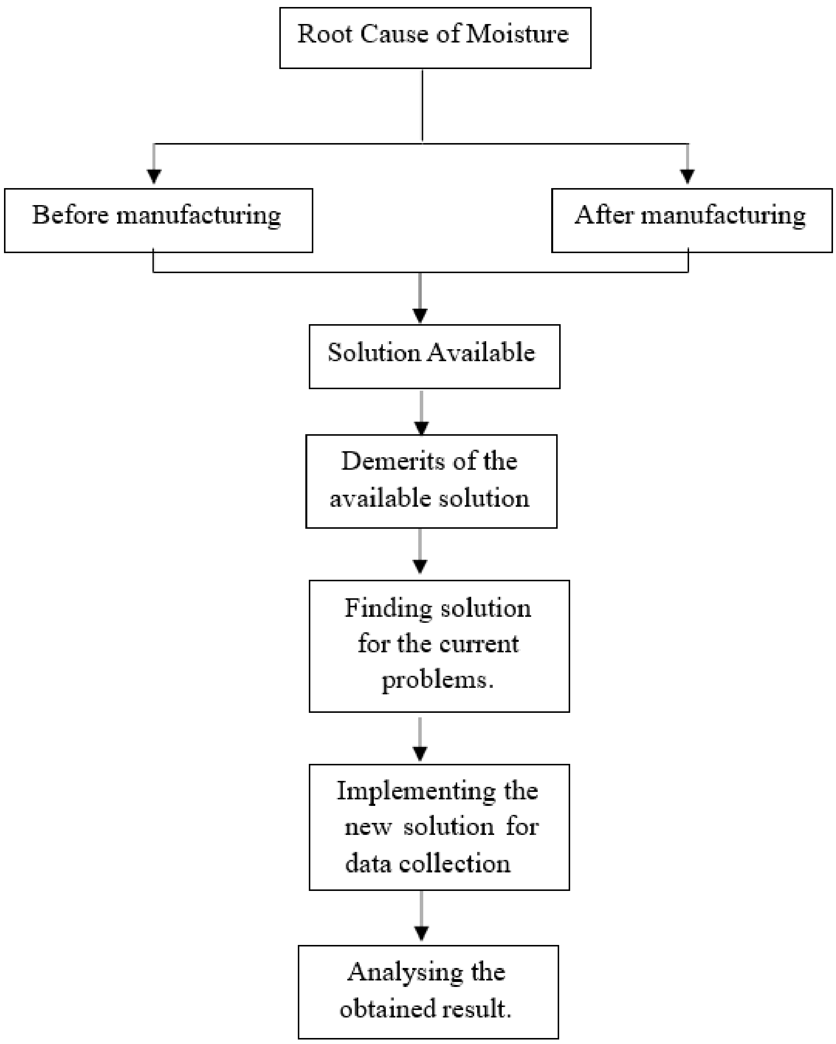

Fig. 3. Methodology

5 Cause of Humidity During The Manufacturing Process

Throughout the manufacturing process of corrugated boxes, various stages such as ink printing, glue lamination, and finishes like lamination generate moisture. This moisture can be detrimental to the quality and appearance of the cardboard material if not managed properly. To ensure that the corrugated boxes are of the highest quality, it is essential to provide sufficient drying time in environments with high humidity and moisture content. Rushing the drying process can result in the glue or ink not fully drying, making the boxes susceptible to damage, deterioration, and other structural issues that can negatively impact their appearance, strength, and durability. Therefore, it is important to prioritize the drying process to ensure that the boxes are fully dried before they are packaged and shipped to their destination.

6 Moisture Measurement in Paper and Corrugated Board

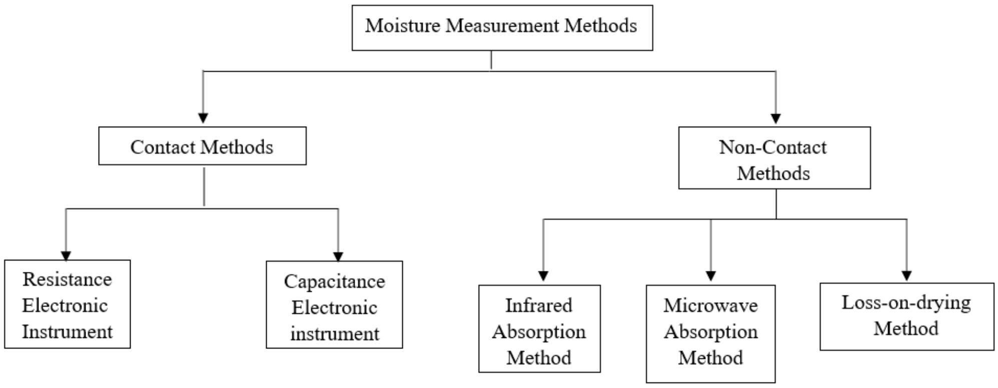

Fig.4. Moisture Measurement Methods

There are various methods to measure the moisture content of paper and corrugated boards. One of the ways is through touch methods which involve using electronic instruments that measure resistance and capacitance[5]. These instruments require direct contact with the material being measured and measure the electrical resistance of the material, which is impacted by absorbed moisture. Although they only measure a small area and require calibration, pre-programmed instrument measurements are usually quick and easy to use.

The non-contact techniques are infrared and microwave absorption, which measure returns and compute moisture percentage by focusing microwaves or infrared light on the material and using a sensor. Another approach referred to as the loss-on-drying method, involves drying using a convection oven. A pre-measured sample is heated to 105 ^{o}C in a convection oven using a balance until it stabilizes at a constant weight. In the corrugated industry, the more popular method is called loss-on-drying. Using the loss-on-drying method, an equation is used to determine the moisture content of paper and corrugated boards[6].

$$\text{Moisture Content \%} = \frac{\text{Weight loss on drying (g)}}{\text{Original Weight (g)}} \quad (1)$$

7 Effect of Moisture On Corrugated Box

When moisture infiltrates the paper board layers, including the outer and inner liners and the corrugated medium, it initiates a weakening process. This weakening occurs as moisture causes the material to swell and soften, diminishing its ability to withstand external pressures. Consequently, the compression strength of the box decreases, making it more susceptible to collapse under loads. Similarly, moisture-induced softening compromises the box's bursting strength, rendering it more prone to puncture or rupture when subjected to internal pressure. To maintain the performance and reliability of corrugated boxes, it's essential to minimize moisture exposure through proper storage and handling practices.

8 How to Control Moisture Content

To regulate the moisture content of corrugated cardboard, it is essential to focus on the following factors:

1. Strictly follow the GB462 standard while handling the corrugated base paper.

2. First and foremost, determine the moisture content of the corrugated base paper.

3. After the production process, store the corrugated base paper at room temperature. Make sure that the relative humidity does not exceed 70%.

4. To prevent moisture, cover the ground with a moisture-resistant substance. Also, store the corrugated base paper vertically in stacks.

5. Keep the storage period for corrugated base paper as short as possible.

During manufacturing, the following should be done:

If the moisture content of the cardboard is too high and the temperature of the preheating roller is not high enough to meet the requirements, increase the steam pressure of the boiler to bring the steam provided from it to saturated steam. The necessary steam pressure is 1.1 MPa + 0.2 MPa. If the base paper's moisture content is low, use the single-sided machine's wetting roller to fully utilize the spray device and raise the moisture content to the necessary levels by adjusting the paper guide roller to reduce the preheating area. Adjust the single-sided machine's glue roller and rubber squeegee distance. The gap between the main corrugating roller and the glueing roller should be at least 0.02 mm larger than the thickness of the corrugated paper being used. The gap between the scraping and glueing rollers should be between 0.2 and 0.25 mm. The double-sided machine requires that the gap between the glueing and pressing rollers be between 0.05 and 0.1 mm smaller than the height of the single-sided corrugated cardboard that goes through. Similarly, the gap between the scraping and glueing rollers should be between 0.25 and 0.25 mm. There are two approaches for drying cardboard boxes after manufacturing:

- Traditional
- Modern

To dry cardboard boxes traditionally, it is recommended to place them in a location that receives direct sunlight for most of the day. Make sure there is enough space between them to allow for even drying and air circulation. To ensure that the boxes dry evenly, it is important to rotate and flip them regularly. Keep an eye on the weather, as exposure to moisture or rain can damage or change the shape of the boxes. In case of rain or moisture, move them to a dry place. The drying process is influenced by factors such as the thickness of the cardboard, the amount of sunlight available, and the humidity of the air. Generally, it takes 30 min to 1 hour.

The ultramodern system involves four methods: steam-hotted cylinders, infrared drying, microwave oven drying, and hot air convection. The corrugated board is guided through a series of large, steam-hotted cylinders, which dematerialize the remaining moisture. Infrared radiation can also be used to dry the corrugated board, and this system is effective and can be precisely controlled to achieve the required moisture content. Microwave oven drying is used in some technical operations and requires a technical procedure. Hot air convection dryers blow hot air over the corrugated box to remove humidity and they are energy-effective and easy to control.

9 Demerits of the Existing Solution

Traditional drying methods, such as air drying or natural drying, have been widely used for decades to dry corrugated boxes. However, these methods have some drawbacks. For instance, they are generally slower, which can lead to longer lead times for manufacturing the boxes. Additionally, the drying process can be uneven, depending on the ambient conditions, which can vary widely. This can ultimately affect the quality and appearance of the boxes.

Natural drying methods are largely dependent on climate and rainfall conditions. For example, in rainy weather, the drying process can be significantly slowed down, while in hot and dry conditions, the boxes may dry too quickly. This can have adverse effects on the box quality and overall production efficiency.

To address these challenges, many companies have switched to modern drying technologies, such as ultramodern drying machines. These machines typically use a combination of heat and airflows to dry the boxes faster and more evenly. However, these modern machines also have some demerits. One of the main drawbacks is that they can be expensive to purchase and install. This can pose a significant financial challenge, particularly for small or budget-conscious manufacturers.

Another challenge is that operating and maintaining these modern drying machines can be difficult. They require skilled laborers to operate and maintain them, which can increase labor costs. Additionally, these drying machines are complex and require careful calculations and control to achieve the required drying results. Any miscalculations or errors can lead to suboptimal drying results, which can affect the quality of the boxes.

In summary, while traditional drying methods have been used for many years, they have their limitations. Modern drying technologies offer faster and more even drying results, but they also come with some challenges. Companies need to carefully consider the costs and benefits of each option before making a decision.

10 Experimental Setup

10. 1. Box Compression Strength Test

To test the bursting strength of corrugated boxes, we need to follow the steps as shown in Fig.5. First choose representative samples that are of the same size, material, and design. These samples should be heated in a controlled environment for at least 24 hours to ensure their moisture content has stabilized. Once the samples are ready, place a conditioned corrugated box on a stable surface and align it beneath the upper plate of the compression testing machine. Gradually apply vertical force at a constant rate using the machine while measuring the applied force and resulting deformation. The test should continue until the box fails, and you should record the maximum load sustained before failure. Repeat the test for multiple samples to ensure consistency, and then analyze the results to calculate the average compression strength.

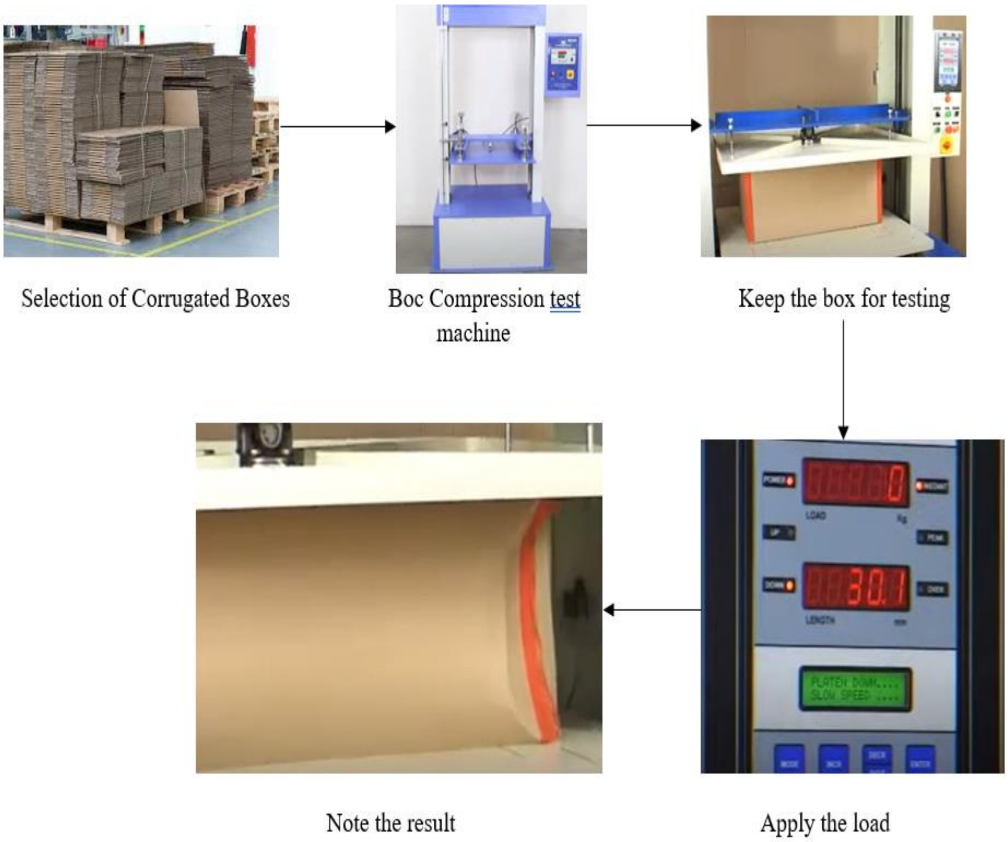

Fig.5. Procedure to conduct Compression strength test

10. 2. Box Bursting Strength Test

To test the bursting strength of corrugated boxes, we need to follow the steps as shown in Fig.6.. First, prepare the corrugated box samples of the same size, material, and construction and cut them into 10 x 10 cm sizes. Then, the samples were in a controlled environment for 24 hrs to stabilize the moisture content. Next, secure the sample in the bursting strength testing apparatus, ensuring proper alignment and clamping. Gradually increase the internal pressure within the sample using the testing apparatus until the box bursts. During the test, record the pressure at which the bursting occurs. For reliable and consistent results, repeat the test for multiple samples. Finally, analyze the data to determine the average bursting strength of the corrugated boxes.

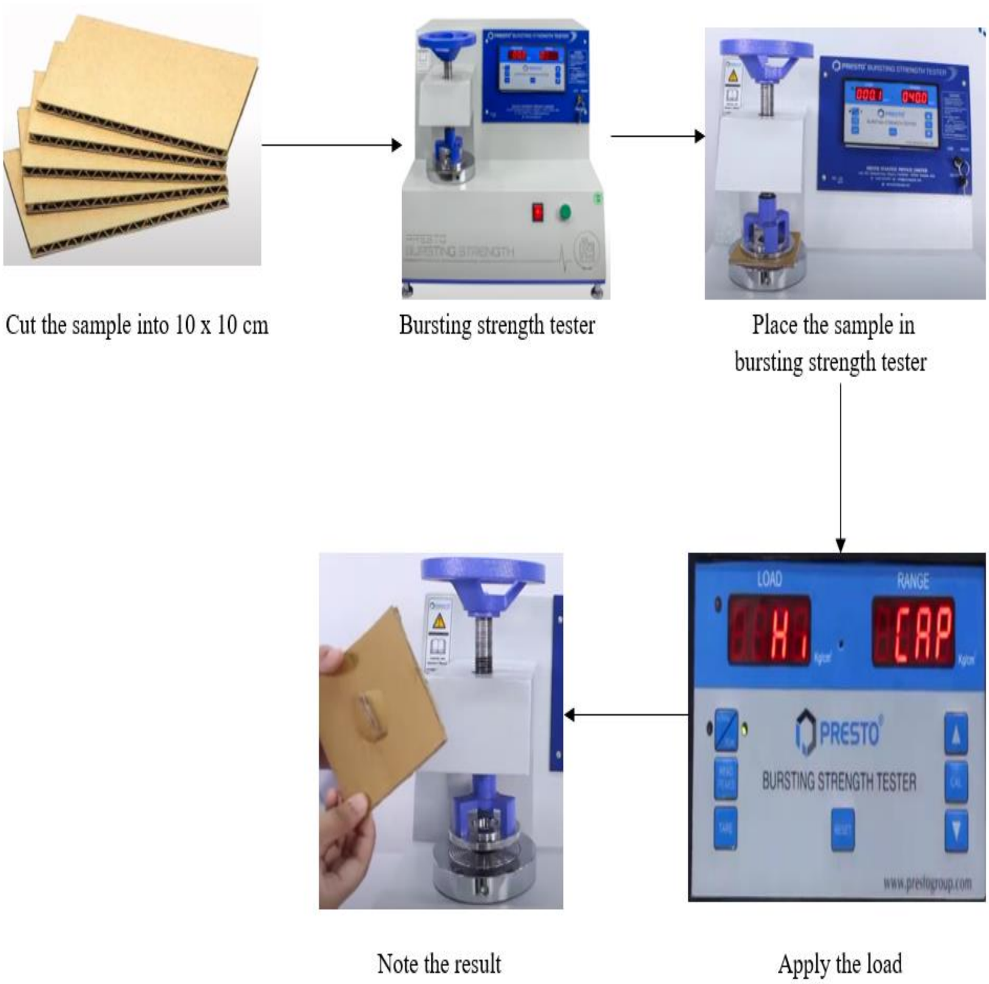

Fig.6. Procedure to conduct Bursting strength test

11 Data Collection

Table 1 Variation of moisture content at different manufacturing stages at Cobb values 30 & 40

Cobb Value	Box Size	Box	Infeed paper	Outfeed (flute making)	Sheet Pasting	After 4hrs	Room Temp.	Relative Humidity
Cobb 30	18"x 9"x 18"	Box1	7-8 %	11-17%	14-19 %	12-15%	22’C	50%
		Box2	7-8 %	10-16%	15-19%	11-16%	22’C	50%
		Box3	7-8 %	9-11 %	16-18%	13-14%	22’C	50%
		Box4	7-8 %	8-12 %	12-17%	9-11%	22’C	45%
		Box5	7-8 %	8-15 %	10-18%	9-12%	22’C	45%
Cobb 40	18"x 9"x 18"	Box1	9-10%	11-17%	15-20 %	13-19%	22’C	60%
		Box2	9-10%	12-16%	17-22%	16-18%	22’C	60%
		Box3	9-10%	13-15 %	14-20%	13-17%	22’C	60%
		Box4	9-10%	11-12 %	18-21%	16-20%	22’C	60%
		Box5	9-10%	12-15 %	16-19%	12-18%	22’C	55%

After analyzing Table 1, we can determine that the Cobb value has a direct impact on the moisture content of corrugated boxes. The Cobb value ranges from 30 to 40, and those boxes with a Cobb value of 30 have less moisture than those with a value of 40. A Cobb value of 30 suggests that the material has average water absorbency but is not highly resistant to water. If a corrugated box with a Cobb value of 30 is exposed to moisture, it may absorb some, causing it to become weaker. The extent of damage depends on several factors, including the duration of exposure, the quantity of moisture absorbed, and the quality of the corrugated material. On the other hand, a Cobb value of 40 indicates even higher levels of moisture absorbency than a Cobb value of 30. Consequently, corrugated boxes with a Cobb value of 40 are more prone to damage caused by moisture. They absorb more moisture, leading to decreased strength and structural integrity. Therefore, it's not advisable to use boxes with a Cobb value of 40 to protect moisture-sensitive items or in wet environments. In conclusion, the Cobb value is a crucial factor to consider when selecting corrugated boxes, and as the value increases from 30 to 40, the moisture absorbency of the material increases, making the box more vulnerable to damage when exposed to moisture.

12 Result and Discussion

12. 1. Box Compression Strength Test

Table 2 shows the box compression strength Cobb values of 30 and 40

	Box	Relative humidity	Peak load (Kgs)
Cobb 30	Box1	50 %	143.5
	Box2	50 %	145.4
	Box3	50 %	146.3
	Box4	45 %	152.4
	Box5	45 %	153.6
	Overall		**148.24**
Cobb 40	Box1	60 %	139.4
	Box2	60 %	96.3
	Box3	60 %	134.2
	Box4	60 %	121.3
	Box5	55 %	140.1
	Overall		**126.26**

Tables 2 demonstrate how the moisture content affects the ability of corrugated boxes to withstand compression. The compressive strength of corrugated material is susceptible to changes in relative humidity (RH) due to the characteristics of paper-based materials commonly used in corrugated boxes. Corrugated materials are hygroscopic, which means they easily absorb and release moisture from their surroundings. In regions with high relative humidity levels, the paper fibers in corrugated materials can absorb moisture, causing them to expand and soften. This swelling can weaken the material's resistance to compression and jeopardize its structural integrity. Conversely, in low relative humidity conditions, the material may dry out and become more brittle, potentially leading to a reduction in compression strength.

12. 2. Box Bursting Strength Test

Table 3 shows the box bursting strength Cobb value 30 and 40

Cobb Value	Box	Relative humidity	Peak load (Kg/cm2)
Cobb 30	Box1	50%	8.6
	Box2	50%	8.6
	Box3	50%	8.6
	Box4	45%	8.6
	Box5	45%	8.6
	Overall		8.6
Cobb 40	Box1	60%	8.1
	Box2	60%	8.1
	Box3	60%	8.1
	Box4	60%	8.1
	Box5	55%	8.1
	Overall		8.1

As the moisture content of paper increases as shown in Table 3, it becomes softer and less rigid, which results in a higher Cobb value. This increase in moisture weakens the internal connections between paper fibers, making the paper more prone to bursting when exposed to strain. Therefore, paper with a higher Cobb 40 is expected to have a lower burst strength due to its increased moisture content.

On the other hand, when the paper has a lower moisture content, indicated by a lower Cobb 30, it tends to be drier and stiffer. In such cases, the fiber-to-fiber bonding within the paper is enhanced, resulting in improved resistance to bursting. This is because the reduced moisture levels contribute to stronger internal connections between the paper fibers.

13 Conclusion

We have successfully adopted a new methodology to control the moisture content in corrugated boxes by varying the Cobb value. This method has allowed us to optimize the moisture content of the paper used in the boxes, which can have a significant impact on the performance of the boxes.

Through our research, we have found that a Cobb value of 30 typically indicates lower moisture content and, therefore, drier paper. Drier paper tends to be stiffer and has better fiber-to-fiber bonding, which can lead to higher burst strength. It can withstand more pressure before bursting. This is because the drier paper has a more tightly packed fiber structure, which allows it to resist deformation better.

In contrast, a Cobb value of 40 indicates higher moisture content and wetter paper. Wetter paper is softer and may exhibit lower burst strength due to weaker fiber bonds, making it more susceptible to rupture under pressure. This is because the wetter paper has a looser fiber structure, which makes it easier for the fibers to separate under stress.

Furthermore, the relationship between compression strength and Cobb value is similar to burst strength. Drier paper (Cobb value of 30) often has higher compression strength because it is more rigid and less prone to deformation under pressure. This means that boxes made from drier paper are less likely to collapse under heavy loads. In contrast, wetter paper (Cobb value of 40) may have lower compression strength as it is softer and more likely to deform under compressive loads.

In conclusion, by optimizing the moisture content of the paper used in corrugated boxes, we can improve their performance and durability. This can result in fewer damaged products during transit, reducing costs and improving customer satisfaction.

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