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Experimental and Analytical Testing Analysis of Graphic Cardboard Package Resistance to Static Loads

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Abstract: ***The Main objective of the project is the progression or methods used for analyzing the effect of windows in paperboard packaging to its strength and its test methodology. The test methodology is which the experimental carried out in a crash test machine and analysis using ANSYS software is carried out. The primary goal of the project is to find which window shapes provides more strength to increase the usage of paperboard packaging and to compare the Analytical and Experimental Results.***

Keywords: Keywords: Paperboard, Compressive Strength, ANSYS, Solidworks Modelling

1. Introduction

With an increasing usage of paperboard packaging all over the world, attention has been focused on all possible methods to increase the usage of paperboard packaging by increasing its strength. The investigation carried out and reported in our project has been confined by the effect of window shapes in paperboard packaging. This model considers the geometrical and mechanical properties of the corrugated cardboard constituents [1]. Three different types of window shapes were used. All three window shapes used in my project uses the same kind of paperboard and packaging. The packaging was tested one by one. These packages were used throughout the project.

The paperboard sector is primarily considered in conjugation with the paper industry. The Paper & Paperboard total commercial size is about 630.9 billion USD. In that 40.1% of Papers are used by Europeans and 50% are used by Packaging Companies. According to ProCarton, the economic usage of paperboard and paper are influencing the curves of Gross Domestic Product (GDP). Gross revenue from the carton in European Community add together to approximately 8 billion Euros worth, they are also very sensitive to atmospheric conditions[2]. Cartons make up one-third by paper and board packaging and 15% of all packaging. The waste papers are used by Europeans for recycling the paper process of theaverage of more than 54%. The manufacturing of this paperboard requires so much energy and capital amount investment.

2. Paper Packaging Benefits

Paperboard is a dense paper-based material which has less weight compared to Cardboard and more weight compared to Paper.The pallet uses corrugated cardboard sheets that are precision cut and scored to be formed about the rigid reusable support stringers [3]. In order to assemble the package adhesives are used. The need for glue introduces an extra step in the assembly process, increases assembly and material costs, and reduces the ability of the beam to be recycled.[4]. The paperboards are the papers which weigh more than 224 g/m2 as per the ISO regulations. However, there are prohibitions. Paperboard could be single- or multi-ply layout. Paperboard could constitute easily cut off and imprinted, are lightweight, and since it's strong, are utilized in packaging.

Whenever we prefer paper-based packaging, we know that we are preferring an inexhaustible, reusable substratum perfectible for engaging consumers and pushing back gross sales. However, there are a lot of dissimilar carton styles, each with singular benefits.

Folding Cartons: The Economic Carton for Customization and Printability

A Case of paperboard packaging that folds up directly for storage and shipping, folding cartons are made of 10 to the36-point board and could comprise fabricated using a wide array of virgin and/or recycled board types (SUS, SBS, CUK, CRB, FBB, etc.). The Folding Cartons can be added flutes in some cases Called “mini flute,” these cartons boast a small E, F, G, or N-fluted (wavy) substrate that is sandwiched between two liner boards.

Since foldable cartons bend flat and consequently take up brief space, they are sparing to ship. And since they are published in sheets of paper containing a lot of carton flats, folding cartons generally accept lower per-unit prices and firmer product accelerates than fixed boxes. They allow first-class impress quality (color enrolment, consistency, fine detailing), and different rigid boxes or eminent print-quality corrugated, the external coat of folding cartons can be published at once, hence saving a step in the product process.

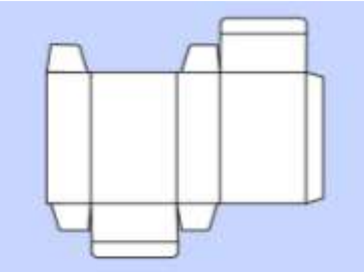


Figure: Folding Cartons [17]

Rigid Boxes

Generally bigger than foldable cartons, fixed (apparatus) boxes are made of blockheaded 36 to 120 pt. board covered with an impressed paper enclose. These boxes broadly do not bend flat.

The Visual appearance and the impressive surface provides a feel of Prestigiousness, lavishness, elegance, and caliber, and are idealistic as lower, high-end details such as jewelry or electronics Contrary to closing cartons, which are embarked compressed and consequently ask fabrication ahead constituting filled up with the product, rigid boxes commonly continue to raise and consequently accept inferior fabrication prices.

Corrugated Packaging: The Unbeatable Box for Strength

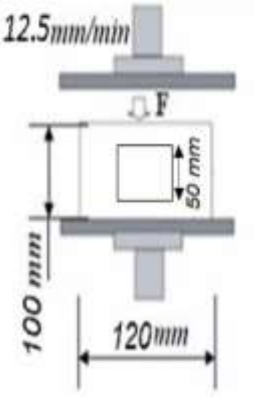
Generally produced of cheap brown Kraft fluted (or crinkled) paperboard that is sandwiched between layers of linerboard. In fact, corrugated could constitute easy custom-made for dissimilar applications that require altering levels of durability and product protection: flutes are available in an extensive variety of heights (A, B, C, E, etc.), and linerboard layers can constitute double- or triple- layer walled for additional durability. The box arrangement has its quality depending upon the side dividers or parcel outlines so that if these are fortified, when the substance is evacuated, the side dividers or segment outlines can't be expelled mostly and particularly, it is extremely cumbersome to remove small articles received in the container or unused box materials in the folded conditions[18].

For imprinting process, Corrugated boxes have a long run restrictions. The best impress caliber and crispness for corrugated is attained using mottled white or bleached white linerboard, or by impressing on a tag that is then affixed to the corrugated board. The box has exterior panels, top and bottom flaps, and interior pads[19].

3. Experimental Analysis

To Perform Crash test for the different shapes of windows to the same type of Paperboard Packaging and to analyze the damage done to the package. Three different shapes for windows are Triangle, Square, and Circle and totally there were 15 packages, 5 in each of the shapes. The Paperboard used here is Arktika and it is 300 grammage. The dimension of this paperboard packaging is 40*20 cm.

Every Package weighed the same. Crash test was carried out for Circle, Triangle, Square separately for the 5 packages out of 15 packages to obtain three different graphs for Circle, Triangle, and Square windows Packaging. Experiment 1 was carried out for Square, Experiment 2 for Circle and Experiment 3 for Triangle respectively.



Figure

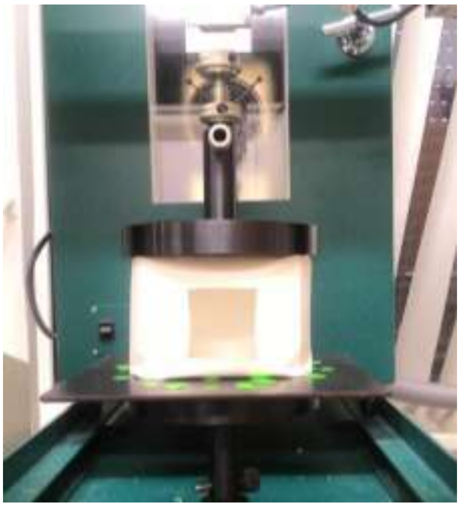
Equipment used

The experimental setup is explained in Figure 1. A tension-compression stand, Tinus Olsen H10KT, was equipped with a fixed plates and sensor. Experimental tests were carried out by using the same type cardboard packaging with three different shapes of cuttings. The tests were carried out at the temperature of 20±2°C and air humidity 65± 2%.Compressive stands top plate 3, during compression has moved 12.5 mm/min speed. Deformation data were recorded on a computer with specialized software QmatPro 1.0.20 support. Compressive strength was used for graphic paperboard packaging with different forms of the local cut-out (Fig 14). In determining the geometric shape of the compression, the survey provides five samples with a square window, the same number of samples with triangular and circle-shaped windows.

Figure

Figure

These are the 15 packages made for Experimental Testing. 5 packages for circle shaped Window, Triangle shaped window, and Rectangle shaped window respectively. The dimension of each box is same but the windows shape dimensions of Square, Triangle, Circle differs as they are of different shapes.



Figure

This figure shows all the Crashed packages after the experimental testing is carried out. The deformation for each package can be seen clearly.

Figure

4. Experimental Results

The load bearing capacity for Square window is given by the graph below:

Figure: Experimental Graph Results for Square windows

The graph shows the experimental results for all the square windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 162.6 N and stress at break point is 0.0211 Mpa.

The load bearing capacity of Triangle window is given by the graph below:

Figure: Experimental Graph Results for Triangle Windows

The graph shows the experimental results for all the Triangle windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 160.68 N and stress at break pointis 0.0171 Mpa.

The load bearing capacity of Circle window is given by the graph below:

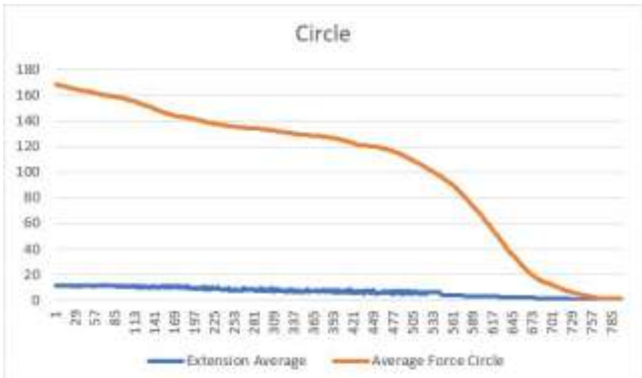


Figure: Experimental Graph results for Circle Windows

The graph shows the experimental results for all the Circle windows. The Extension is displayed in X-axis in mm and to the Force in Y-axis. The maximum force is at 168.31 N and stress at break point is 0.0242 Mpa.

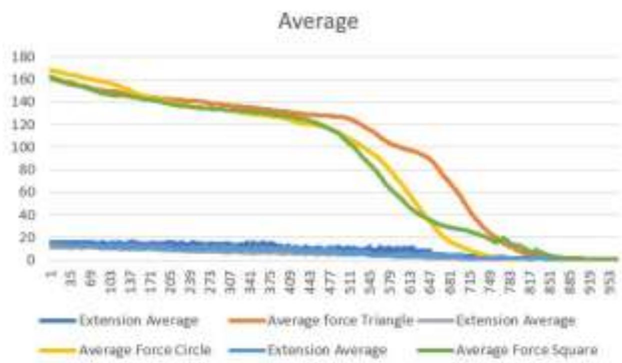


Figure: Average Compiled Graph results

This Graph is a compilation of all the average Extension and average force capability for each window shapes. The circle window can take more load and less deformation while the Triangle shows more deformation even with lesser load values.

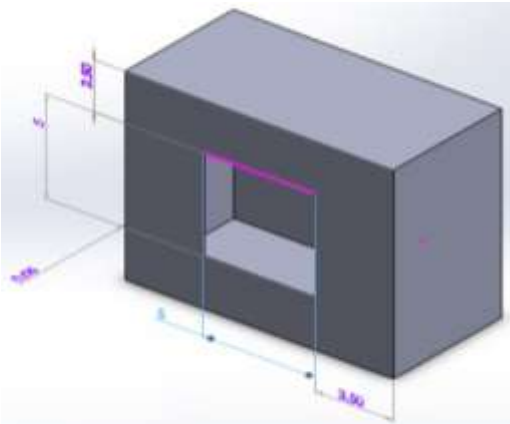
Experimental Result Analysis

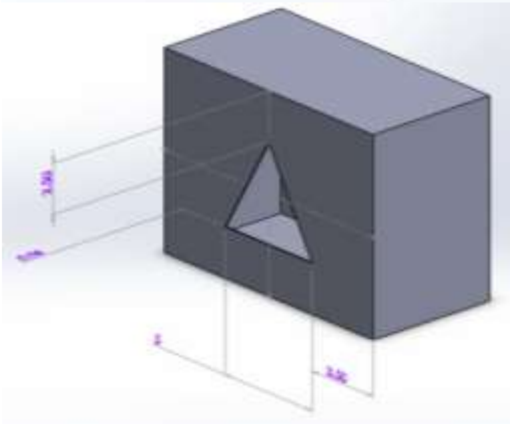
1) From the experimental data, we have found out that Square window bears a maximum force of 162.6 N with a maximum stress of 0.0211 Mpa
2) From the experimental data, we have found out that Triangle window bears a maximum force of 160.68 N with a maximum stress of 0.0171 Mpa
3) From the experimental data, we have found out that Circle window bears a maximum force of 168.31 N with a maximum stress of 0.0242 Mpa

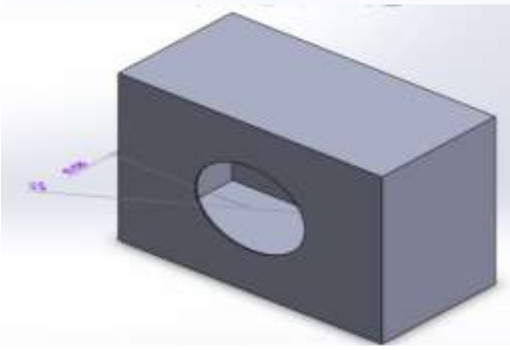
Analysis Part

The Models for analysis is created using solid works with the dimension
Length= 12 cm
Breadth= 10 cm
Width= 6 cm
Thickness= 0.05 cm

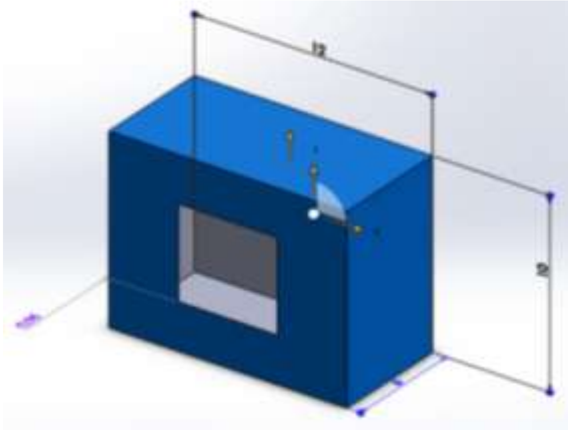
And the hole dimension is same but varies according to shape

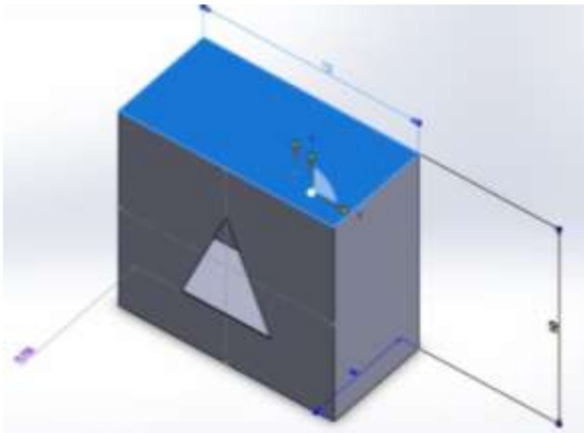


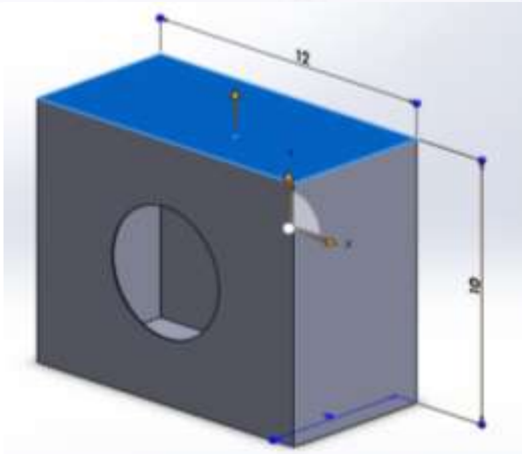




Isometric Views:







Ansys is used for Analysis and Solidworks is used for modeling.

- Ansys 14.0 is used here for Analysis.
- The drawings from Solidworks are imported to Ansys using step format.

Generally, Analysis is divided into 3 types:

1) Pre-Processor
2) Solver
3) Post-Processor

Pre-Processor includes Geometry Model, Material Property, Mesh and Boundary Conditions.

- Solver- Run and solve to get results.
- Post-Processor- To get Results.

The Input values are given to get the required output or results. The Values given are:

- Young’s Modulus,

- Poisson's Ratio and
- Density

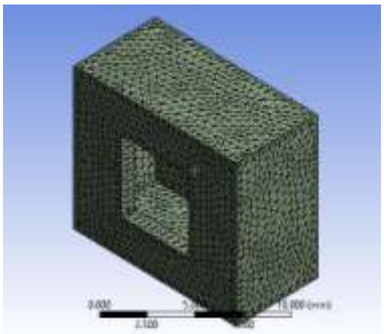
These values are calculated using formulas and the values obtained for

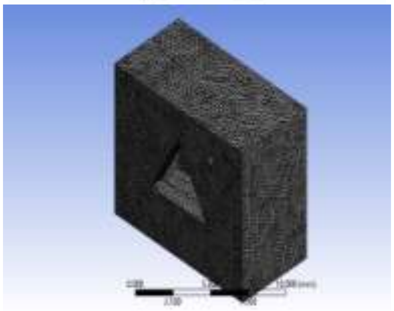
1.Circle:
a. Young's Modulus = $8.6e^{(-11)}$ GPa
b. Poisson's Ratio = 0.31
c. Density = 1.00 grams per cubic centimeter

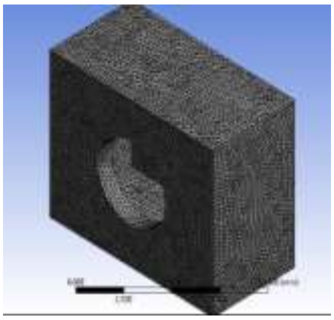
2.Triangle:
a. Young's Modulus = $1.73e^{(-10)}$ GPa
b. Poisson's Ratio = 0.33
c. Density = 1.00 grams per cubic centimeter

3.Square:
a. Young's Modulus = $1.09e^{(-11)}$ GPa
b. Poisson's Ratio = 0.35
c. Density = 1.00 grams per cubic centimeter

Meshing:



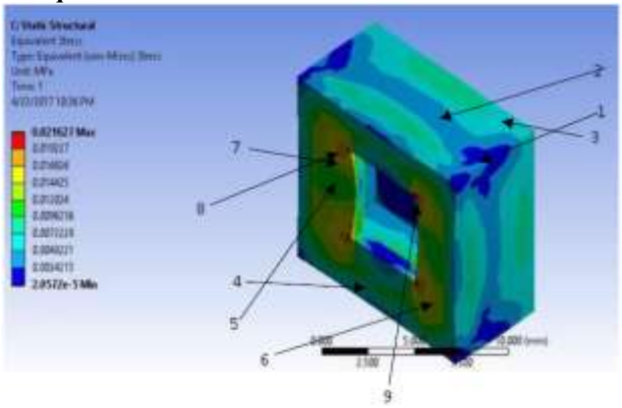




Meshing divides the whole component into several sub-Components to analyze each sub-component precisely.

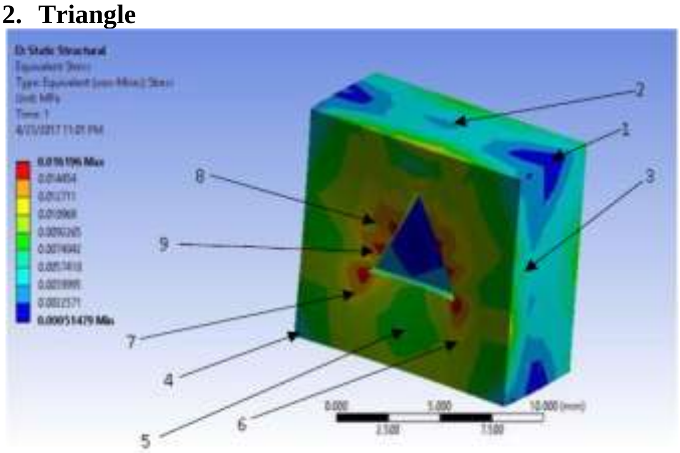
Analysis Results

1. Square



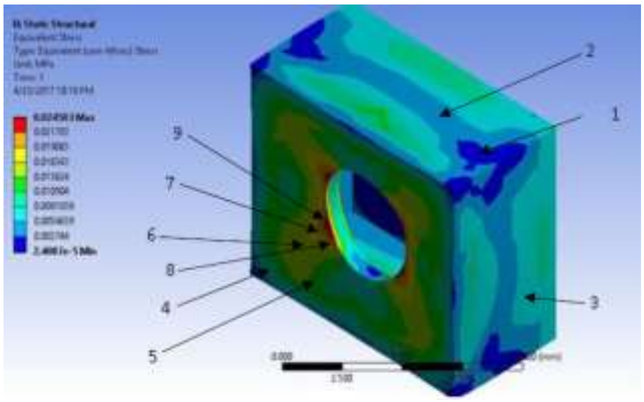
The amount of stress acting at a point is given by the color code with the highest point of stress being 0.021627 and the lowest being 2.0572 e^{-5}.

2. Triangle



The amount of stress acting at a point is given by the color code with the highest point of stress being 0.016196 and the lowest being 0.00051479.

3. Circle



The amount of stress acting at a point is given by the color code with the highest point of stress being 0.024503 and the lowest being $2.4087e^{-5}$.

The minimum stress is at 1 and gradually the stress increases and the maximum is at 9 and the values of stress are shown in the pictures 33, 34 and 35 for Square, Triangle and Circle Window Packages.

5. Results

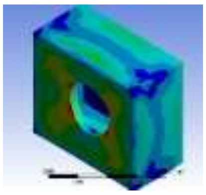
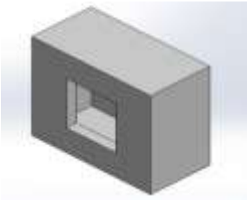
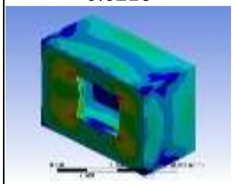
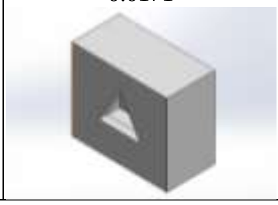
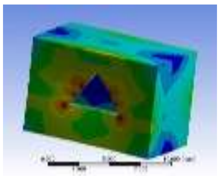
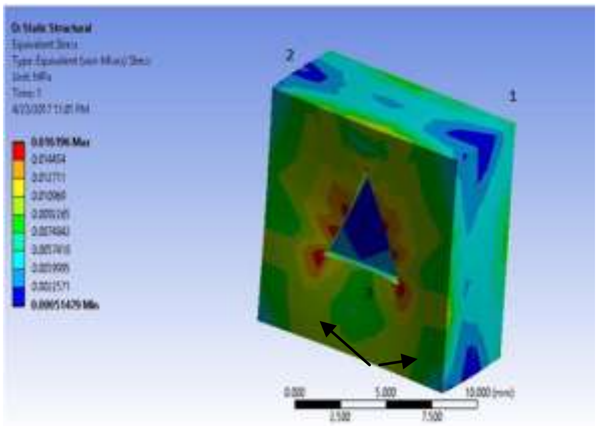
Shapes	*Experimental (Max. Stress)*	*Analytical (Max. Stress)*
Circle	0.0242 	0.0245 
Square	0.0211 	0.0216 
Triangle	0.0171 	0.0161 

Table: Results

- The circle window has a stress value of 0.0242 Mpa for experimental and 0.0245 Mpa for analysis.
- The Square window has a stress value of 0.0211 Mpa for experimental and 0.0216 Mpa for analysis.
- The Triangle window has a stress value of 0.0171 Mpa for experimental and 0.0161 Mpa for analysis.

Both Analytical and experimental results are similar when compared. From the results, it's found out that circle window has the highest load bearing capacity.

6. Results Verification



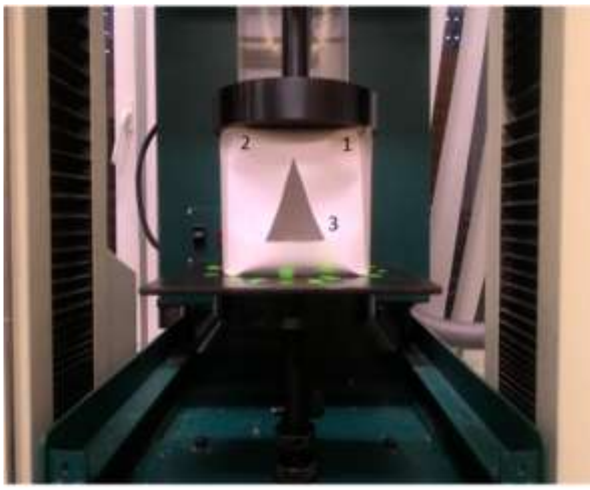


Figure: Experimental and Analytical Methods

At the point 1 and 2 act, the minimum stress whereas the maximum stress acts in point 3. It is clear from the above picture that the minimum and maximum stress acts exactly at the same point in both experimental and analytical.

7. Conclusions

From the above results and calculations, it is concluded that the Circle Window Packaging provides Maximum Stress for the force applied compared to Triangle and Square and thus having more Strength. The three kinds of Packaging are tested and analyzed in Results and the results are same in both experimental and analytical and thus the results are accurate.

- The Square shaped window package stress value at break point forExperimental- 0.0211 Mpa and Analytical-0.0216 Mpa; Maximum force are at 162.6N and Extension of 7.96 mm.
- The Triangle shaped window package have stress value at break point for Experimental-0.0171 Mpa and Analytical-0.0161 Mpa; Maximum force are at 160.68N and Extension of 9.74 mm.
- The Circle shaped window package have stress value at break point forExperimental- 0.0242 Mpa and Analytical-0.0245 Mpa; Maximum force are at 168.31N and Extension of 7.86 mm.
- The Circle window has more Extension when compared with Square and Triangle windows and from this experiment, it is also concluded that the experimental and analytical results are similar. So that, we can use analytical testing to reduce the wastage of paper or material used in experimental testing since both yields the same result and also reduces time.

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