

# ***A Review on Optimum Design & Analysis of Corrugated Sheet Box Size for an Industrial Part***

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## ***Abstract***

*For every industrial product we need packing box to store and transport from one place to another place, in that Corrugated sheet box are produced in large volume for packaging purpose an application which place high demand on its strength and structural stability. While studying boxes, it was observed that the deformation of the boxes and strength are weak in load bearing capacity. In this paper by reducing the clearance and change in dimension of actual corrugated sheet box, all the deformation and strength will be calculated. Reducing area and specific weight of corrugated board will be found using optimization procedure and FEA. The present study focused on the optimum design of the corrugated sheet box.*

***Keywords:*** Corrugated sheet box, Finite element analysis, Packaging strength, craft paper

## **INTRODUCTION**

Corrugated packaging is a versatile, economic, light, robust, recyclable, practical and yet dynamic form of packaging. There is much more to corrugated than just a box. Daily it is providing global solutions and benefits for

all sorts of applications in all spheres of daily life. Corrugated cardboard is a paper based on material that consisting of a fluted corrugated sheet and one or two flat linerboard. It is widely used in the manufacture of corrugated cardboard boxes and shipping containers. We all

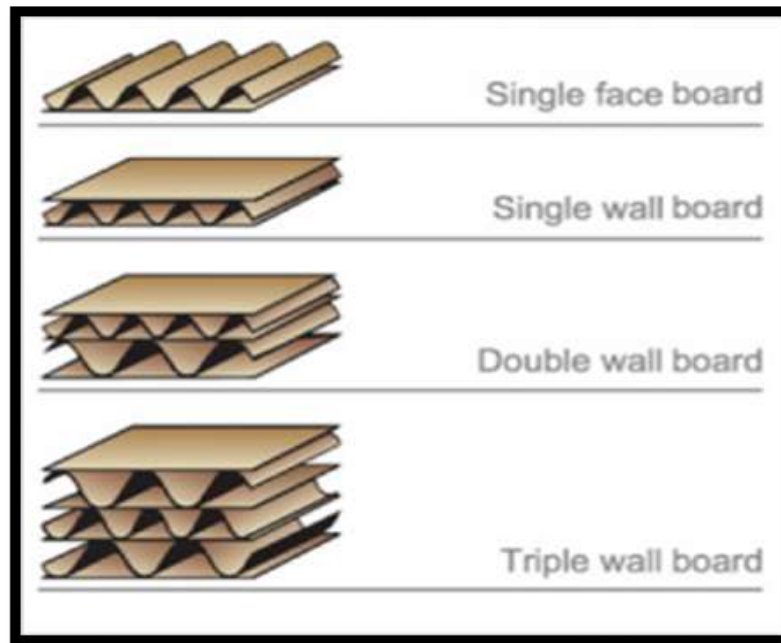
know corrugated board as used in boxes, but its origin is something different.

In the 19th century, hand- cranked corrugated roller presses were used to generate corrugated paper. Corrugated paper replaced the plain paper which was used to keep the shape of the tall, stiff hats worn by gentlemen. It is a machine which is used to crease the corrugated sheet and along that creased edges, the sheet is folded to make the box. Corrugated cardboard pertaining to papers family is one of the most used packing currently. This success is due to the different quality of this material: good protection of the product, minimum cost and can be recycled.

In its most common form single-wall board, two face sheets, called liners, are bonded to a wave shaped web called fluting or medium. The resulting pipes make the board extremely stiff in bending and stable against buckling in relation to its weight. Consequently, the strength of the wood fibers in the board is also utilized in an efficient way. Corrugated flutes are S shaped waves/arches of a corrugated box that make up the board,

this is called the board corrugation. Flutes are essentially the reinforcement that make up the board. They run parallel to depth of the container and give it its rigidity and crushing/stacking strength as well as providing stacking strength, flutes also provide insulation that protect product from sudden temperature changes. Generally speaking, larger flute like A & B profile provide greater strength and cushioning while smaller flute profile like D & E provide better printability and foldability.

B flute having 42-50 flutes per foot and 2.1-3.0mm thick, they provide highest arc size. B flute provide good stacking strength and crushing resistance so this is ideally used for canned goods & display. C flute have 39-43 flutes per foot and 3.2-3.9mm thick, they are the medium between A & B flute. C flute is providing good crushing, stacking and printing properties so this is ideally used for glass, furniture and dairy.



***Fig. 1: Types of corrugated board.***

## LITERATURE REVIEW

M.A. Jimenez-Caballero and I. Conde explained through a set of application shows how different Abacus modeling capabilities can be applied for solving the different problems that arise when modeling corrugated board. The integration of these capabilities led to the development of virtual prototypes for the two most common corrugated board packages boxes and agricultural from the experience in these box types and taking advantage from the inherent modeling simple of the composite layered models together to the flexibility offered by the available modeling techniques in Abacus these virtual prototypes have been increased as a design tool for very different types of corrugated board

packages. Abacus provides the required framework for the development of a virtual prototyping framework for the corrugated board industry. Presented results shows that this application offers possibilities ranging from selection of flute geometry, to detailed design of package geometry for a set of given requirements [1].

Daxner, Flatscher an application which places high demands on the structural stability of the employed corrugated board containers. This is taken into account in the optimization procedure for reducing the area-specific weight of corrugated board which is presented in this paper. For predicting effective properties of corrugated board designs, the geometry of

the board is discredited by finite shell elements, and a minimum wall is used for this purpose. By application of appropriate periodicity boundary conditions, the effective mechanical behavior of a theoretically infinite board can be predicted within the limits of linear shell theory. Therefore, local loss of stability can also be calculated. Numerical optimization schemes were then used to produce improved corrugated board designs by iterative changing the principle geometrical parameters of the corrugated board in the sense of a sizing optimization. Compared to reference geometries a 15.5% weight reduction was achieved for the board made from isotropic material and a 18.2% weight reduction was achieved for the board made from orthotropic material [2].

Arsalan Jamialahmadi studied vibrations and shocks acting on pallets during transportation are transferred to the corrugated boxes and considerably reduce the integrity and life time of the boxes. In this present a technique used for investigation these stress based on a pressure sensitive film, which gives many data point. Study on the forces existing between the boxes shows Rayleigh force system. In this use I- scan system for load distribution analysis. Hysteresis and drift

effects in the I-scan be accounted for in static condition but in dynamic testing, statistical measures should be used to estimate the error [3].

Tomas Nordstrand A panel compression test (PCT-) rig, The PCT-rig furnishes simply supported boundary conditions, that the edges of the panel are prevented from moving out-of- plane without any rotational restraint. The first part of the expression is similar to ordinary Euler buckling of a column, where the maximum compressive load is limited by the critical buckling load. In the second part of the expression the membrane forces produce a parabolic relationship between the compressive load and out-of- plane displacement. The results show an 18 % difference between experimentally estimated critical buckling load and the analytically predicted critical buckling load for orthotropic plates [4].

P. Patel, Nordstrand, and Carlsson, L.A. in this paper an experimental study of failure corrugated boxes under combined stress has been performed. The effective collapse stresses of the board in the absence of local buckling were predicted from stress analysis of the cylinder in combination with the Tsai-Wu failure criterion [5].

T. Nordstrand, Blackenfeldt, M. and Renman, M. A method for prediction of the top-to-bottom compression strength of corrugated board containers using finite element analysis was developed. Up to triple-wall corrugated board is accommodated in the finite element model. In order to keep computational time down, the corrugated main layer is considered to be homogeneous with effective material properties, and the complete corrugated board is represented by a multiply eight node iso-parametric shell element. Buckling and large displacements are considered in the analysis, and container collapse loads are predicted using the Tsai-Wu failure criterion [6].

Zhiguo Zhang, Tao Qiu, Riheng Song and Yaoyu Sun the study based on nonlinear finite element analysis of the fluted corrugated sheet in the corrugated cardboard based on software SolidWorks2008. The model of corrugated board with three or more flutes is reliable for stress and displacement measurement to eliminate the influence of the number of flute in model. According to the static pressure test with the flute height and radius increased, the maximum stress in the models decreased and the maximum displacement increased. The

maximum stress and maximum displacement in the models increase nonlinearity. The optimal flute angle could be 60° for corrugated board [7].

Adeeb A. Rahman This study focused on the glue material in a finite element model that represents the actual geometry and material properties of a corrugated board. The model is a total representation of the different components of the structure (adhesive, linerboard, medium) to perform buckling analysis of corrugated structures under compressive loads. An increase in the modulus of elasticity of the adhesive increases the buckling strength of the fiberboard up to 50% when adhesive modulus is 20 times greater than linerboard modulus. A decrease in adhesive properties relative to the linerboard stiffness does not change the fiberboard strength in a dramatic way, provided that a perfect bond is still present between components. This behavior can be explained by the load sharing principle [8].

R. C. McKee, J. W. Gander, and J. R. Wachuta The top-load compression strength of vertical flute, corrugated boxes which are not extremely short depends on the edgewise compression strength of the combined board, the flexure stiffness of

the combined board in both principal directions, And the box perimeter. A common method of determining flexure stiffness is by testing a specimen of material as a centrally-loaded (three-point) beam. The test results from this type of beam test reflect both the flexure stiffness and the shear rigidity of the material [9].

### RESEARCH GAP

In the Literature review we have found the research paper on the various methods for calculating failure in the corrugated sheet box under compression and tensile load, also buckling constraints gives set of parameters which describe a new design, but we did not find any research on optimum design and analysis of corrugated sheet box size. So, by using FEA we will be carrying out the further calculation on the basis of strength and dimensions. The calculated FEA dimensions are compared with actual dimensions on the basis of strength.

### DESIGN OF CORRUGATED BOX

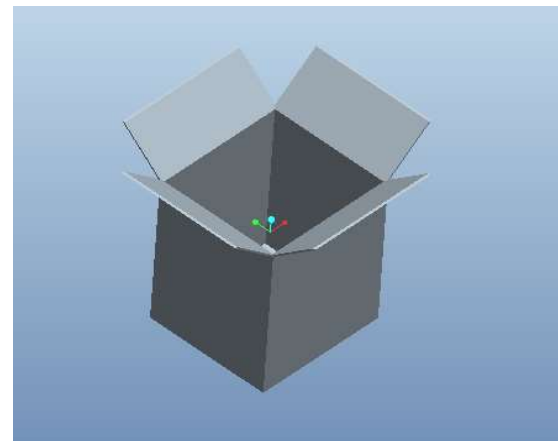
All the corrugated sheet box design in three parameters:

Length X Width X Height (mm)

#### A) *Design of first box:*

The product dimension 620 X 590 X 870 the box outer size is 660 X 630 X 910 and inner dimension of the box is 650 X 620 X

900. The entire dimensions are in mm. Weight of product present in box is 30 kg and maximum load on the bottom side of the box is 7-ply paper used for upper layer of box is 200gsm and inner layer is 120gsm and B type flute is used, it also called as narrow flute.



**Fig. 2: model of first box**

Area of the box: -

$$\begin{aligned}
 A &= (W+H+13) \times (2W+2L+48) \\
 [10] \\
 &= (630+910+13) \times (1260+1320+48) \\
 &= 4081284 \text{ mm}^2 \\
 &= 4.1 \text{ m}^2
 \end{aligned}$$

Weight of the box: -

$W = \text{Area} \times \text{Used paper}$

Used paper for outer layer is 200gsm and for inner layer is 120gsm and for flute paper it is 40% more than that of plane paper.as the box is 7ply so there are 4 plane layer and 3 flute present.

For upper layer 200x1=200gsm, for inner layer 120x3=360gsm, for flute layer 168x3=504gsm Since the total paper is 1064gsm

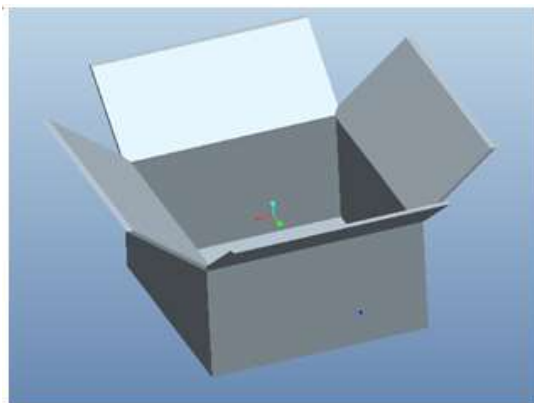
Weight =  $4.1 \times 1064$

= 4342 gm

Weight of box is 4.3 kg

### **B) Design of second box: -**

The product dimension 390 X 390 X 280 the box outer size is 430 X 430 X 280 and inner dimension of the box is 620 X 420 X 270. The entire dimensions are in mm. Weight of product present in box is 20 kg and maximum load on the bottom side of the box is 7-ply paper used for upper layer of box is 200gsm and inner layer is 120gsm and B type flute is used, it also called as narrow flute.



**Fig. 3: Model of second box**

Area of the box: -

$A = (W+H+13) \times (2W+2L+48)$

=  $(430+430+13) \times (860+860+48)$

= 1278264 mm<sup>2</sup>)

= 1.2 m<sup>2</sup>

Weight of the box: -

W=Area x Used paper

Used paper for outer layer is 200gsm and for inner layer is 120gsm and for flute paper it is 40% more than that of plane paper.as the box is 7-ply so there are 4 plane layer and 3 flute present.

For upper layer 200x1=200gsm, for inner layer 120x3=360gsm, for flute layer 168x3=504gsm Since the total paper is 1064gsm

Weight =  $1.2 \times 1064$

=1360.07 gm

Weight of box is 1.3 kg

### **CONCLUSION**

From above its concludes, packaging influences the customer while purchasing a product. It also provides protection to the product. There are various methods for calculating failure in the corrugated sheet box under compression and tensile load. Also buckling constraints gives set of parameters which describe a new design, but this paper focuses on optimum design and analysis of corrugated sheet box size. So, by using FEA we will be carrying out the further calculation on the

basis of strength and dimensions. The calculated FEA dimensions are compared with actual dimensions on the basis of strength.

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