CHAPTER 3

CORRUGATED FIBREBOARD BOXES

Corrugated fibreboard boxes have become increasingly and perhaps the most popular means for packaging in the industries. They are low in cost and offer adequate protection for products. The popularity of these boxes is evidenced in their being used widely for various industries.

A good corrugated box is a result of a proper design able to afford protection for products contained therein throughout their journey, in the meantime, it should facilitate handling and transporting. In addition, it should be reasonable in cost. Corrugated fibreboard boxes currently in use are made of either single wall, double wall or triple wall fibreboard. In Thailand, however, the triple wall fibreboard has not been adopted quite widely since the local industries do not necessitate the use of such strong packages.

To obtain an optimal design for corrugated fibreboard boxes, study must be made on all factors concerned, beginning from the product itself to the feature and style of the box, the environment, means of transportation, storage condition, etc.

DEFINITION

The following definitions apply in this thesis,

1. Corrugated Fibreboard Box : A rigid container made of

single wall, double wall or triple wall fibreboard having closed faces and completely enclosing the contents.

2. Combined Weight of Facings : Total weight of linerboards, exclusive of coating or adhesive, etc.

3. Gross Weight : Total weight of corrugated fibreboard box with contents.

4. Length : The larger of the two inside dimensions of the open face (see Figure 3.1).

5. Width : The lesser of the two inside dimensions of the open face (see Figure 3.1).

6. Depth : The distance between the innermost surfaces of the box measured perpendicular to the length and width (see Figure 3.1).

7. Box Perimeter : The sum of the three inside dimensions (the length, the width and the depth) of the box.

8. Drop Test : The test to determine the ability of corrugated fibreboard box (with contents) to withstand the damage which can be caused by the sudden shock when dropped from a height which can occur in handling.

9. Manufacturer's Joint : That part of a fibreboard box where the ends of the box blank are joined together in the manufacturing process by taping, stitching or gluing.

10. Box Compression Strength : The ability of the box to withstand the compressive load applied at a uniform rate until

failure occurs (see Figure 3.2).

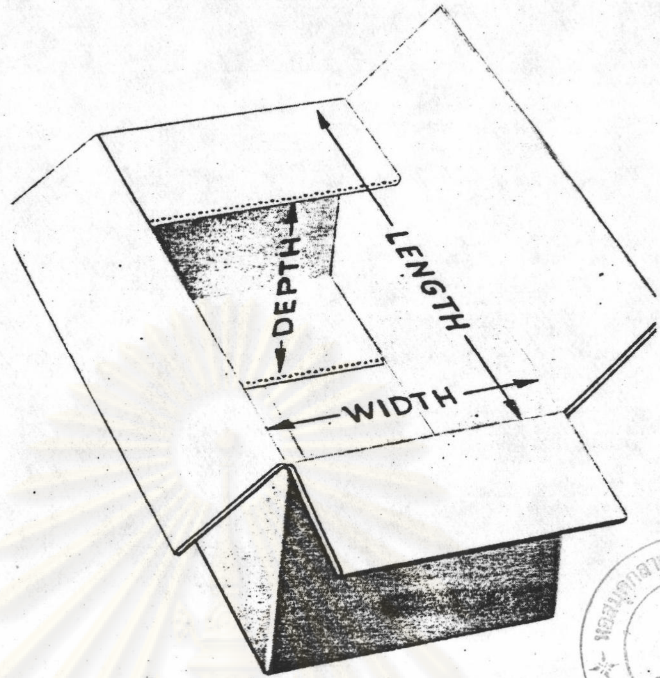


Figure 3.1 Box Dimensions

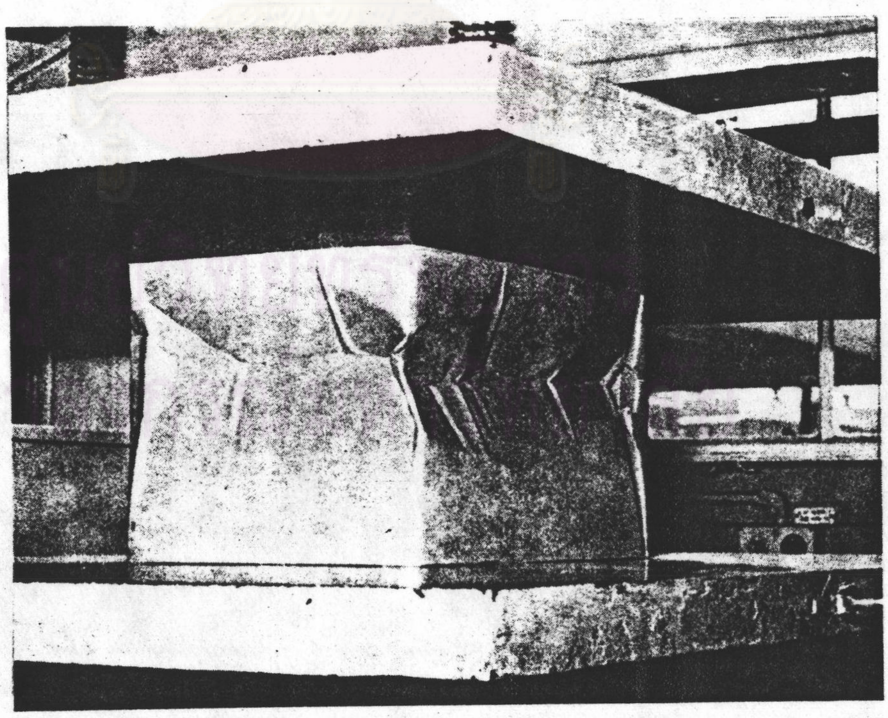


Figure 3.2 Box Failure Under Compression

STYLES OF CORRUGATED FIBREBOARD BOX AND THEIR USES.[2),3)]

The international code for solid fibreboard and corrugated fibreboard transport cases has been established to denote the various designs or types of solid and corrugated fibreboard packgings by means of a simple system of symbols.

The selected types of corrugated fibreboard boxes are described below.

1. Regular Slotted Container (RSC). All flaps same length. Outer flaps meet (Figure 3.3 and Figures C.1-C.2 in Appendix C.).

All the flaps of a regular slotted container are the same length. The outer flaps meet at the centre of the box. The space between the inner flaps varies depending upon the relation of box length to width. These boxes are used more than any other style because they are the simplest to manufacture and are adapted to the shipment of most commodities.

2. Overlap Slotted Container (OSC).

All flaps same length. Outer flaps overlap specified amount (Figure 3.4 and Figures C.3-C.4 in Appendix C.).

This box is similar to the RSC, but the outer flaps overlap not less than one inch nor more than the full width of the box. The inner flaps do not meet. The length of inner flaps is generally no less than one-half the width of the box.

3. Half-Slotted Container with or without Separate Cover (HSC).

A slotted container with one set of flaps only (Figure 3.5 and Figures C.5-C.8 in Appendix C.).

The half-slotted container, with cover, differs from other styles of slotted containers in that it has a separate flanged cover. The cover is separate or is attached, depending upon the particular use of the container. This style is preferred to other styles of slotted containers when it is to be used as a combination shipping and shelf package.

4. Five-Panel Folder (FPF).

End-flap construction and tuck to be specified (Figure 3.6 and Figures C.9-C.10 in Appendix C.).

When assembled, this box has several thicknesses of corrugated board in each end. This provides considerable strength and makes the five-panel folder an excellent container for shipping canes, rods, shade rollers, light fixtures, umbrellas, etc. This style is illustrated open, and closed with paper sealing tape.

5. One-Piece Folder (1PF).

Tucks of specified length (Figure 3.7 and Figure C.11 in Appendix C.).

This economical design is simply a scored and slotted sheet. For the shipment of books, catalogues, or articles of that nature the one-piece folder is used extensively. It is shipped flat to the user, ease of packing is facilitated by the use of a jig or fixture, and closure is generally accomplished with tape.

6. Two-Piece Folder (2PF).

Two scored sheets. Tucks of specified length (Figure 3.7 and Figure C.12 in Appendix C.).

This style consists of two essentially identical scored sheets which are folded around the product. The two-piece folder is stronger than the one-piece folder, as both top and bottom consist of two thicknesses of fibreboard.

This style is used principally for parcel post shipments. It may also be used for express shipments.

7. Three-Piece Folder (3PF).

Three scored sheets. Tucks of specified length (Figure 3.7 and Figure C.12 in Appendix C.).

This style is quite similar to the two-piece folder consisting of three scored sheets with tucks of specified length. It finds wide use with items which are relatively long and flat. All folders are easily stored flat, set-up, packed and closed.

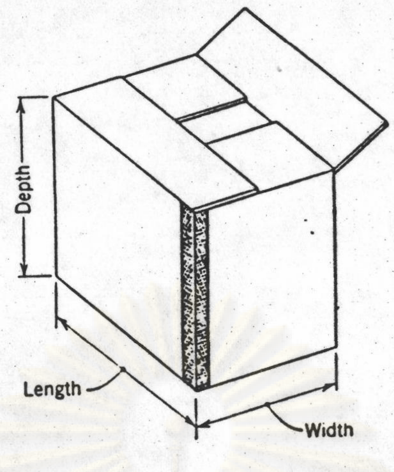
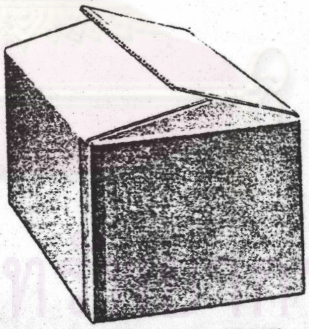
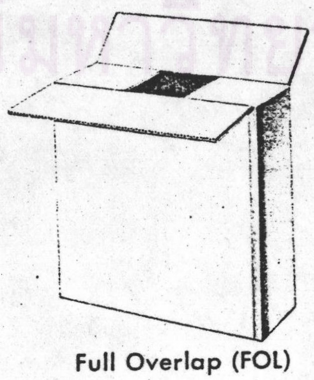


Figure 3.3 Regular Slotted Container (RSC)

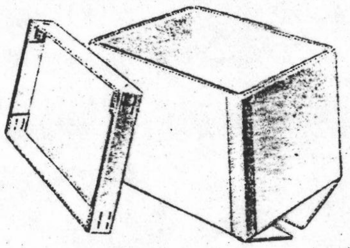


Partial Overlap (OSC)

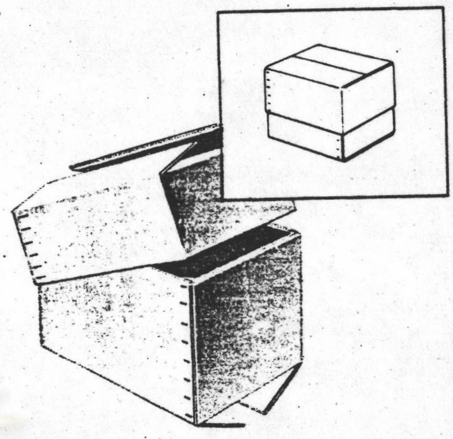


Full Overlap (FOL)

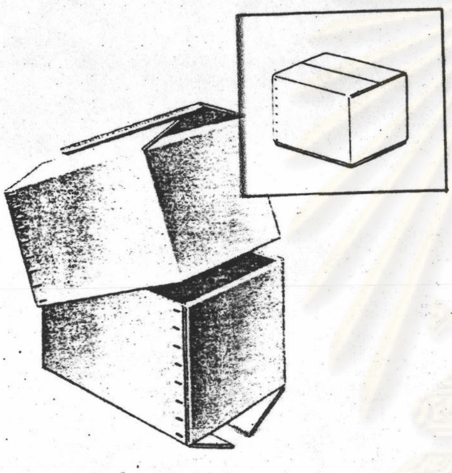
Figure 3.4 Overlap Slotted Container (OSC and FOL)



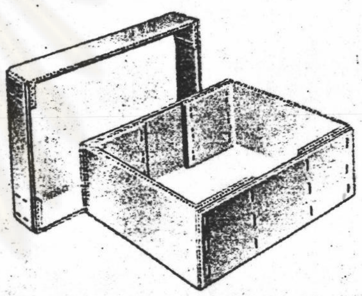
Half Slotted with Cover (SCHS)



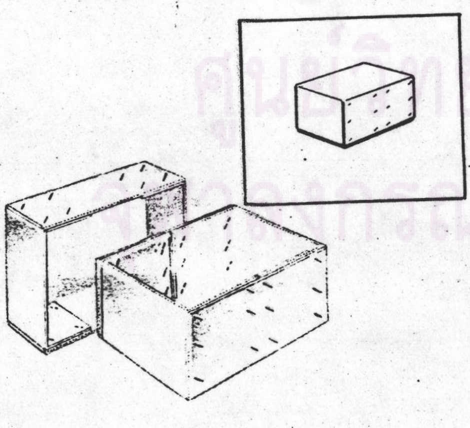
Half Slotted with Half Slotted Partial Cover (PTHS)



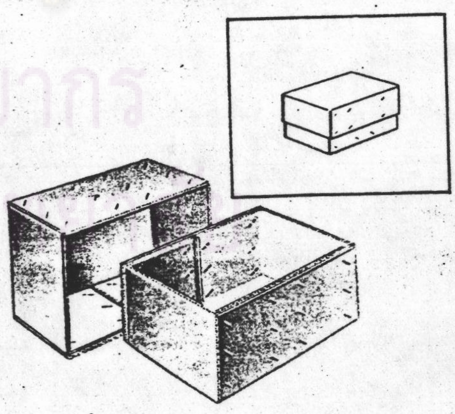
Full Telescope Half Slotted Box (FTHS)



Design Style Box with Cover (SCD)



Full Telescope Design Style Box (FTD)



Partial Telescope Design Style Box (PTD)

Figure 3.5 Half Slotted Containers

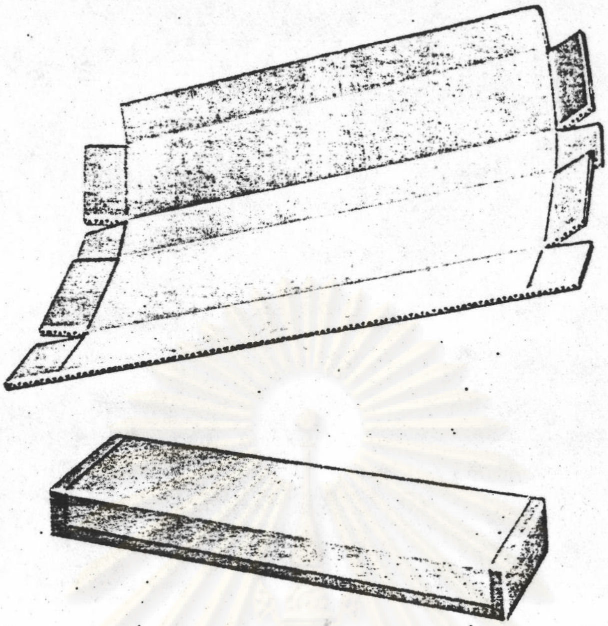


Figure 3.6 Five Panel Folder (FPF)

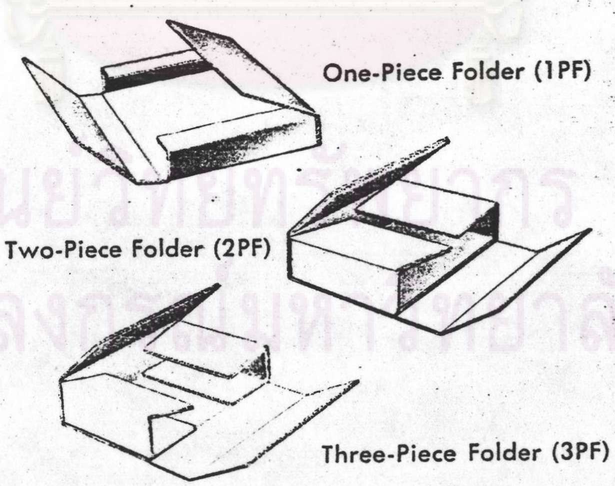


Figure 3.7 One-Piece, Two-Piece
and Three-Piece Folders

8. Interior Packing Pieces.[3)]

A further example of the versatility and remarkable utility of fibreboard is in its application as interior packing pieces. It is used in flat form, folded or die-cut and can be fabricated into a variety of forms, shapes, and patterns. Interior packing devices accomplish one or more of the following functions in the protection of a product ; i.e. retention, separation, suspension, cushioning, protection against abrasion, insulation, blocking, clearence, and positioning.

Interior packing pieces are illustrated in Figure 3.8.

MANUFACTURING PROCESS.[5)]

Chapter 2 shows how corrugated fibreboard can be manufactured. The corrugated fibreboard passes between blanket belt conveyers towards the slitting and scoring units and the cut-off.

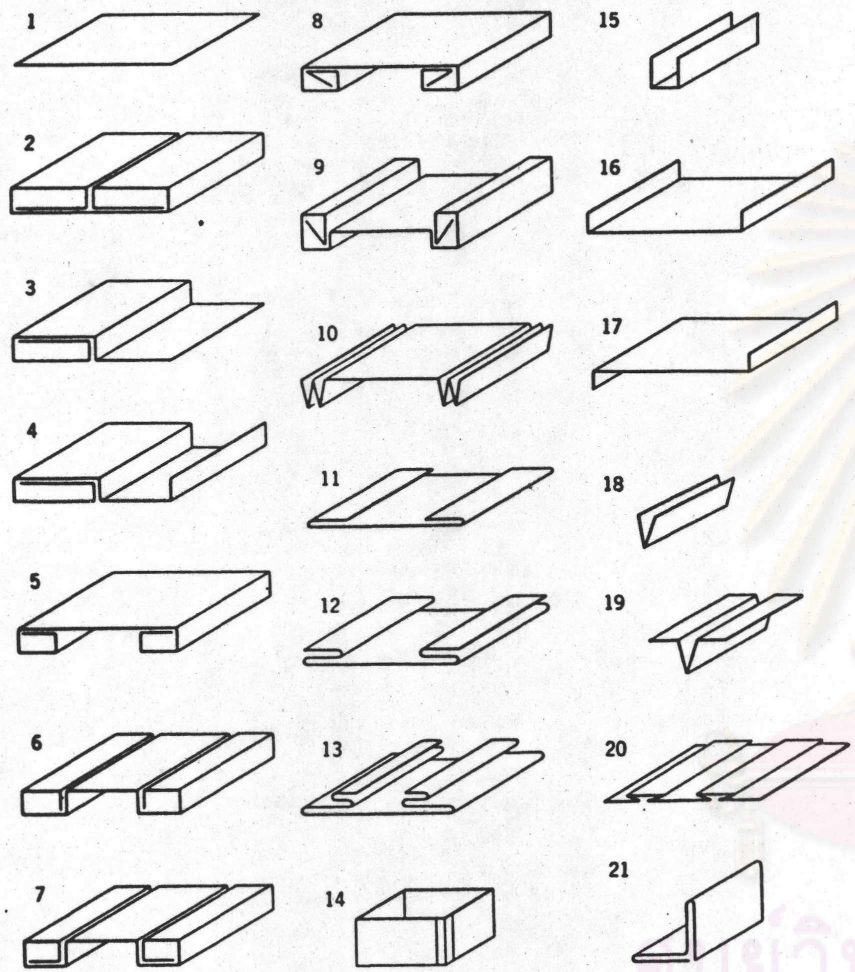
Thus, the corrugator produces "blanks" cut to the outside dimensions required and, if the blanks are for cases, with the machine-direction scores already made.

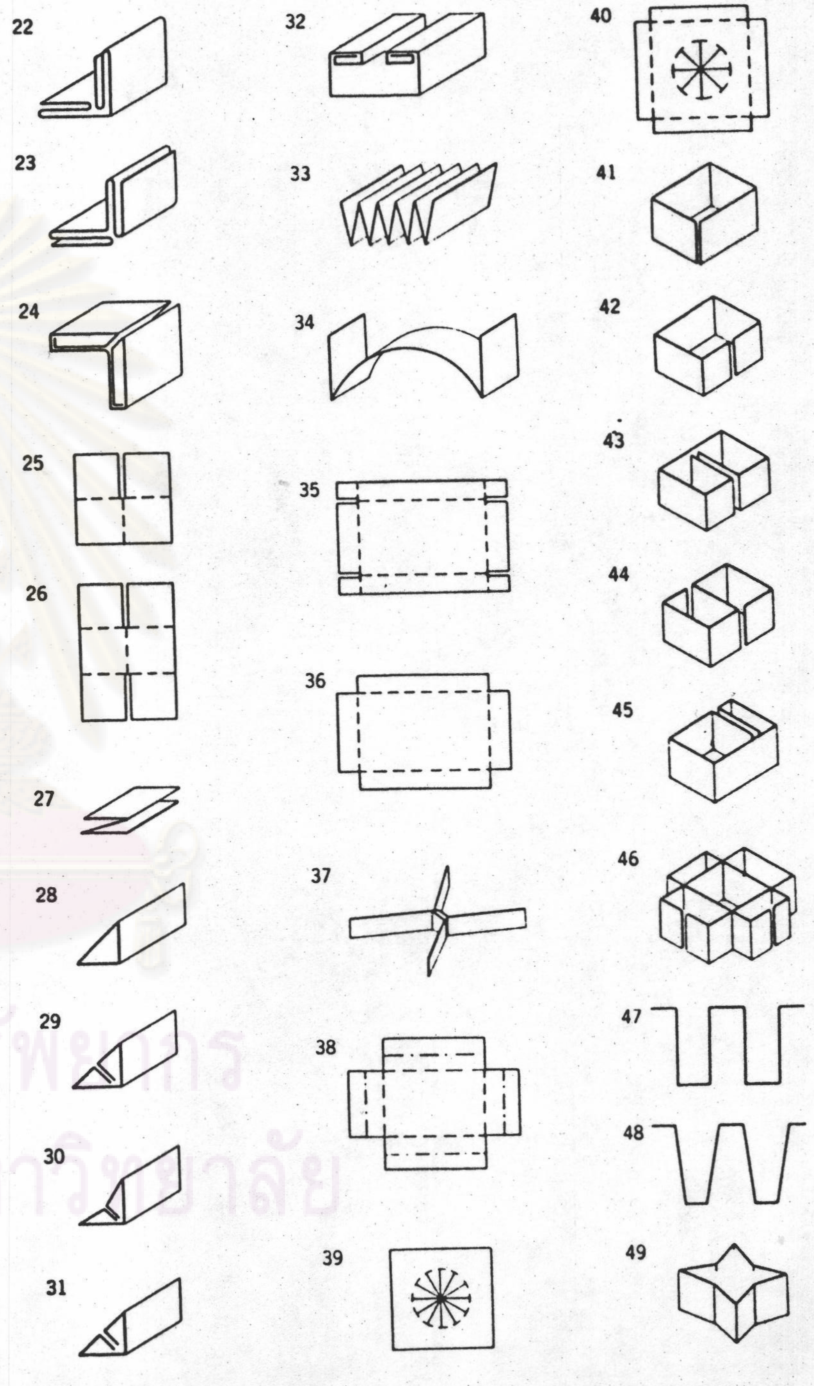
These blanks pass to the printer-slotter where they are printed, the cross-direction scores added (the blanks pass through the machine in the cross-direction) and, if stitched or glued, the joining flap cut.

The board enters the machine as a rectangular blank with the two scores produced on the corrugator, and merges as a printed "cut-out" that merely requires folding and joining to turn it into a case.

Three types of joint are possible and, from this point, the

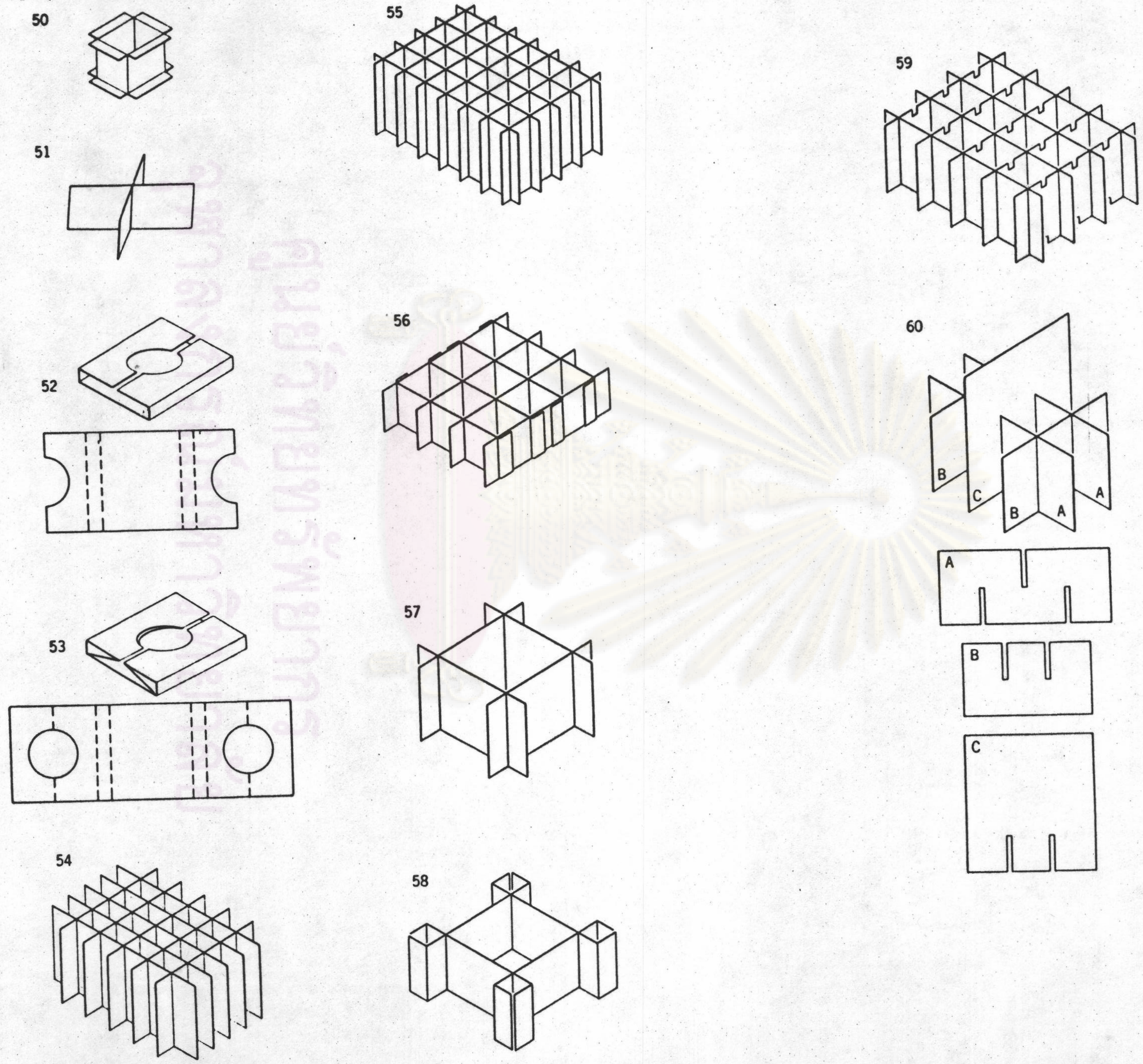
Figure 3.8 Fibreboard interior packing devices.





1—Plain pad
2 to 9—Rat-trap pads
10—Clearance pads
11 to 13—Folded pads
14—Collar
15—U-shaped protector
16 and 17—Flanged trays
18 and 19—Brace pads
20—Cushion
21 to 26—Corner protectors
27—Space filler
28 to 31—Corner rounders
32—Scored liner
33—Cylinder brace
34—Curved protector
35, 36, 37—Trays
38—Tray support
39—Die-cut pad
40—Die-cut tray
41 to 44—Open liners
45 and 46—Compartment fillers
47—Bottle separator
48—Bottle nest
49—Star liner
50—Flanged sleeve
51—Four-compartment partition
52 and 53—Die-cut anchors
54 to 56—Partitions
57 and 58—Single cells
59—Stemware partition
60—Shoulder-to-shoulder partition

Figure 3.8 (*Continued*)



blank passes either to the stitcher, the gluing machine or the taping machine (see Figures 3.9 and 3.10).

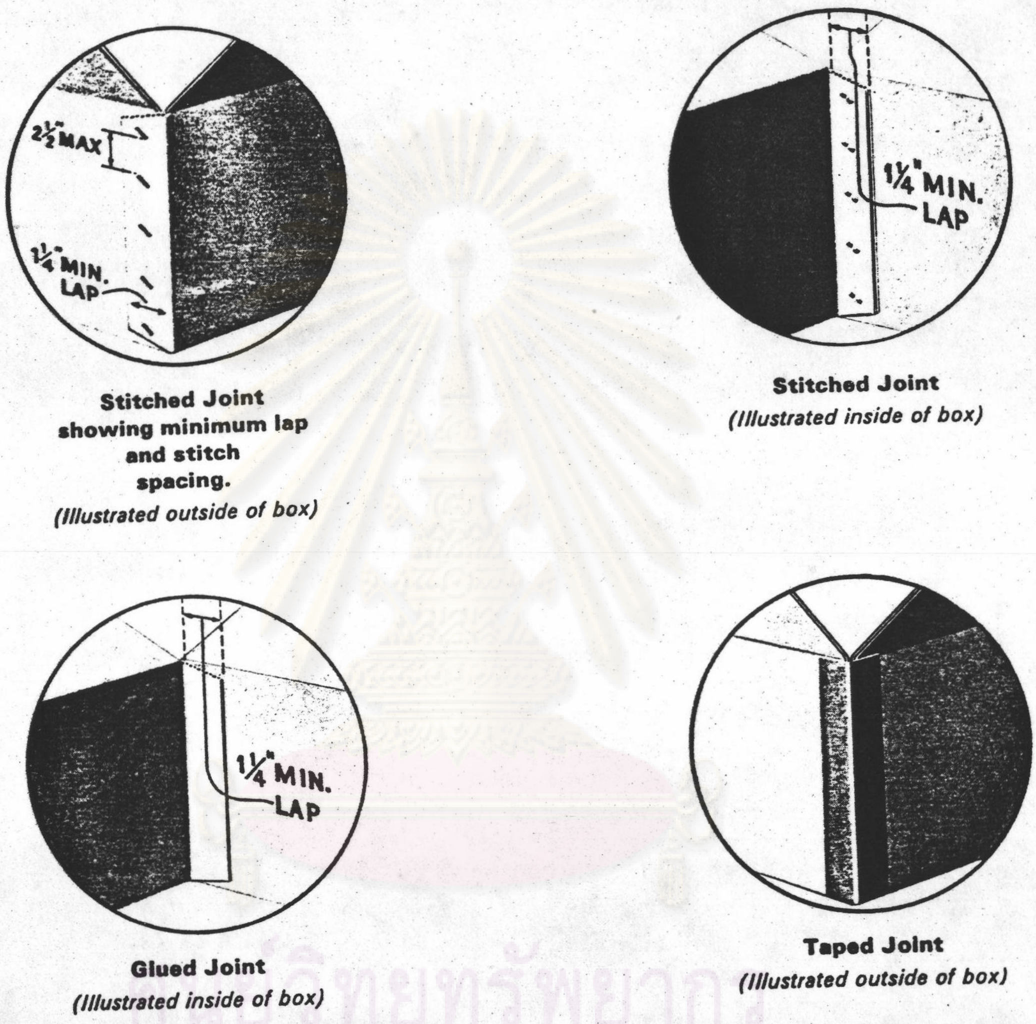


Figure 3.9 Manufacturer's Joints.

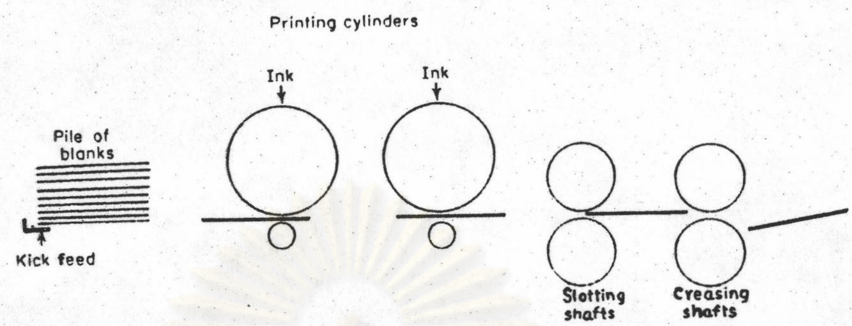


Figure 3.10 The Printer-Slotter

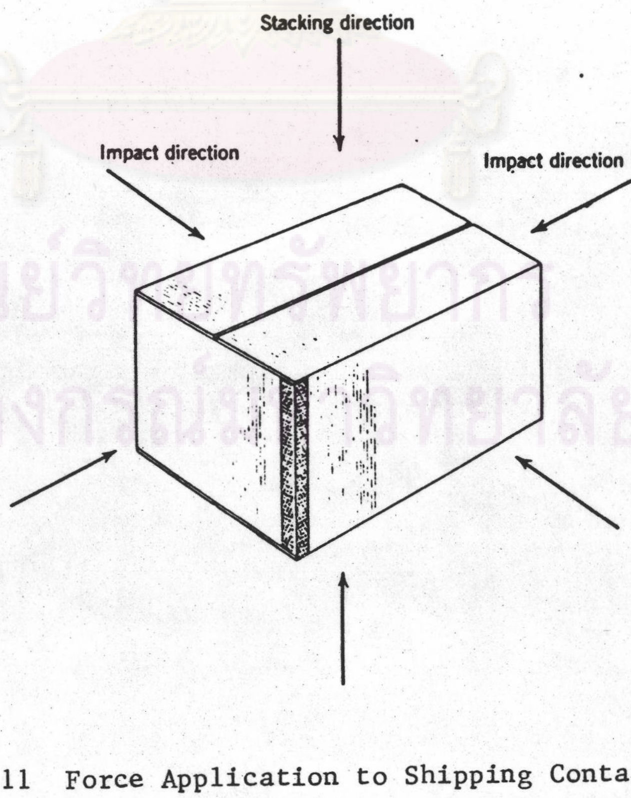


Figure 3.11 Force Application to Shipping Container.

PROBLEMS OF CORRUGATED FIBREBOARD BOX.

Generally speaking, problems which always happen to the boxes are as follows :

1. Transportation.

Frequent handling and transporting, especially the long transporting distance are a cause of damage for corrugated fibreboard boxes.

2. Manual Handling.

Manual handling is the main cause of box damage. As usual practice, most workers mistreat the boxes by throwing when handling them and eventually weaken and even damage the box.

3. Climate.

The higher the humidity in the environment is, the weaker the box becomes.

4. Boxes.

Variation in manufacturing standard such as inconsistency of paper weight or thickness, poorly maintained machine, cause boxes to vary standard variation. See chapter 4, Tables 4.1-4.6.

FORCE APPLICATION TO CORRUGATED FIBREBOARD BOXES.

During transportation or storing in warehouse, boxes are constantly submitted to forces applied from various directions (see Figures 3.11 and 3.12). It should be noted that these are dynamic forces, not the static forces found in warehouse where the lowest box in a stack supports the same constant load over a period of time. Therefore, compression strength data of boxes is useful for comparing box construction, designs and board combinations. The load distribution on a box is illustrated in Figure 3.13.

A-flute board gives the highest stacking strength and followed by C-flute, B-flute and E-flute.

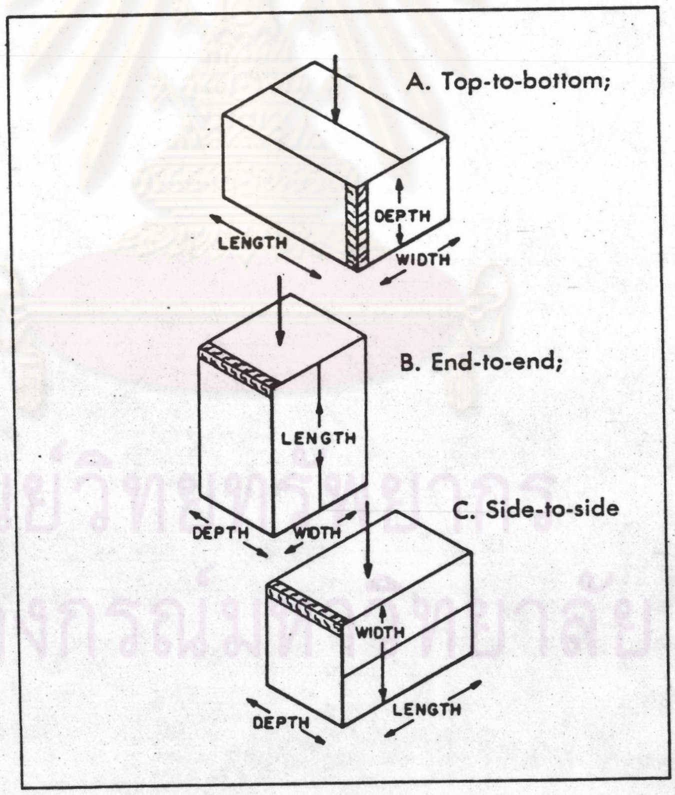


Figure 3.12 Box Stacking.

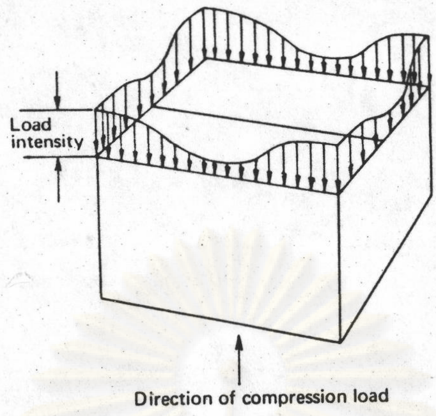


Figure 3.13 DISTRIBUTION OF COMPRESSION LOAD AROUND THE PERIMETER OF A BOX : Failure of a box in compression is considered to be due to failure of the combined board at the vertical edges. The magnitude of the stresses involved relate well to end crush of the board. The total load supported by the box amounts to the sum of the loads carried by each part of the perimeter.

DESIGN OF CORRUGATED FIBREBOARD BOXES.

The design of a corrugated fibreboard box is dependent upon the service it was intended for. However, 3 factors dominent in the design of boxes may be given below.

- Strength
- Economy
- Attractiveness

In this thesis, only the design for strength of box will be dealt with, i.e. the design which provides adequate protection for products such that they remain in acceptable condition when reach their destination.

1. Design for Box's Strength Purpose.

The strength of corrugated fibreboard boxes may be roughly determined from their bursting strength, puncture resistance, and box compression strength. A box having high values of all 3 properties is regarded as having high strength.

1.1 Factors Affecting Strength of Box.

1.1.1 Combined basis weight.

1.1.2 Type of flute.

1.1.3 Type of corrugated board.

1.1.4 Style of box.

Details of these 4 factors are given in chapter 2.

1.1.5 Interior packing. (The interior packing has been mentioned in the precede section)

1.1.6 Contained products. The products contained in the box also affect the box's strength. For example, products which are solid and stable in themselves, such as those in cans or bottles, benefit the box compression strength where the stacking load is concerned. Thus, for the design of box in the case of self-supporting products, the compression strength of the box may not be considered as prime importance. The cost, as a result, is reduced.

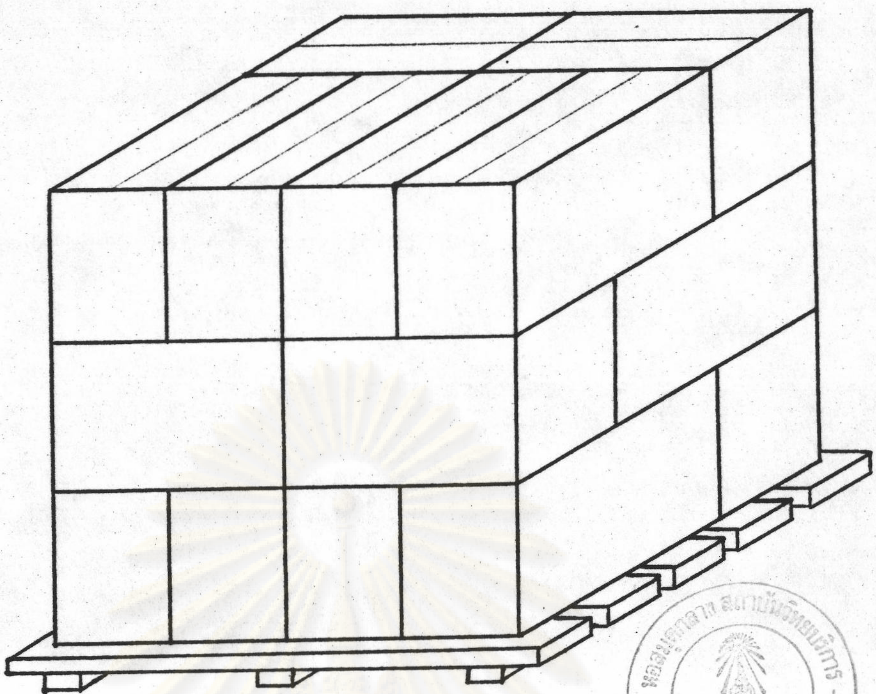
1.1.7 Dimensions of box.[3)] The three dimensions of box are the lenght, width and depth. The size most suitable for handling and superposing stacking composes of a length 1½ times the width, and of a depth slightly smaller than the width. However, where economy is concerned, the designed ratio of length : width : depth of corrugated fibreboard box should be 2 : 1 : 2.

1.1.8 Stacking pattern. Stacking pattern, especially of boxes to be stored for a long period of time, affects the box's strength. Two main stacking patterns are given below.

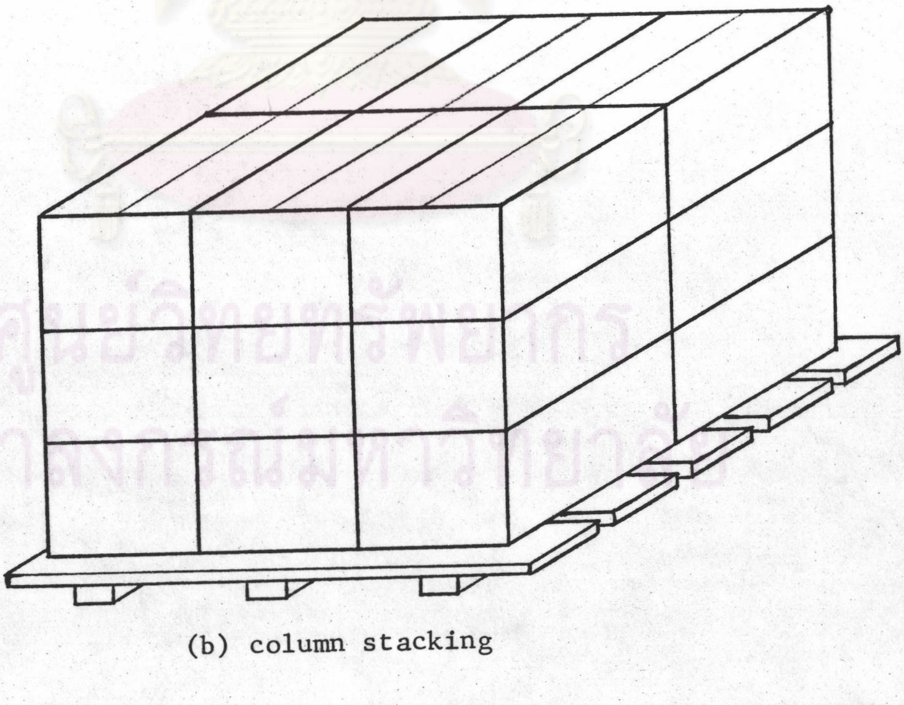
a) Interlocking stacking. The interlocking stacking pattern is as shown in Figure 3.14 (a). This pattern has the advantage of creating binding forces between boxes and preventing falling although they may piled up in several layers. It may, however, result in unequal compression strength of boxes in lower layers and deformation of boxes, especially at points where they are least strong (at the centre of each face). The reduction of box's strength in case of interlocking stacking is given in Table A.3 of Appendix A.

Pallets used are another factor. Pallets with very wide gaps, with nails protruding, having defects, etc., they all result in the reduction of box's strength.

b) Column stacking. The column stacking pattern is as shown in Figure 3.14 (b). This type of stacking enables load to be uniformly applied to the lower boxes along the four sides of the boxes. However, the lack of binding forces between boxes often causes the upper layers of boxes to fall. To prevent falling, a rope may be used to tie up all the boxes on the top layer in providing some cushion at point of contact between the box corners and the rope.



(a) interlocking stacking



(b) column stacking

Figure 3.14 Stacking Patterns.

1.1.9 Relative humidity. The humidity of fibreboard is dependent upon the relative humidity which affects directly the box's strength. The higher the relative humidity, the lower box compression strength (see Figure A.1 in Appendix A.).

1.1.10 Storage duration. The stacking pattern not only decreases the ability of boxes to withstand load, but, with time, also gradually deteriorate compression strength of boxes in lower layers (see Figure A.2 in Appendix A.). Therefore, long storage period should be avoided to prevent product damage and increase in inventory cost.

1.1.11 Frequency of handling. Handling of boxes containing products, whether by manual or mechanical means, affects box's compression strength. Boxes which have been subjected to frequent handling and transportation are low in compression strength. (See Figure A.3 in Appendix A. for reduction in compression strength of boxes submitted to frequent handling).

1.1.12 Self-supporting contents. The self-supporting products contained in a box, i.e. canned sadine, etc., may be able to withstand compression load applied on them. The Formula used to estimate the average load, applied on each content, is given below :

$$TL = N \cdot P \cdot f_p$$

where TL = total load applied on the contents

N = total units of the contents

P = average load applied on each content

f_p = factor of load withstand of product ranging from 0.0 to 1.0

The f_p value differs from case to case and ranges from 0.0 to 1.0. That is f_p is zero for fragile products, 0.5 for products in cartons and 1.0 for canned product in cans.

1.2 <u>Design Formulae.</u>[1)]

The formulae used in estimating box property parameters, derived by The Siam Kraft Paper Co., Ltd., are given below:

$$ECT = k \left| \Sigma\, RCT_{liners} + \Sigma\, (c \cdot RCT_{mediums}) \right| \qquad -(1)$$

$$BCT = 5.87\ ECT \sqrt{Z.H} \qquad -(2)$$

$$(n-1)\ W = BCT \cdot f_{rh} \cdot f_t \cdot f_h \cdot f_a + N.P.f_p \qquad -(3)$$

where

ECT = edgewise crush resistance of corrugated fibreboard in kg/cm.

RCT = ring crush resistance in kg/cm.

k = a constant for corrugated fibreboard (see Table A.2 in Appendix A.).

c = take-up factor

BCT = top-to-bottom box compression strength of corrugated fibreboard box in kg.

Z = box inside perimeter in cm.

H = thickness of corrugated fibreboard in cm.

n = number of stacking layers of boxes

W = gross weight of box with contents in kg.

f_{rh} = relative humidity factor (see Figure A.1 in Appendix A.)

f_t = storage duration factor (see Figure A.2 in Appendix A.)

f_h = handling frequency factor (see Figure A.3 in Appendix A.).

f_a = stacking pattern factor (see Table A.3 in Appendix A.).

1.3 Examples Calculation.

Example 3.1 : A corrugated fibreboard box will be designed for fragile products based on the following data :

- dimensions of product length x width x depth : 30 cm x 15 cm x 20 cm ;
- package size : 12 units per box ;
- total weight of contents : 5 kg./box ;
- stacking layers : 20 (8 boxes in each layer), pallet weight : 8.8 kg. ;
- stacking layers per pellet : 10 (interlocking stacking pattern) ;
- average storage period : 10 days , average relative humidity : 65 % ;
- handling frequency : 3 times (average).

Calculation : Boxes in the lowest layer should be taken as representative since they are subjected to most of the load.

Step 1 : Calculate dimensions of corrugated fibreboard box using computer in Appendix D. for convenience. Alternatively, the reader may calculate dimension of the box, using data and formulae given in Appendix C.

With the aid of the program computer, the following data were obtained :

Box dimensions (length x width x depth) : 60cm x 30cm x 60cm

Style of box : RSC

Pattern configuration : 2 1 x 2 w x 3 d

Area of board/box : 16,836.83 cm^2

Step 2 : Calculate primary BCT of the box.

$$(n-1).W = BCT \cdot f_{rh} \cdot f_t \cdot f_h \cdot f_a + N.P.f_p$$

when $n = 20$

$W = 5$ kg

f_{rh} at 65 %RH = 0.87 (Figure A.1 in Appendix A.)

f_t = 0.80 (Figure A.2 in Appendix A.)

f_h = 0.895 (Figure A.3 in Appendix A.)

f_a = 0.50 (Table A.3 in Appendix A.)

$N = 12$

$f_p = 0$

However, since boxes in the lowest layer also receive load of pallet, the average load of pallet applied to each box can be given as $\frac{8.8}{8}$ = 1.1 kg/box.

When these values are applied in the formula ;

$$(20-1)(5) + 1.1 = BCT \times 0.87 \times 0.80 \times 0.895 \times 0.50 + 0$$

then $$BCT = 308.55 \text{ kg.}$$

Step 3 : Calculate ECT of board from the formula :

$$BCT = 5.87 \, ECT \sqrt{ZH}$$

where
$$BCT = 308.55 \text{ kg}$$
$$Z = 2\,(60+30)$$
$$= 180 \text{ cm.}$$
$$H = 0.51 \text{ cm (Table A.2 in Appendix A.).}$$

A-flute is selected for the making of package for the product (see under "Properties of Corrugated Fibreboard "and" Uses of Corrugated Fibreboard" in chapter 2).

$$308.55 = 5.87 \times ECT \times \sqrt{(180) \times (0.51)}$$

then $$ECT = 5.49 \text{ kg/cm}$$

Step 4 : Calculate RCT of linerboards (due to product being light in weight, single-wall board and corrugating medium grade CA 125*) are used).

*) See Table A.1 in Appendix A.

$$ECT = k \left| \Sigma \ RCT_{liners} + \Sigma \ (c \ RCT_{mediums}) \right|$$

when $ECT = 5.49$ kg/cm

$k = 1.10$ (Table A.2 in Appendix A.)

$c = 1.52$ (Table A.2 in Appendix A.)

$RCT_{medium} = 0.62$ kg/cm (Table A.1 in Appendix A.)

$$3.66 = 1.10 \left| \Sigma \ RCT_{liners} + 1.52 \ (0.62) \right|$$

then $\Sigma \ RCT_{liners} = 4.04$ kg/cm

$$\text{RCT of each linerboard} = \frac{4.04}{2}$$

$$= 2.02 \ \text{kg/cm}$$

Step 5 : Using Table A.1 in Appendix A., the RCT value obtained will give the grade of linerboard required. In this case, Grade KA 335 is selected.

As a result, the design of corrugated fibreboard box for the mentioned product comprises the following :

- box dimension (length x width x depth) : 60 cm x 30 cm x 60 cm ;
- pattern configuration : 2 l x 2 w x 3 d ;
- box style : RSC ;
- fibreboard used : single-wall with A-flute ;
- area of board used per box : 16,836.83 cm^2 ;
- basis weight of linerboards : 335 g/m^2 ;
- basis weight of corrugating medium : 125 g/m^2.

2. Design for Saving Purpose.

As far as economy on the use of fibreboard is concerned, the designed ratio of lenght : width : depth of corrugated fibreboard box should be 2 : 1 : 2 (this ratio is the result of the experiment of Australian Paper Manufacturers Ltd. which has been accepted worldwide).

However, this type of box may not be strong enough to offer protection just as the making of strong boxes may not be saving in terms of fibreboard use. Therefore, it is entirely dependent upon the designers to select the design of box that best suits their purpose.

3. Design for Attraction Purpose.

Artistic design is usually made on packages such as cartons which often contain small and expensive items of product. Such design is rarely seen in corrugated fibreboard boxes except in those made with E-flute board.