CHAPTER 5

DISCUSSION AND CONCLUSION

RESULTS AND DISCUSSION

Table 4.16 shows that specification of liners and medium used for the proposed boxes is satisfied the minimum requirement specification assigned by The Siam Kraft Paper Co., Ltd. (Table A.1 in Appendix A.).

Results of test can be classified as follows.

1. Effect of Transporting Distance.

Comparison is made between the mechanical properties of pre-packing boxes and those of post-shipment boxes both obtained from Kiang Hua Co., Ltd. The boxes which were submitted to the same test conditions were of the same category, i.e. the same style, dimensions, grade, flute type, etc. The results reveal that, with a short transporting distance : 40 kilometres (approximately) and with a short storing duration : 2 days (average), the most affected mechanical property is the box compression strength which was decreased by 33 %, approximately. See Tables 4.1-4.3 and Figure 5.1.

Under the similar conditions of test, the test results, of Kwaung Paisarn Food Product boxes, reveal that the affected mechanical properties of boxes, with a long transporting distance : over 800 kilometres and with a long storing duration : over 60 days, are the flat crush resistance (decreased by 60 %, approx.), the edgewise crush resistance (decreased by 49 %, approx.) , and the box compression strength (decreased by 72 %, approx.). See Tables 4.4-4.6 and Figure 5.2 .

As a result, it shows that transporting distance affects FCT, ECT and BCT more than it does other mechanical properties of boxes.

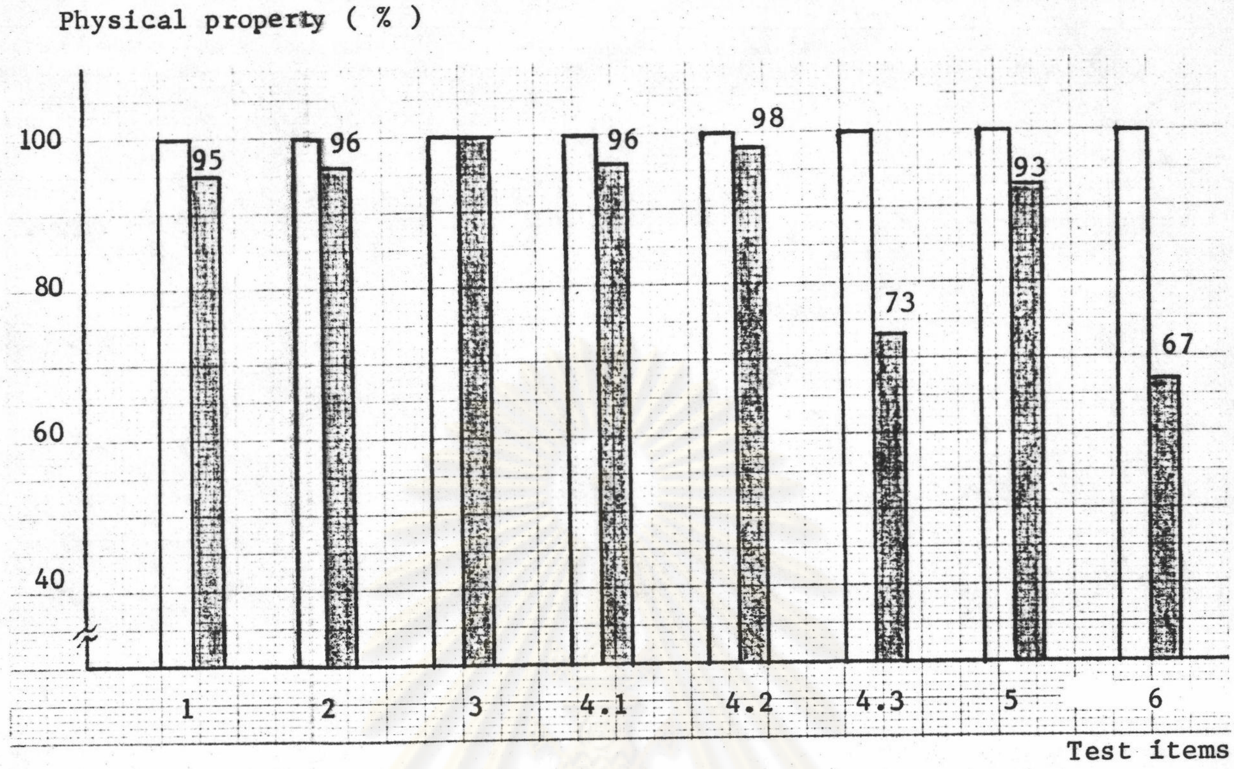

Figure 5.1 Bar-Chart of Physical-Property Comparision between Pre-Packing Boxes and Post-Shipment Boxes of Kiang Hua Co., Ltd.

Remark ☐ Pre-packing boxes

▩ Post-shipment boxes

1. = Bursting strength

2. = Puncture resistance

3. = Flat crush resistance

4. = Ring crush resistance

4.1 = RCT of outer liner

4.2 = RCT of medium

4.3 = RCT of inner liner

5. = Edgewise crush resistance

6. = Box compression strength

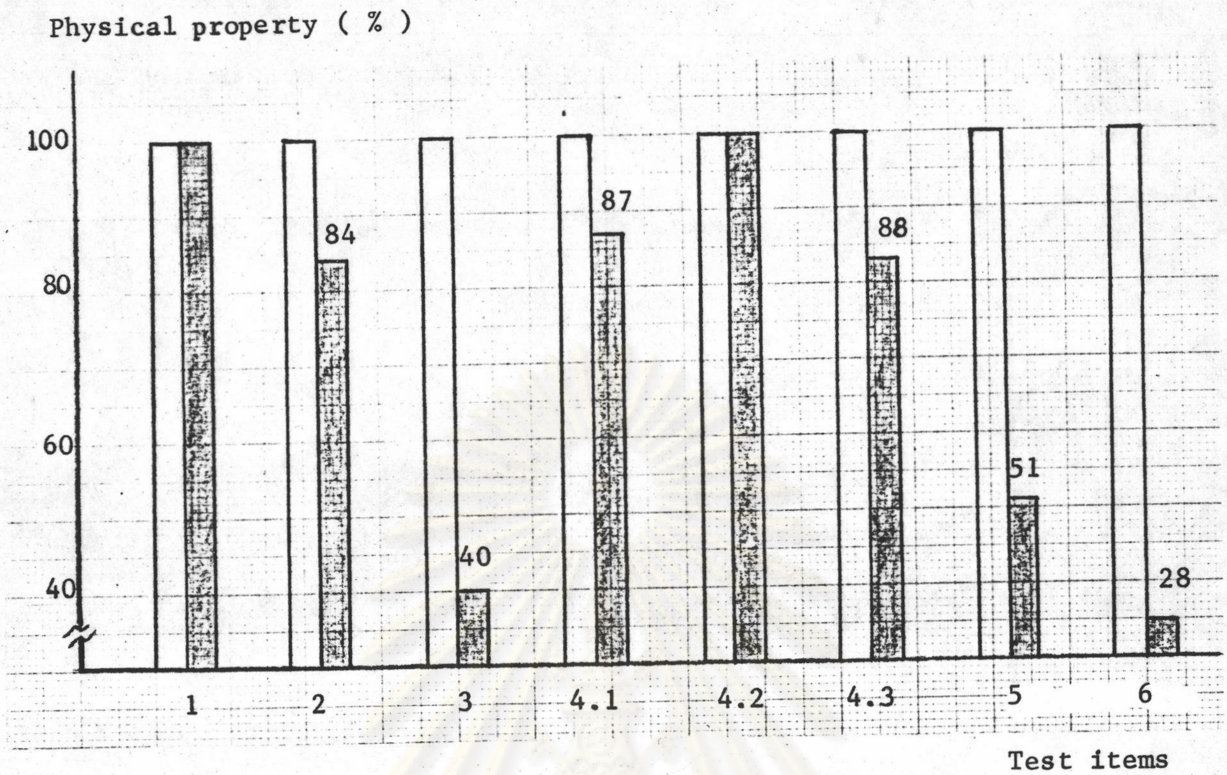

Figure 5.2 Bar-Chart of Physical-Property Comparison between Pre-Packing Boxes and Post-Shipment Boxes of Kwaung Paisarn Food Product Co., Ltd.

Remark ☐ Pre-packing boxes

▦ Post-shipment boxes

1. = Bursting strength

2. = Puncture resistance

3. = Flat crush resistance

4. = Ring crush resistance

4.1 = RCT of outer liner

4.2 = RCT of medium

4.3 = RCT of inner liner

5. = Edgewise crush resistance

6. = Box compression strength

2. <u>Ring Crush Resistance</u>.

Table 5.1 shows that RCT varies with basis weight on both pre-packing and post-shipment boxes.

3. <u>Factors Affecting the Test</u>.

3.1 Test results of Kiang Hua boxes. Table 4.3 indicates that flat crush resistance value (item 3) of post-shipment boxes is higher than that of pre-packing boxes which is unrealistic. However, this may have resulted from the test specimen being prepared from the glued portion of corrugated board ; dried glue would strengthens the test specimen.

3.2 Test results of Kwaung Paisarn Food Product boxes. Table 4.6 shows high values of bursting strength, puncture resistance and ring crush resistance of post-shipment box, even though, the basis weight value of post-shipment boxes is lower than pre-packing boxes'. The higher values obtained might have been caused by the test specimen being prepared from the sound portion of the corrugated box,in fact, it should have been cut from the same portions of each box, whether those portions were damaged or not. Based upon the observation, the uncontrollable amout of glue applied on corrugated board attributes to the high value of the test result.

As a result, the researcher recommends that the test of edgewise crush resistance be given more significance than ring crush resistance test. If the ring crush resistance is to be determined, the test should be made on linerboard and corrugating medium before they are assembled into a corrugated board so as to obtain accuracy.

Table 5.1 : Basis Weight Values and RCT of Pre-Packing and Post-Shipment Boxes.

Board types	Before-study boxes								After-study boxes											
	Kiang Hua boxes				Kwaung Food Product Paisarn boxes				Kiang Hua boxes				Proposed boxes (RSC, top-loading)				Proposed boxes (RSC, end-loading)			
	Pre-packing boxes		Post-shipment boxes		Pre-packing boxes		Post-shipment boxes		Pre-packing boxes		Post-shipment boxes		Pre-packing boxes		Post-shipment boxes		Pre-packing boxes		Post-shipment boxes	
	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)	Basis weight (g/m^2)	RCT (kg/cm)
1. Outer liners	177.6	1.75	178.6	1.68	197.0	1.99	1.86.2	1.75	178.6	1.42	175.8	1.36	147.1	1.15	142.3	1.07	145.0	1.15	143.6	1.17
2. Inner liners	181.3	1.90	173.0	1.39	190.7	1.87	1.80.9	1.66	180.9	1.50	176.9	1.38	122.8	0.83	122.3	0.80	128.2	0.88	126.7	0.89

4. Overlapping of Manufacturer's Joint.

The study reveals that overlapping width of manufacturer's joint varies inversely to the perimeter of box, i.e. the smaller the overlapping width, the greater the box perimeter, and vice versa (see Table 5.2). It should be careful if the proper inside dimensions of box are desired.

Table 5.2 Overlapping Width of Manufacturer's Joint.

Box sample	Kiang Hua Co.,Ltd.		Kwaung Paisarn Food Product Co.,Ltd.	
	Manufacturer's joint (mm.)	Box perimeter (mm.)	Manufacturer's joint (mm.)	Box perimeter (mm.)
Pre-packing boxes.	27.6	822.8	26.9	836.2
Post-shipment boxes	24.8	828.4	28.7	834.6
Difference	-2.8	+5.6	+1.8	-1.6

5. Bursting Strength.

Table 5.3 shows that bursting strength values of pre-packing and post-shipment boxes are rarely different, whether the distance of transportation is short or long. It is believed that bursting strength value does not depend upon the characteristic of box, i.e. frequency of handling and transportation, storing duration, transporting distances, etc.

The research also reveals that bursting strength value of corrugated board is higher when the side of board with a higher basis weight of liner is placed in contact with the diaphragm of the Mullen Tester.

Table 5.3 : Comparison between Bursting Strength of Pre-Packing and Post-Shipment Boxes.

Items	Units	Pre-packing boxes	Post-shipment boxes
<u>The first stage of the research</u>	kgf/cm^2		
Kiang Hua boxes		10.90	10.43
Kwaung Paisarn boxes		11.61	11.79
<u>The second stage of the research</u>	kgf/cm^2		
Controllable boxes		7.21	7.98
Proposed boxes (top-loading)		5.94	6.12
Proposed boxes (end-loading)		5.97	6.06

6. <u>Box Compression Strength</u>.

Table 5.4 shows that the residual BCT of post-shipment boxes of the proposed boxes (top-loading) is higher than that of the controllable boxes. As far as boxes' dimensions are concerned, the inside dimensions of the controllable boxes are larger than those of the proposed boxes (top-loading). It could be concluded that the appropriate inside dimensions of boxes fitting the canning products contained therein give a higher residual BCT.

The comparison between the proposed boxes (top-loading) with the proposed boxes (end-loading) shows that the residual BCT of the former is higher than the latter's due to the difficulty of packaging by manual resulting in the decreasing of box strength. However, the unit cost of corrugated box of the latter is lower than the former's (Table 5.5).

Tables 4.8, 4.11 and 4.14 show that the lowest residual BCT is the box positioned at A3 for the controllable box, at B2' for the proposed box (top-loading) and at C4 for the proposed box (end-loading). The positioning of boxes is shown in Figure 4.7.

Table 5.4 : The Residual BCT of Post-Shipment Boxes.

Items	Units	Controllable box	Proposed box (top-loading)	Proposed box (end-loading)
1. Inside dimensions of box	mm			
1.1 Length		551.2	541.4	270.6
1.2 Width		275.6	271.0	180.2
1.3 Depth		183.2	180.6	540.8
2. The residual BCT	%	65.5	78.2	57.2

RECOMMENDATION AND CONCLUSION

The research reveals that good corrugated fibreboard boxes should be of the size that is suitable for the products contained. It should not leave, in the box, unoccupied area that would allow the cans to move around and cause breakage to the box. In addition corrugated fibreboard used should have B-flute because it is higher in flat crush resistance and can better withstand the load of cans.

The study reveals that the residual strength of boxes submitted to humidity (see Appendix A.) should take into account the time factor. Humidity in fibreboard varies according to the climatic humidity. Therefore, the values of f_{rh}, in Appendix A. (Figure A.1), should be multiplied by the time factor before further calculation is made.

In the same manner, the value of stacking pattern factor (f_a) should be multiplied by the time factor. From Table A.3, Appendix A., the interlocking stacking with the use of pallets reduces the box compression strength by 50 % which means that the box is required to have twice as much the design BCT. And when compared between boxes kept 1 day and those stored for over ½ year in the warehouse, the former very slightly will be affected by the stacking. According to engineering principles, subjects submitted to static load for a longer period of time, will develop fatigue which eventually lessen their strength (see example 3.1 in chapter 3).

Corrugated fibreboard boxes may be designed based on the following criteria.

1. Corrugated fibreboard boxes for products in general (where products are non-load supporting : Steps to be taken for the designing of corrugated fibreboard boxes for general products are :

- Study the feature and characteristics of products ;
- Study factors which may affect products, i.e. the compression-withstand of products ;
- Study the characteristics required of corrugated fibreboard box and design the box accordingly :
- Select the appropriate flute type (details are given in chapter 2) ;
- Select the appropriate style of box (details are given in chapter 3) ;
- Select the appropriate grade of board and calculate the size of box (see datails in chapter 3).
- Put the designed box to use and follow-up on the result.

The following formulae are for design calculation of corrugated fibreboard boxes for products in general.

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

$$BCT = 5.87\ ECT\ \sqrt{ZH} \quad \ldots \quad (2)$$

$$ECT = k\ |\Sigma\ RCT_{liners} + \Sigma(c.RCT_{mediums})| \quad \ldots \quad (3)$$

(Details are given in chapter 3 under "Design of Corrugated Fibreboard Boxes").

2. Corrugated fibreboard boxes for load-supporting products : Steps to be taken for the designing of corrugated fibreboard boxes for load-supporting products, especially canned products, are :

- use B-flute board (see under "Properties of Corrugated Fibreboard" in chapter 2) ;
- use RSC box style (for domestic transportation) ;
- select the appropriate grade of board and calculate the size of box.

In this research, the method of designing based on minimum requirement box compression strength was applied (see design calculation of corrugated fibreboard boxes for canned sardine in chapter 3). The design so obtained was put to test, i.e. the boxes so designed, containing the same number of cans were submitted to the same handling and transporting practice. The result : products reached the destination in sound condition. And the physical properties of the boxes are shown in Tables 4.10-4.12.

The test results given in Tables 4.1 to 4.3 indicate that corrugated fibreboard boxes of Kiang Hua Co., Ltd. are too strong. After analysis, the new design could decrease the cost per unit of corrugated fibreboard boxes as shown in Table 5.5.

In the case of Kwaung Paisarn Food Product Co., Ltd., damage of the boxes resulted from frequent handling, long period of storing and long transporting distance. Therefore, the cost of the new designed box will be slightly higher (see Table 5.6) but worthwhile when taking into account the protection it could provide for the products. Furthermore, additional reduction in cost and expense will be achieved if the factory can lessen the frequency of handling and the duration of storing.

Nevertheless, putting several designs of box to trial may single out the most satisfactory box. This method, though giving reliable result, is rather impractical, takes a great deal of time and work and costs highly.

This research is expected to be of some assistance to the designing of corrugated fibreboard boxes, saving time and associated cost. Giving the properties of various styles of corrugated fibreboard boxes to suit the types of products, different flute-types and corrugated fibreboard, the research is readily available for application by the readers.

FURTHER RESEARCHES.

The researcher wishes to recommend 2 topics for further researches.

1. Study on mechanical properties of linerboard and corrugating medium, i.e. bursting strength, puncture resistance, flat crush resistance, edgewise crush resistance, and etc. The study may be made respective to the grades of liner and medium, types of corrugated fibreboard, flute-type, etc. The study should also be conducted on each individual factor affecting the strength of boxes, i.e. frequency of handling, relative humidity and stacking pattern at various storage duration, transporting distance, etc. Data are collected for the use or application in domestic industries.

2. Study on minimum requirement of mechanical properties for each type of product and development of Tables or Charts for technical or local industrial use.

The author believes that the two studies when applied together with this research will be beneficial to the economy as a whole as readers can be selective in applying them to suit their work.

Table 5.5 Comparison between Controllable Boxes and Proposed Boxes (Kiang Hua Co., Ltd.).

Items	Controllable box	Proposed box (top-loading)	Proposed box (end-loading)
1. Type of box	Single wall	Single wall	Single wall
2. Style of box	RSC(top-loading)	RSC(top-loading)	RSC(end-loading)
3. Flutes type	B-flute	B-flute	B-flute
4. Dimensions of box			
4.1 Length	550.4 mm.	540.0 mm.	270.0 mm.
4.2 Width	272.4 mm.	270.0 mm.	178.0 mm.
4.3 Depth	180.4 mm.	178.0 mm.	540.0 mm.
5. Grade of papers*)			
5.1 Outer liners	KI 185	KI 125	KI 125
5.2 Corrugating mediums	CA 125	CA 125	CA 125
5.3 Inner liners	KI 185	KI 125	KI 125
6. Total costs**) (Baht/box)	7.75	6.05	5.43
7. Cost reduction (%)	-	21.94	29.94

Remark : *) See Appendix A.

**) The Siam Kraft Paper Co., Ltd.

Table 5.6 Comparison between Factory's Boxes and Designed Boxes (Kwaung Paisarn Food Product Co., Ltd.).

Items	Factory's box	Designed box	Cost increase (%)
1. Type of box	Single wall	Single wall	-
2. Style of box	RSC	RSC	-
3. Flutes type	B-flute	B-flute	-
4. Dimensions of box			
4.1 Length	554.2 mm.	540.0 mm.	-
4.2 Width	282.0 mm.	270.0 mm.	-
4.3 Depth	190.8 mm.	178.0 mm.	-
5. Grade of paper*)			
5.1 Outer liners	KA 185	KA 230	-
5.2 Corrugating mediums	CA 125	CA 125	-
5.3 Inner liners	KA 185	KA 230	-
6. Total costs**) (Baht/box)	8.30	9.20	10.84

Remark : *) See appendix A.

**) The Siam Kraft Paper Co., Ltd.