SPECIFICATION AND QUALITY CONTROL TECHNIQUE FOR CORRUGATED BOXES OF EXPORTED TAIWAN BANANAS

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ABSTRACT

SPECIFICATION AND QUALITY CONTROL TECHNIQUE FOR CORRUGATED BOXES OF EXPORTED TAIWAN BANANAS

by Chuen-Ming Li

The purpose of this study is to establish proper specification for corrugated boxes of exported Taiwan bananas and to manufacture high, more uniform compression strength of corrugated boxes through quality control.

Prior to setting proper specification, all factors which affect the quality of corrugated boxes have to be taken into consideration. Key factors such as environmental influence and component materials can not be neglected. Methods of quality control from incoming materials to finished boxes must be established to maintain standards.

One of the most important qualities in corrugated boxes is compressive (stacking) strength. This study places emphasis on optimum compression strength for exported Taiwan banana boxes.

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I. Introduction

Although Taiwan is not a large island, it is abundant in agricultural products. The economy of Taiwan greatly depends upon agricultural products. They are indispensable not only for rural prosperity but for foreign exchange as well. Bananas, the most important of the exported fruits, play an important part in the economic development of Taiwan.

Taiwan bananas have been exported to foreign countries, mostly exported to Japan. Prior to 1968 all exported bananas were shipped in bamboo baskets. Then the decision was made to switch to boxed shipments. The corrugated boxes not only make a more compact loading unit, but upgrade the quality of delivered bananas in that entire shipments seldom suffer damage.

Although the corrugated boxes improve the quality of bananas at the point of delivery, there is still a problem with the quality of corrugated boxes. The corrugated box is an extremely complex engineering structure. A fabricated box, whether good or bad, greatly depends upon its components, manufacturing ability or skill of the maker, and machine.

The specification is important and can not be underestimated. A proper specification can materially improve the profitability of a plant's operation and can achieve the best quality with minimum cost. Before establishing specification the environmental influence, component materials, and other important factors must be considered.

In order to manufacture good corrugated boxes, quality control technique must be set up after establishing specifications. The advantages of quality control are as follows:

1. It is easier for inspectors to check qualities and for quality control men to test whether the finished boxes meet the tolerance of standards or not.
2. It is easier and quicker for operators to find where the problem is.
3. High, more uniform quality boxes can be manufactured.

The quality of corrugated boxes must be emphasized on compressive (stacking) strength because it greatly affects the degree of protection during stacking and shipping.

Bear in mind that all manufacturing, engineering, and quality effort are in vain if the box reaches destination is in a damaged condition. In this study, the destination of exported Taiwan banana boxes is Japan.

II. Specification

The heart of a corrugated box plant is the corrugator, while the specification is the heart of a quality control. The specification determines the degree of precision that has to be used in the manufacturing department. It is a communication from the designer to the purchasing department, and ultimately to the supplier. It also can eliminate the unnecessary waste, reduce the cost of inspection, and provide right materials. In addition, a proper specification will give finished corrugated boxes with the best quality at minimum cost.

1. Preparation Of Specification

Before setting specifications, all factors which influence the quality of the corrugated boxes must be taken into considerations. Particularly, major factors such as environmental influence, component materials, and compressive strength can not be neglected. The factors should be considered are as follows:

Environmental Influence

Truck Environment

The corrugated boxes filled with exported bananas are transported from packing houses to the harbors by trucks. They are stacked seven high in trucks. Each of the boxes weighs 35.2 pounds. The average compression strength is about 3,500 pounds at 50 % R.H. and 73° F.

Vibration and impact greatly affect compressive strength of boxes during transportation. If they are great during truck transportation, the boxes will crush.

In Ostrem and Rumerman's studies (1), it has been found that when trucks run on paved (smooth asphalt) roads, the acceleration is low and ranges from 0.025 to 0.35 G within 300 c.p.s. (Figure 2-1).

In O'Brien, Claypool, Leonard, York, and MacGillvray's studies (2), four kinds of truck suspension systems were used to measure accelerations. They found that trucks with conventional leaf springs had lower amplitude than any other kind of spring system. And it was found that when conventional leaf spring was used,

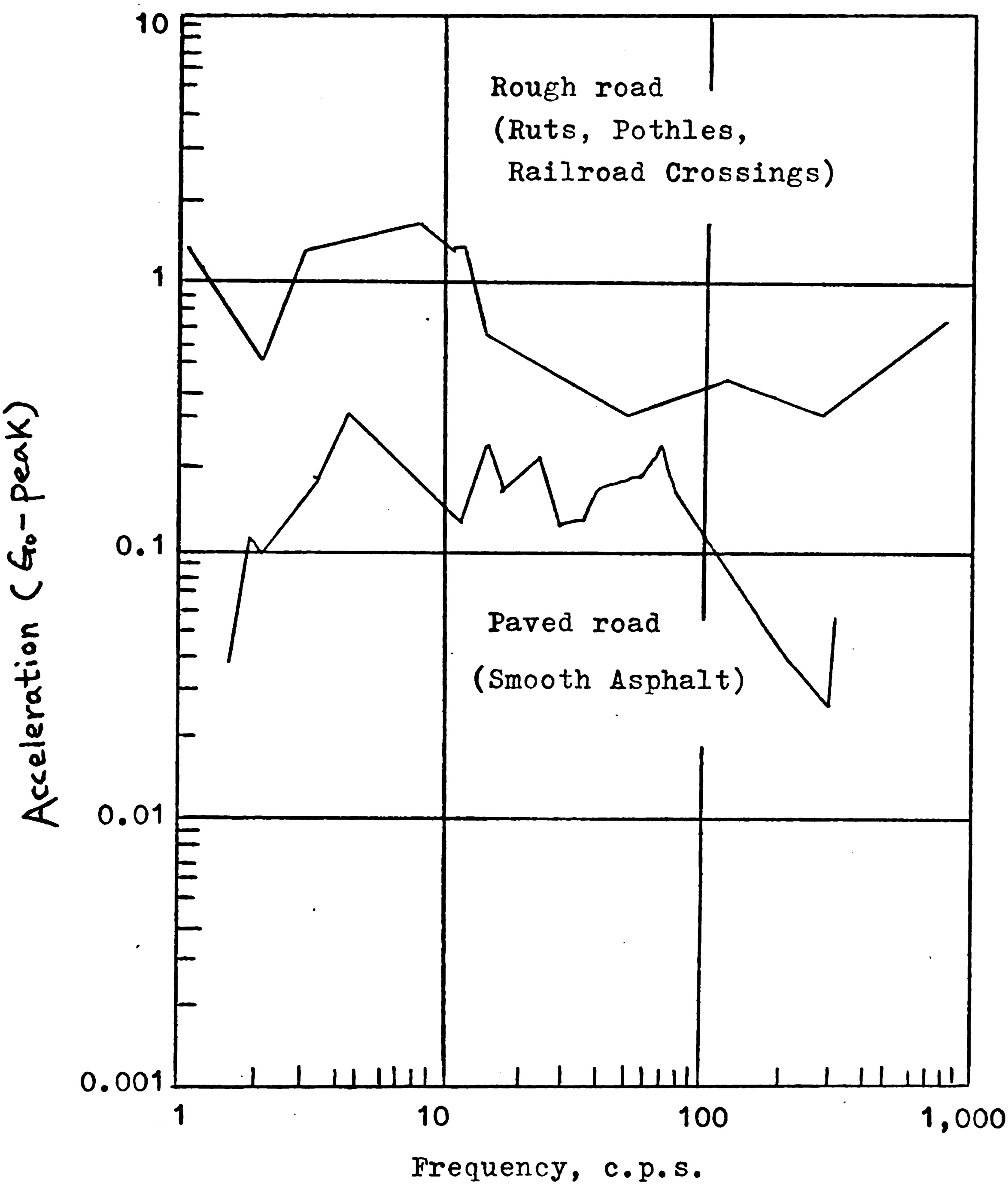


Figure 2-1. Truck Acceleration Envelopes-Road Condition Composites.

accelerations between 0.1-0.5 G had low single amplitude ranging from 0.003 to 0.015 in., and frequency fell be-ween 6 and 20 c.p.s. The average frequency was 12 c.p.s.

Fortunately, almost all of our trucks are built with conventional leaf springs, and most of the roads which trucks pass are paved roads. It has been observed that no crushing happens to corrugated boxes when trucks arrive at harbors.

Ship Environment

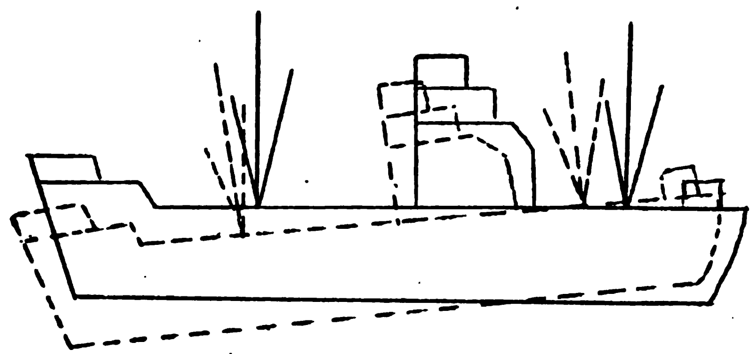
The corrugated boxes are generally stacked eight high in ships during ocean shipping. Ship environment also involves vibration and impact.

In the area of ship transportation, the most extensive report in relation to fiberboard packages has emanated from the Institute for Overseas Packaging in Hamburg, Germany. After examining the report, Maltenfort (3) found that in general, the experimental test shipping was not noticeably affected by pitching. Accelerations were mostly near 0.03 G level and did not exceed 0.12 G. Pitch creates maximum accelerations of 0.6 G and frequency range is 0.1-0.2 cycle/sec. (Figure 2-2). Vibration does not seem to be a problem, and can be considered non-significant. But impact during ship transportation greatly affects stacking strength. When the ship bottom impacts on the surface of the water (acceleration due to pitch plus impact), occasionally, acceleration can go to 1.0 G. The stacking pressure (load) almost periodically increases and decreases by ± 50 % at an acceleration of 1.0 G (4).

Relative Humidity & Temperature

The greater the relative humidity, the higher the moisture content. The higher the moisture content the weaker the corrugated box. So the relative humidity has to be taken into consideration prior to fabricating corrugated fiberboard boxes. According to Seborg, Doughty, and Baird's study (5) and Kellicutt's study (6), the relationship among relative humidity, moisture content, and percent compression strength for corrugated boxes can be tabulated as shown in Table 2-1.

Taiwan is in a subtropical area. The maximum relative humidity can go to about 88 %. It is important



	Acceleration due to pitch (+impact)
Maximum	0.6 G (1.0 G occasionally)
Rarely	0.3 G
Frequently	0.1 G
Frequency	0.1-0.2 cycle/sec.

Figure 2-2. Acceleration and pitch of ship at sea.

Relative Humidity (%)	Moisture Content (%)	Stacking Strenght (%)
0	0	100
10	2.5	83
20	4	74.5
30	5.5	69
40	6.5	62.5
50	8	58
60	9.5	51.5
70	11.5	44
75	13	38
80	15	34
85	17	31
90	21.5	24
95	27	15.5

Table 2-1. Relationship among relative humidity, moisture content, and stacking strength for corrugated boxes.

to mention that the relative humidity is extremely high during ocean shipping. Recently, Maltenfort (3) examined an extensive report describing the package environment on a trip to southeast Asia, and found that maximum relative humidity inside ships could reach about 95 %. On main deck, it could go up to 99 % that was the same as outside air.

In Paronen and Toroi's studies (7), it has been found that the effect of temperature changes on moisture content of fibre raw material is very small, 0.7 %, within temperature range from 0° to 40° C (32° to 104° F). It can be considered non-significant.

Duration Of Stacking

An important factor that will influence the stacking strength of corrugated boxes is the duration of load. Based on Kellicutt's study (8) and Moody and Skidmore's study (9), the relationship between duration of load and percent stacking strength is shown in Table 2-2. They found that loads of a magnitude of 70 to 80 % of stacking strength of the box caused failures

Duration of load (Day)	Stacking strength (Percent)
1/12	80
1/4	78
1/2	76
1	73
10	63
20	61
30	59
50	57
70	55
90	54

Table 2-2. Relationship between duration of load and percent stacking strength for corrugated boxes.

usually within hours, and 80 to 90 % within minutes. So the maximum load can not exceed 70 % of total compressive strength of box.

Our corrugated boxes filled with bananas are stacked eight high in packing houses for one day, at harbor for one day. In order to meet inevitable postponement, a maximum of stacking should be three days for each place. It must take four days for ship to arrive at Japan. Thus, the maximum length of time from packing houses to Japan is ten days.

Component Materials

Liner and Medium

In this study, both liner and medium must be American-made. Kraft liner has to be used because it has higher quality than others. Although jute is cheaper than kraft, higher grades of jute than kraft are needed to meet the same strength. In addition, the freight fee of jute will be higher than that of kraft because of weight. Light material is one of the most important considerations for corrugated boxes.

For the same reason, semichemical medium must be used to manufacture good flutes.

Ring crush value of paperboard is important because it has been widely used to predict the compression strength of box prior to fabrication. In the study of "How the relationship of fiber orientation and basis weight of paperboard affects its strength" by Kellicutt, together with the data from Mr. Guins' lecture, Table 2-3 shows crush strength of different grades of kraft liners, Table 2-4 semichemical media.

The direction of load on corrugated box is the cross direction of paperboard made on machine. The machine direction of paperboard is slightly stronger than the cross direction. But when two liners and medium are adhered with adhesive, crush strength of combined board in cross direction is the same that of total individual paperboard in machine direction. So the machine direction of paperboard is used to calculate compressive strength of box.

The basis weight of the corrugated medium does not vary widely because difficulties in the corrugating process are encountered with heavier weights and caliper

Basis Weight of kraft Liner (lb/1,000 sq.ft.)	Ring Crush Values (lb/in., M.D.)
26	11.7
33	13.8
38	16.5
42	17.9
69	30.5
90	38

Table 2-3. Ring crush strength of different grades of kraft liners.

Basis Weight of Medium (lb/1,000 sq.ft.)	Ring Crush Values (lb/in., M.D.)
22	7.3
26	10.2
31	12.7
34	13.8

Table 2-4. Ring crush strength of different grades of semichemical media.

of corrugating media.

Adhesives

Starch and silicate are the most economic adhesives for paperboard bonding. Chemically speaking, any type of starch can be used to make a corrugating adhesive. Cornstarch has emerged as the principal material for containerboard adhesive, with tapioca a distant second and potato starch third. Starch adhesive contains caustic soda and borax. Caustic soda is used to speed up complete gelatinization. Borax can greatly increase the tackiness of the soluble portion of the starch granule. Silicate adhesive is commonly known as water glass or silicate of soda containing a Na_2O to SiO_2 ratio of 1:3.38 mixed with about 60 % water. When silicate adhesive dries, it makes a very brittle film and has a good humidity-resistance. Silicate adhesive are normally formulated and produced by the supplier, whereas starch adhesive must be carefully formulated by user to obtain good quality.

Major advantages of starch are found in its effect on equipment during operation. It does not adhere to metal surfaces after drying out and does not have a dulling effect on the cutting edges. Conversely, once silicate adhesive adheres to a machine, it is very difficult to remove. It has a dulling effect on any cutting edges due to the glass-like nature and hardness of the adhesive. Starch may have higher flexibility than silicate when corrugated boxes are stacked.

Ideally, the use of water-resistant adhesives such as resin or starch-resin is best. However, from an economic standpoint, water-resistant adhesive is much more expensive and has more complex chemical reactions than starch or silicate.

Each kind of adhesive has its advantages and disadvantages. Very importantly, no matter what kind of adhesive is used, if poor bonding occurs, a strong corrugated box can never be fabricated.

Flutes

Two liners and one medium are combined to make double-face corrugated of A-, B-, or C-flute. A-flute has 36 ± 3 flutes per foot and is approximately 0.180 inch high, B-flute 50 ± 3 flutes and 0.092 inch high, C-flute

42 ± 3 flutes and 0.140 inch high. The more flutes the corrugated board has, the stronger the score lines. In top-to-bottom stacking strength, A-flute is a little higher than C-flute, but both A- and C-flute are superior to B-flute.

Generally speaking, A-flute would be used for packing fragile articles. B-flute is used for packing canned foods or other heavy products. C-flute has properties in between A- and B-flute. The strength of score lines is important to corrugated boxes. Once the score lines fail, reduction in stacking strength is great. Among these three kinds of different flutes, B-flute has the strongest score lines, and A-flute the weakest. B- and C-flute can maintain stronger score lines, both vertical and horizontal, than A-flute during heavy shipping.

In addition, the take-up ratio (the ratio of the lineal feet of medium to lineal feet of liner) of B-flute is the smallest, and A-flute the greatest. The greater the take-up ratio, the higher the cost. So either B- or C-flute should be used. C-flute may be the best choice because it has just a little weaker stacking strength than A-flute and its take-up ratio and strength of score lines are between that of B- and A-flute.

Style Of Corrugated Box

A full telescope half slotted box must be used because it provides highest stacking strength with minimum materials. The ratio of material used for regular slotted container to that used for FTHS is 1:1.4 with stacking strength of 1:1.82. It has been agreed that the best-shaped box for handling and storage is one in which the length is approximately 1.5 times the width, and the depth is little less than the width.

For a couple of years, a box with optimum dimensions of 22 by 13.2 by 9.1 inches has been used. The dimensions shall be within the limit of $\pm$ 1/16 inch, and all filler piece dimensions within $\pm$ 1/32 inch.

Manufacturer's Joint

The selection of the optimum type of joint depends upon two prime considerations: functional effectiveness and cost. Both stitched and glued boxes have overlap requirements. Both types of boxes with laps on the inside are better than on the outside because of compact stacking and avoiding abrasion.

If a taped or glued joint is used, the adhesion between liner and medium must be strong, otherwise there may be a separation of these elements. This will be more serious with glued joints. Such a condition can be prevented by stitching because properly formed and applied stitches grip all six elements. Boxes with stitched joints provide easier inspection than those with taped and glued joints, particularly the latter. It is easier to visually examine whether the required number of stitches has been applied and whether they have been clinched properly than to examine whether the full area under the tape or under glue lap is bonded. Tap cost per inch of depth of the boxes is higher than the stitching wire or glue cost. Glue cost is the lowest. Taking both functional effectiveness and cost into considerations, using stitches seem to be better. If stitches are used, the first and last stitches should not be more than one inch from horizontal score lines.

The construction of the manufacturer's joint should be in accordance with Rule 41 of the Uniform Freight Classification.

Sealing and Closing

If labor is not an important factor, the most economical method to seal boxes is with adhesive. Stitch is a clean, dry operation which make a strong package. But stitches will damage contents unless pads are provided at top and bottom.

Examination of actual practices indicates that taping and gluing are generally preferred for light gross weights and small boxes. Conversely, stitching is preferred for heavy gross weights and larger boxes during shipping. The bottom of the box fastened by stitches is better than by glue or tapes if pad is provided. On the contrary, glue or tape is better for the top of the box because it does not hurt the contents if no pad is used. But if contents will not be damaged by stitches, we should use stitches or glue because of cost. Generally, the speed of gluing is lower than that of stitching.

In so far as only material is concerned, glue is the most inexpensive, stitch the second, and tape the third. The use of glue on the top of box may reduce cost and can avoid damage to the contents.

The construction of sealing and closing of box should also comply with Rule 41 of the Uniform Freight Classification.

Ventilation Holes And Handholes

All side ventilation holes and handholes must be stripped. If they are improperly placed, the stacking strength will be reduced. Although reduction in strength is not great, they should be taken into consideration. It is important to mention that when material is removed from an area too close to the horizontal and vertical edges of the box, the reduction in strength is greatest. Thus, the ventilation holes and handholes should be far from horizontal and vertical edges of the box.

Slitting And Scoring

All slitting has to be clean, free from ragged edges, and without crushing of corrugations. For the purpose of air circulation, The body flaps of FTHS must be shortened $1\frac{7}{16}$ in., and cover flaps shortened $1\frac{3}{4}$ in.

In the study of "horizontal scoring related to compressive strength of corrugated boxes" by Carlon, it was found that boxes made with light score had the highest compression strength, and heavy score the lowest. Importantly, the lightest depth score is needed if board can be accurately folded along score lines without causing any problem.

Printing And Slotting

An excess of printing must be avoided, otherwise corrugations will be crushed. Crushing of corrugations from the printing process shall not exceed the following thickness reductions from the unprinted to printed area:

A-flute-----0.015 in.

B-flute-----0.011 in.

C-flute-----0.013 in.

Corrugated boxes should provide essential information on all sides. The essential information includes co-operative (or company) name, the name of nation, product name, brand name, and quantity. The name of nation and co-operative (or company) name can best be printed on the bottom of each panel. The arrangement does not have a universal standard, but they should be properly arranged.

The boxmaker's certificate must be put on one of the outer bottom flaps. It should include the style of box, bursting strength, maximum gross weight, dimensions, boxmaker's name, date of manufacturing, basis weight of liner and medium.

All slotting must be clean, free from ragged edges, and without crushing of corrugations. Slots must be of proper depth to permit flaps being closed without bulging or leaving holes at the corners.

Calculating Box Compression Strength Needed

Major factors which affect compressive strength include transportation, relative humidity, and duration of stacking.

Table 2-1 shows that when relative humidity increases from 50 to 88 percent, the stacking strength decreases from 58 to about 27 percent, and that when increasion in relative humidity is from 88 to 95 percent, the strength reduces from 27 to 15.5 percent. In other words, when relative humidity increases from 50 to 95 percent, the stacking strength of box conditioned and measured at 50 % R.H. and 73°F. is much lower. From Table 2-2, 10-day duration of stacking will be reduced to 63 percent of total stacking strength. Owing to ship pitch plus impact, stacking pressure increases 50 percent which must be subtracted.

The boxes are stacked eight high in ship. Each box weighs 35.2 pounds. Thus, every bottom box is subjected to 246.4 pounds of pressure (load). In order to safely arrive at Japan, the compression load on the boxes can not exceed 70 % of their average compression strength.

To calculate compressive strength of corrugated boxes needed, we must calculate initial compressive strength at 50 % R.H. and 73° F. that will result in a compressive strength of 246.4 pounds ($246.4 \div 0.70 = 352$ pounds) when they reach their destination. The computation is as follows:

$$X \times \frac{27}{58} \times \frac{15.5}{27} \times \frac{50}{100} \times \frac{63}{100} = 352 \text{ pounds}$$

X=4,181.46 pounds----initial compression strength needed at 50 % R.H. and 73° F.

From Table 2-3 and 2-4, author would select 69 lb. per 1,000 sq ft. with 30.5 lb/in. ring crush for outer and inner liners and 31 lb. per 1,000 sq ft. with 12.7 lb/in. ring crush for medium. C-flute will be used.

According to Forest Products Laboratory Report

R1911,

Combined ring crush=M.D. ring crush values for outer liner + M.D. ring crush values for medium × flute factor + M.D. ring crush values for inner liner.

The flute factor of combined ring crush is 1.532; 1.361; or 1.477 for A-, B-, or C-flute.

Therefore,

Combined ring crush=30.5 lb/in. + 12.7 lb/in. × 1.477 + 30.5 lb/in.=79.76 lb/in.

From Kellicutt and Landt's equation for RSC,

$$F=2.52 \times C \times A^{2/3} \times Z^{1/3} \times J$$

Where F is compression strength at 50 % R.H. and 70° F.

C=combined ring crush.

A=flute factor 8.36, 5.00, or 6.10 for A-, B-, C-flute.

Z=the perimeter of the box in inches.

J=box factor of 0.59 for A-flute; 0.68 for B-flute and C-flute.

As mentioned earlier, the dimensions of the box are 22 × 13.2 × 9.1 inches. So the perimeter=2(22+13.2)=

70.4 in.

Therefore, $F = 2.52 \times 79.76 \times 6.1^{2/3} \times 70.4^{1/3} \times 0.68$

$= 1,885.96$ pounds

It has been found that the ratio of compressive strength of an RSC to that of an FTHS is 1:1.82. Therefore, the compressive strength of an FTHS can be computed as follows:

$1,885.96 : Y = 1 : 1.82$

Y=3,432.45 pounds---compressive strength of FTHS at 50 % R.H. and 73°F.

From the result, 3,432.45 pounds of compressive strength is lower than initial compression strength needed. In order to reach required compression strength, an arrangement of interior forms of packaging such as liner, U pad, etc. can be structured to increase the compression resistance and meet the required compression strength.

For the purpose of maintaining higher, more uniform compression strength, the tolerance standards of raw materials and combined board for body and cover should be as follows:

1. 69 lb. per 1,000 sq ft. kraft liner.
   a. Basis weight: 69 ± 3.45 lb.
   b. Caliper: Ave. 0.022 in. (Ideally, 0.022 ± 0.0002 in.)
   c. Ring crush: Min. 28.5 lb/in.
   d. Bursting strenght: Min. 135 lb/sq in.
2. 31 lb. per 1,000 sq ft. semichemical medium.
   a. Basis weight: 31 ± 1.55 lb.
   b. Caliper: Ave. 0.0103 in. (Ideally, 0.0103 ± 0.0002 in.)
   c. Ring crush: Min. 11.2 lb/in.
3. Combined board.
   a. Height: 0.159 in.
   b. Weight: Min. 0.174 lb/sq ft.
   c. Flat crush: Min. 40 lb.
   d. Puncture resistance: Min. 290 puncture units.
   e. Bursting strength: Min. 275 lb/sq in.
   f. Column crush: Min. 75 lb/in.

2. Setting Specification

Full telescope half slotted banana box, with body flaps shorted 1.44 in. and cover flaps shorted 1.75 in. plus interior forms of packaging.

Inside dimensions: 22 in. long by 13.2 in. wide by 9.1 in. high (body); 22.375 in. long by 13.575 in. wide by 9.225 in. high (cover).

Body: 275-lb. test, 69/31/69, C-flute; stitched joint, lap on inside; all holes stripped.

Cover: 275-lb. test, 69/31/69, C-flute; stitched joint, lap on inside; all holes stripped.

The interior forms of packaging must be properly designed to fall within tolerance standards by the packaging department. Once they are made, the tolerance standard of raw materials and combined board should be established.

All kraft liner of body and cover must be 69 lb/1,000 sq ft. and all semichemical medium of body and cover must be 31 lb/1,000 sq ft.

Adhesive: starch.

Closing: both body and cover---stitching.

The details should be in accordance with the section of " Preparation of Specification."

III. Quality Control Technique

Quality control technique is quite important in a corrugated box plant. No matter how good machines and raw materials a plant may have, it is impossible to manufacture a good corrugated box if people underestimate quality control. High productivity coupled with good quality can only be obtained from a combination--excellent materials, smoothly run machines, and good human operation.

Quality control has only one important function --that is to help the manufacturing department fabricate corrugated boxes with the best quality at minimum cost. To do this, the quality control department must emphasize tests and inspections to know whether raw materials, corrugated board, and finished boxes are kept within limits set forth in specification or not. In addition, the results of tests and inspections must be reported to a flow chain of superiors so that they can take action when quality does not fall within tolerance of standards. Remember that the corrugator has to be kept at peak efficiency by operators during manufacturing.

1.Method Of Quality Control

Although our box plant is concerned about quality, a concrete method of quality control has not yet been established. The effective method of quality control should be as follows:

Raw Material Test

Purchasing department should purchase raw materials according to specification. When purchased materials come in, samples must be tested by the quality control department to make sure whether they fall within the tolerance of standards or not. Paperboard tests must be conditioned at 50 % R.H. and 73°F. The important tests include basis weight, caliper, bursting strength, and ring crush. After samples are tested by quality control people, the results must be recorded on a raw material test report form (Figure 3-1).

Rating Demerits Of Corrugated Board

This method is not a complex process. The inspector picks up a sample without making a choice from machine, and checks it. Of course, the inspector must

Raw Material Test Report Form

Roll Number (liner or medium): Date:

Items		Spec.	Actual Test
Basis Weight (lb/1,000 sq. ft.)	Ave. Min. Max.		
Caliper (in.)	Ave.		
Bursting Strength (lb/sq. in.)	Ave. Min.		
Ring Crush (lb/in., M.D.)	Ave. Min.		

Comment:

General Manager:

Manager:

Head:

Tested by:

Figure 3-1. Raw material test report form.

know what is a perfect corrugated board, and what is an imperfect board. When the inspector finds demerits, he has to record on a quality inspection form (Figure 3-2) and immediately tell the foreman the demerits found. Then the foreman has to check both machine and operator to solve the problem. Sometimes it is very difficult to find where the problem is, but there is a method to decide. That is, if one operator shows higher demerits than another, we can almost be sure that the problem lies not in the machine, but rather with operator; whereas if two operators show the same demerits, it can almost be decided that the problem is in the machine and it has to be checked.

How many samples should the inspector inspect periodically ? No standard answer can be found for this question, but we can reasonably set the number of samples. The inspector may pick 5 samples at random to check qualities every two hours when machine is being run.

Combined Board Test

The test values of combined board should meet the specifications. The number of combined boards tested can be decided by the quality control department. The

Quality Inspection Report Form

Inspected Quantities:

Date:

Items	Demerits 1	2	3	4	5	Remark
1. Bonding failure						
2. Blisters						
3. High-low flutes						
4. Leaning flutes						
5. Lower flutes						
6. Warped corrugated board						
7. Wet board						
8. Wrinkles						
9. Washboarding						
10. Crushing of corrugations						
11. Slitted edge not bonded						
12. Ragged slitting						
13. Too heavy score						
14. Too light score						
15. Printing crushing						
16. Poor definition						
17. Poor coverage						
18. Ragged slotting						

Foreman:

Inspected by:

Figure 3-2. Quality inspection report form.

essential tests include bursting strength, puncture resistance, flat crush, and column crush. The testing room must be maintained at 50 % R.H. and 73°F. The results obtained by quality control people have to be put in combined board test report form (Figure 3-3).

Establishing The Standard Of Compressive Strength Of Finished Boxes

High, more uniform compression strength of boxes is relatively important for our exported banana boxes because it is impossible to choose bottom boxes which have the highest compression strength during stacking and shipping.

Because a corrugated box is a very complex engineering structure, the completely uniform compression strength boxes are impossible to be manufactured. So proper tolerance standards must be established.

Based on Kellicutt and Landt's calculation, McKinlay(10) predicted compressive strength of different sizes of boxes and found that deviation of compressive strength ranged from ± 5 to ± 6 percent. In the box plant,

Combined Board Test Report Form Date:		
Items	Spec.	Actual Test
Bursting Strength (lb/sq.in.) Min. Ave.		
Puncture Resistance (unites) Min. Ave.		
Flat Crush (lb.) Min. Ave.		
Column Crush (lb/in.) Min. Ave.		
Comment: Plant Manager: Head: Foreman: Tested by:		

Figure 3-3. Combined board test report form.

the proper tolerance of compressive strength should be set about ± 6 %.

How many finished boxes should be tested ? Of course, ideally, we would like to test none. Practically, we must test some. Let us establish that at least ten boxes conditioned at 50 % R.H. and 73° F. should be tested by the quality control department per day when machine is run. After testing, if results of compressive strength are shown as follows:

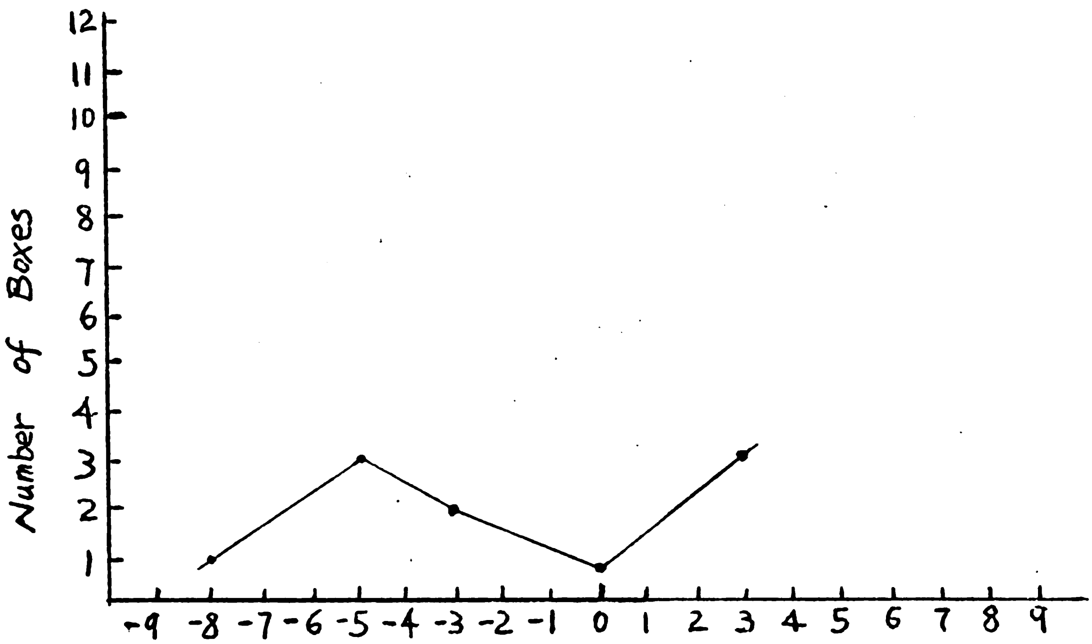
Tested quantities	Compressive strength (% of standard)
1	-8
3	-5
2	-3
1	0
3	3

The results of the tests are plotted on a chart (Figure 3-4). From the chart, it is shown that one of the tested boxes falls outside the minimum standard. We should back to rating demerits of corrugated board to check which demerits are higher. Then steps are taken to correct the problems.

This twofold method of quality control will result in better manufactured boxes of more uniform compression strength.

Box Compression Strength Test Chart

Tested Quantities: Date:



± % Of Standard Compression Strength

Standard Compression Strength (pound) :4,450

Outside 9 %:

Outside -9 %:

Comment:

Plant Manager:

Head:

Foreman:

Tested by:

Figure 3-4. Box compression strength test chart.

2. Reporting System

Raw Material Test Report

After the quality control man records the results of testing and signs the report form, it must be directly sent to the purchasing people. Then, the purchasing people report to the manager of the packaging department who reports to the general manager. The report form must be signed by all of them.

Rating Demerits Report

This is a daily report. After recording the results on quality inspection form, the inspector must sign and then send it to foreman. The foreman takes average demerits from one-day quality inspection forms. For example, assuming that the inspector inspects six times a day, a total of 30 samples are checked. Then, the foreman must put 30 on the top of quality inspection form A (Figure 3-5). If he finds a total of five leaning flutes from six forms, 5 must be put on the blank of number 4.

The total number of demerits divided by the number of samples inspected gives a demerits per sample quality rating. Suppose that the total number of

Quality Inspection Report Form A

Inspected Quantities: Date:

Items	Number of Demerits	Remark
1. Bonding failure		
2. Blisters		
3. High-low flutes		
4. Leaning flutes		
5. Lower flutes		
6. Warped corrugated board		
7. Wet board		
8. Wrinkles		
9. Washboarding		
10. Crushing of corrugations		
11. Slitted edge not bonded		
12. Ragged slitting		
13. Too heavy score		
14. Too light score		
15. Printing crushing		
16. Poor definition		
17. Poor coverage		
18. Ragged slotting		

Plant Manager:

Head:

Foreman:

Figure 3-5. Quality inspection report form A.

demerits is sixty, average demerits per sample are equal to 60 divided by 30. Then we get a average of 2 demerits per sample.

Both total number of demerits and average demerits have to be recorded on quality inspection form A. This kind of report is only sent to the head of the manufacturing department and the plant manager.

Combined Board Test Report

This kind of report is sent to the foreman, the head of the manufacturing department, and the plant manager after quality man records the results of testing on combined board test report form.

Box Compression Strength Report

A flow of box compression strength reports from lower level of workers to president should be made. The procedure of reporting is that after the chart is plotted by quality control man, it must be sent to the foreman, the head of the manufacturing department, and the plant manager daily.

The weekly report made by the plant manager is delivered to the manager of the packaging department, the general manager, and the president. The plant manager should precisely fill out the weekly box compression strength report form (Figure 3-6) according to one-week charts prepared by the quality control department.

All of the reports have to be signed by those responsible, and hopefully, each of them would make a comment.

Weekly Box Compression Strength Report Form

Tested quantities: Date:

Items	Quantities	Remark
Outside Max. Standard		
Between Standard & Max. Standard		
Standard		
Between Standard & Min. Standard		
Outside Min. Standard		

Standard Compression Strength : 4,450 lb.

Tolerance of Standard : ± 6%.

President:

General Manager:

Manager:

Plant Manager:

Figure 3-6. Weekly box compression strength report form.

V. Summary And Conclusion

Although corrugated box is a very complex engineering structure, great effort should be made to fabricate good corrugated boxes. Manufacturing good corrugated boxes are greatly dependent upon proper specification and superior quality control technique.

Proper box specifications not only can provide right materials, but also can achieve the best quality with minimum cost. In addition, it can also provide suitable corrugated boxes for handling and shipping. Superior quality control technique has to rest on appropriate methods of quality control and high machine efficiency.

In short, corrugated boxes with good quality can only be obtained from three extremely important factors---excellent raw materials, smoothly run machines, but above all from high human performance. These three factors must be geared to one another and can not be separate and independent.

Bibliography

1. Ostrem F. E., and Rumerman, M. L., "Shock and Vibration Transportation Environmental Criteria", Contract NAS-8-11451, 1965.

2. O'Brien, M., Claypool, L. L., Leonard, S. J., York, G. K., and MacGillivray, J. H., "Causes of Fruit Brusing on Transport Truck", Hilgardia, June 1963.

3. George G. Maltenfort, "The Structure of Corrugated Board", TAPPI, July 1970.

4. Orginally published in German (NEUE VERPACKUNG, April 1966) and written by Dipl. lng. Ernst Schmidt and Dipl. Phys. Heinz Mielke, "Packaging In An Ocean Shipping Environment", Paperboard Packaging, Feb. 1967.

5. C. O. Seborg, R.H. Doughty, and P.K. Baird, "Effect of Relative Humidity on the Moisture Content and Bursting Strength of Four Container Boards", Paper Trade Journal, Oct. 1933.

6. K. Q. Kellicutt, "Influence of Moisture on Compressive Strength", Paperboard Packaging, April 1960.

7. J. Paronen and M. Toroi, "How the Atmosphere Influence Board Strength and Stiffness", BoardPackAge, Nov. 1962.

8. K. Q. Kellicutt, "Stacking Strength of Boxes", Paperboard packsging, Sept. 1960.

9. Russel C. Moody and Kenneth E. Skidmore, "How Dead Load, Downward Creep Influrnce Corrugated Box Design", Package Engineering, August 1966.

10. A. H. McKinlay, "Predict Stacking Strength of Corrugated Boxes Accurately", Packaging Engineering, Oct. 1960.