

Effect of Manufacturer's Joint Fastening Techniques on Compression Strength of Corrugated Fiberboard Boxes

J. SINGH^{1,*}, A. ATTEMA², E. OLSEN³ and K. VORST³

¹Associate Professor, Industrial Technology, Cal Poly State University,
San Luis Obispo, CA

²Research Assistant, Industrial Technology, Cal Poly State University,
San Luis Obispo, CA

³Assistant Professor, Industrial Technology, Cal Poly State University,
San Luis Obispo, CA

ABSTRACT: A flat piece of corrugated fiberboard, which has been cut, slotted and scored, is often referred to as a box blank. For several box styles, in order to convert the box blank into a box, its two ends must be fastened together with tape, staples or adhesives such as water soluble glues. The location at which the two ends meet is known as the manufacturer's joint. There are several variations within the three fastening techniques mentioned with most corrugated box manufacturers following their own protocols for fastening the manufacturer's joints. This study explored the compression and tensile strengths of RSC style corrugated boxes based on adhesive (glue) coverage, three different types of tapes (acrylic, paper and reinforced paper) and application angle of staples. The fabricated boxes were also tested for compression strength and deflection. Test data ($N = 10$) was collected for each dependent variable of peak force, deflection at peak force and tensile strength using the analysis of variance procedure with a Turkey probability distribution at a 0.05 critical limit. The results suggest an overall higher tensile strength for glue than the other fastening techniques evaluated ($P < 0.05$) with no significant difference ($P > 0.05$) for peak force or deflection at peak force for all glued, stapled or taped treatments.

1.0 INTRODUCTION

DUE to its high strength to low weight ratio corrugated packaging is poised as the leading choice for transport packaging in the United States. By some estimates corrugated packaging is used to package ap-

*Author to whom correspondence should be addressed. Email: jasingh@calpoly.edu

proximately 90% of all products for retail distribution in the United States [1]. The popularity of corrugated packaging also stems from the fact that it is practical, useful, economical, renewable and recyclable [1]. It is also a substrate that can be custom designed and provides excellent merchandising appeal through printing on box panels. Twede [2] accounted that 80% of the \$46 billion worth of paper based packaging used is corrugated fiberboard shipping containers.

Corrugated fiberboard is a paper-based material consisting of a fluted containerboard sheet and at least one flat linerboard. It is widely used in the manufacture of corrugated boxes and shipping containers. Throughout the journey of a containerboard from the paper mills to box plants, which include the corrugated box plants and sheet plants, close quality control is provided to material properties such as basis weight, caliper, burst strength, water absorption, porosity to air and smoothness. Variations in material properties can affect the strength and performance of corrugated boxes.

Boxes from the corrugated fiberboard sheets can be formed in the same plant as the corrugator or alternatively, sheets of corrugated fiberboard can be shipped to a sheet plant for conversion into boxes. At both these facilities the corrugated board is creased or scored to provide controlled bending of the board. Slots are typically cut to provide flaps for boxes. The Regular Slotted Container (RSC, FEFCO 0201) is the most common style of corrugated box used in the industry [1]. All flaps for this style of construction are the same length and the outer (major) flaps meet at the center of the box. Figure 1 illustrates a box blank for a RSC style box as well as an assembled box.

At the conversion plants, the two ends of the box blank are fastened together with tape, staples or adhesives (glue) for conversion to a box. The location at which these two ends meet is known as the manufacturer's joint. It may be noted that not all corrugated containers, such as bliss

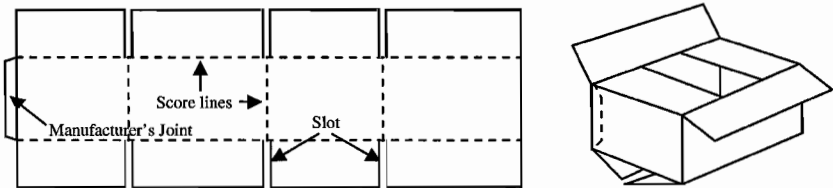


Figure 1. Box Blank Showing Score Lines, Slots & Manufacturer's Joint and Assembled RSC.

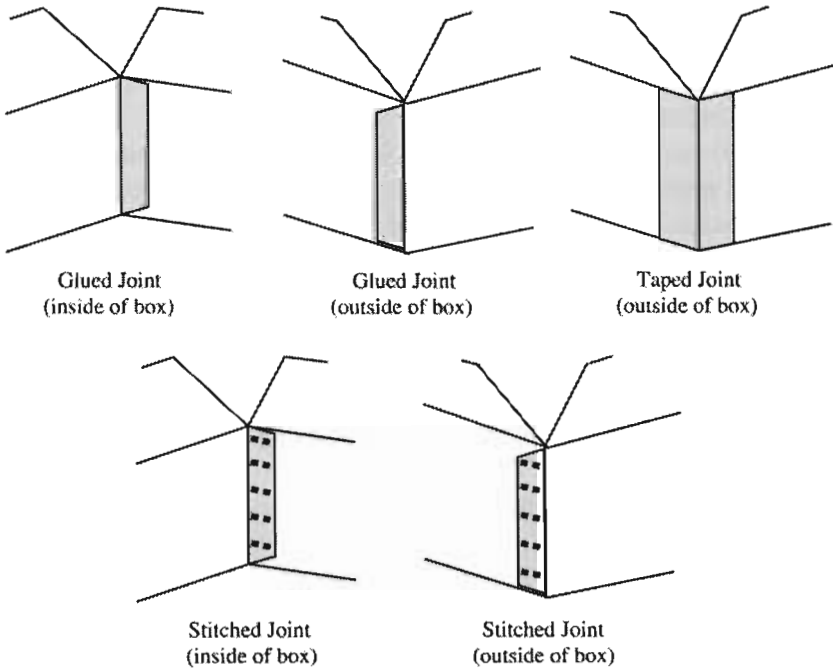


Figure 2. Common Styles of Manufacturer's Joints.

boxes, have manufacturer's joints. Figure 2 illustrates the common types of manufacturer's joints used by the industry.

The side panel thickness and paper basis weight commonly determine the kind of fastening technique used for manufacturer's joints. Adhesive joints are also referred to as "glue" joints in this paper. Glue and tape joints are most commonly used for most single wall constructions whereas, staples are frequently used for double and triple wall constructions. All three techniques have their own advantages and disadvantages as discussed below:

- *Glued Joints:* Provide higher strength and rate of productivity, are better for rough handling, typically provide higher tensile strengths, do not interfere with printing when placed on the inside and offer lesser likelihood of scratching the product and personal injuries. They are the most economical method but can be messy in the manufacturing environment. They are also sensitive to temperature and humidity.
- *Stitched/stapled Joints:* Preferable for containers subjected to moisture such as waxed board, required on weather resistant boxes for U.S.

government, objectionable when used with food products, may interfere with printing layouts, may scratch a finely finished product's surface and may cause wrinkles and permit the corner of the box to fold on the line of stitches.

- *Taped Joints*: They do not require a tab and hence use lesser material and by providing more efficient layouts decrease scrap, knocked down boxes lie flatter in tied bundles, the inside of the box is smoother, provides convenient means of easily opening the box, interferes with some print layouts and is more expensive than glue. A simple shift from glue to taped boxes reduces corrugated material use, but can result in additional costs.

1.1 Manufacturer's Joint Related Regulations

There are several regulations related to corrugated products such as those set by carriers (rail and truck), U.S. government (DOT, FDA, USDA, and EPA) and the Council of State Governments which provide guidelines regarding corrugated container construction [1,2]. More clearly defined specifications which can be considered as industry standards for corrugated materials are provided by the Fiber Box Association (FBA) or the Association of Independent Corrugators (AICC), and machinery and fabrication equipment guidelines and standards can be obtained from the Packaging Machinery Manufacturers Institute (PMMI) [3,4,5]. Although the tolerances provided by FBA and PMMI are voluntary, most corrugated manufacturing companies and many corrugated users consider these as specifications to be used when manufacturing or specifying most corrugated packaging.

The carrier rules provide the following guidelines for manufacturer's joints [1]:

Single and Double Wall Fiberboard Constructions

Boxes must have manufacturers' joints formed by lapping the sides of the box forming the joint not less than 3.18 cm, where the 3.18 cm is the actual overlapping or mating area (Figure 3). As regards to fastening techniques, the following guidelines are provided:

- *Metal staples or stitches*: generally spaced not more than 6.35 cm apart except when weight of box and contents is 63.5 kg or more—spaced not more than 2.54 cm apart.

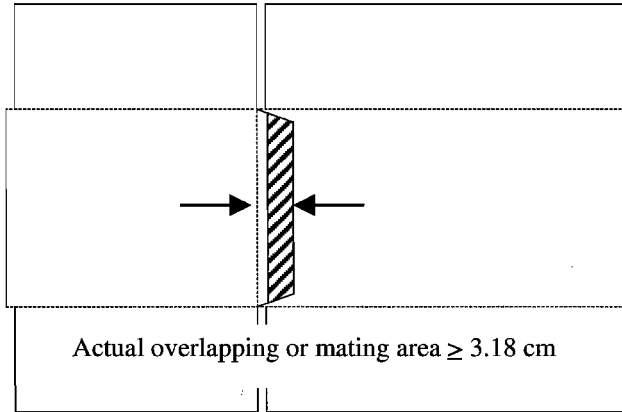


Figure 3. Carrier Rule for Manufacturer's Edge Overlap.

- *Glue*: gluing the entire area of contact with a water-resistant adhesive.
- *Taping (butted joints)*: sealing strips firmly glued to the box and extending the entire length of the joint. Sealing strips must be of sufficient strength that rupture of the joint occurs with fiber failure of one or more of the facings.

Triple Wall Fiberboard Construction

Boxes must have the manufacturer's joint formed by one of the following methods:

1. By lapping the sides of the box forming the joint not less than 5.08 cm and fastening the joint with *metal staples or stitches* spaced not more than 2.54 cm apart. Both sides of the joint must be crush-rolled in the area of contact before stapling or stitching.
2. By lapping the sides of the box forming the joint not less than 7.62 cm. The joint must be firmly *glued* with 100% glue coverage in the area of contact with glue, or adhesive which cannot be dissolved in water after the film application has been dried under pressure.

Corrugated shippers are designed to overcome the distribution environment hazards so that the products they carry reach the consumers, intact and ready for use. The transportation and warehousing hazards faced commonly by corrugated shippers include compression, shock, vibration, temperature, creep and humidity among others. Most material (containerboard) and corrugated package testing procedures are provided by the Technical Association of the Pulp and Paper Industry

(TAPPI) and American Society for Testing and Materials (ASTM) [6,7,8,9].

When a shipping container is dropped during handling or compressed during stacking, its manufacturer's joint is subjected to stresses along with all other edges. The TAPPI Test Method T 813 om-04 (Tensile Test for the Manufacturer's Joint of Fiberboard Shipping Containers, Test Method) helps determine the strength of the manufacturer's joint of commercially made corrugated and solid fiberboard shipping containers and is applicable to taped, stitched, or glued joints which may also be used to evaluate laboratory fabricated joints similar to commercially made joints [6]. ASTM D 642 (Standard Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads) is commonly used for measuring the ability of the container to resist external compressive loads applied to its faces, to diagonally opposite edges, or to corners [7].

At present there is no data available to demonstrate the effect of variations in the prescribed methods of joining the manufacturer's edge as related to the compression or the tensile strengths of corrugated boxes.

The two objectives of this study were to:

1. Compare the strength of various methods used to fasten the manufacturing joint in RSC style boxes.
2. Evaluate the affect of manufacturer's joint fastening methods with respect to box compression strength and deflection.

2.0 SURVEY OF INDUSTRY PRACTICES

Before initiating the experimental study a survey was conducted targeting the manufacturers of corrugated boxes with regards to the common practices used to form the manufacturer's joint. Responses were received from ten leading corrugated packaging manufacturers. It was found that most manufacturers did not agree on the same technique. Based on their operational capabilities and customer orders most follow their own protocols for fastening the manufacturer's edge. The following were some key findings from this survey:

- 90% used glue and 10% used staples.
- 80% made internal manufacturer's joints for 75% or above of their production.

- 80% made external manufacturer's joints for 25% or below of their production.
- 90% had at least 3.5 cm overlapping/mating between the manufacturer's joint and the panel.
- Of the manufacturers using staples, only 33.3% used 2.54 cm spacing between staples. Others used 3.81 cm to 5.08 cm as the spacing; with one manufacturer using a double stitch start and then a spacing of 2.54 cm between adjacent staples.
- 55.6% of all users that stapled the manufacturer joint used a 45° angle of application, followed by 22.2% of users who applied horizontal staples along the depth of the box.
- 70% of the manufacturers that used glue, had at least 75% glue coverage between the manufacturer's joint and the panel. 30% used 50% or less glue coverage.
- Of the manufacturers using glue, 70% applied the glue using one or more vertical lines along the depth of the box.
- 89% of the manufacturers that used tape, preferred reinforced paper tape along 100% of the depth of the box.

3.0 MATERIALS AND METHODS

3.1 Manufacturer Joint Tensile Testing

The TAPPI test standard T 813 om-04 (Tensile Test for the Manufacturer's Joint of Fiberboard Shipping Containers, Test Method) was used to compare the performance of various fastening methods for manufacturer's joints. This test gives an indication of the ability of the joint to withstand rough handling without failure, to the extent that failure is related to the tensile strength of the joint itself [6]. The initial jaw span for the tensile tester was set at 180 ± 5 mm and the rate of separation used was 25 ± 5 mm/min. A Testometric tensile tester Model M350-5kN (Testometric Materials Testing Machines Company, Lancashire, United Kingdom) was used for all tests. C-flute corrugated fiberboard was used with a basis weight of 20/15/20 kg/ 92.9 sq. m. (44/34/44 lb/ 1000 sq. ft.), a bursting strength of 125 N/cm², and an edge crush test (ECT) of 79 N/cm.

Figure 4 indicates the location of the test samples obtained as related to the corrugated container.

Tensile test strips were prepared in accordance to TAPPI T 813 om-04

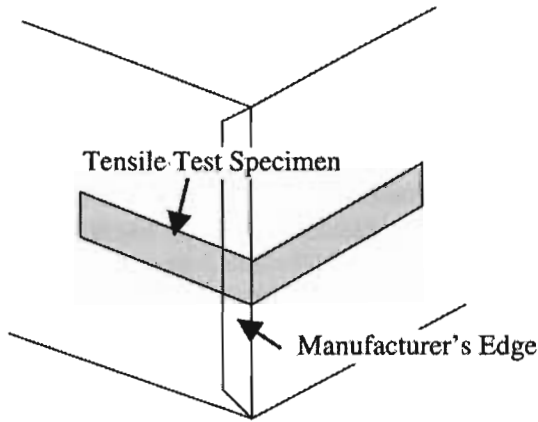


Figure 4. Tensile Test Specimen Location.

(Figure 5). The length of all samples was 200 mm. Glued and taped manufacturer's joints used a width was 25 ± 0.5 mm, with stapled joints having a 38 ± 0.5 mm in accordance with the standard. The distance between the outer edge of the staples and the corresponding outer edge of the joint was 6.35 mm and only one staple was included per sample.

Table 1 provides details of materials used to fasten the manufacturer's joint. All materials were procured from Uline Shipping Supplies (Waukegan, IL, USA)

For the glue joint, 25, 50 and 75 percent of the area on the manufacturer's joint tab was covered with hot melt glue. For the stapled joints, the angles of staple applications were varied between 0, 15, 30 and 45 degrees along the depth direction. Ten samples for each variable were

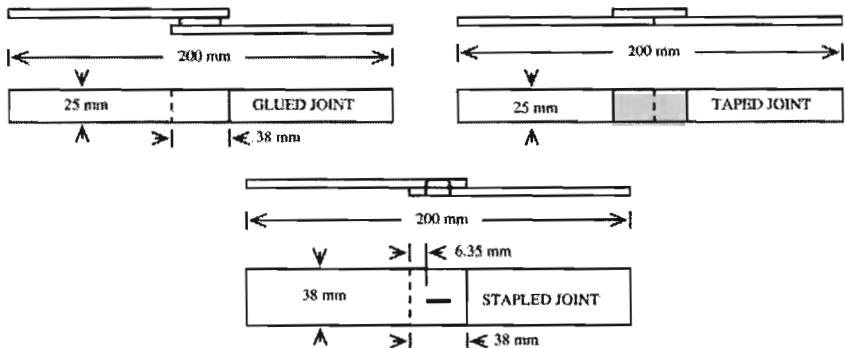


Figure 5. Tensile Test Samples for Glued, Taped and Stapled Joints.

Table 1. Materials used for Fastening the Manufacturer's Joints.

	Material	Supplier	Model No.	Description
1	Reinforced paper tape	Uline	S-2350	7.6 cm wide, Kraft paper reinforced with fiberglass yarn, water activated
2	Paper tape	Uline	S-9682	5.1 cm wide, pressure sensitive
3	Acrylic tape	Uline	S-472	5.1 cm wide, solvent acrylic adhesive
4	Glue	Uline	S-509	1.3 cm diameter, hot melt glue
5	Staples	Uline	S-1396	3.2 cm crown width, 1.9 cm leg length

tested after conditioning for 24 hours at 23°C and 50% relative humidity in accordance with ambient conditions as described in ASTM D4332 [8].

3.2 Box Compression Strength Testing

The ASTM D 642 (Standard Test Method for Determining Compressive Resistance of Shipping Containers, Components, and Unit Loads) was used to test the compression strength [7]. The procedure is commonly used for measuring the ability of the container to resist external compressive loads applied to its faces, to diagonally opposite edges, or to corners. This test method is also used to compare the characteristics of a given design of container with a standard, or to compare the characteristics of containers differing in construction. This test method is related to TAPPI T 804 om-02 [9]. The tests were conducted using a fixed platen arrangement on a Lansmont compression tester Model 152-30K (Lansmont Corporation, Monterey, CA, USA), with a platen speed of 1.3 cm/minute and a pre-load of 22.68 kg for zero-deflection in accordance with the standard.

The same materials and joining methods as described in 3.1 were used for box compression testing. The spacing between the staples for all angles was maintained at 5.08 cm. All boxes used for this study were regular slotted containers (RSC) style with dimensions of 50.8 cm × 40.6 cm × 25.4 cm and having a 3.8 cm wide manufacturer's joint. All corrugated box samples used for this study were created using ArtiosCAD software and the Premium Line 1930 model of the Kongsberg table (Esko Graphics, Ludlow, Massachusetts, USA). Five box samples for each variable were tested after pre-conditioning for 24 hours at 50% relative humidity and 23°C.

4.0 DATA AND RESULTS

Test data was collected for each dependent variable: peak force, deflection at peak force, and tensile strength on ten samples of each joining method. A total of 300 observations were used for this study. The test data were compared for the three dependent variables using one way analysis of variance (ANOVA) with a Tukey post-hoc test. A family-wise error rate of $p = 0.05$ was used to determine significance. Table 2 provides a summary of the test data.

4.1 Peak Force

The data showed little difference among the fastener technologies with respect to peak force capability. None of the general categories of glue, staple, or tape were consistently higher or lower than another. The overall ANOVA was significant at a 0.05 level. Variability was observed within the fastener technologies with a 45 degree stapling having particularly low values and reinforced tape having particularly high values (Table 3). Overall glue coverage did not affect the peak force performance significantly ($P > 0.05$) indicating that 25 percent glue coverage was as effective as 75 percent. Similarly, no significant difference was found between tape systems ($P > 0.05$). Table 3 indicates the 95 percent confidence intervals for each fastening system.

4.2 Deflection at Peak Force

All tape systems used in this study allowed significantly more deflection than the other general categories of fasteners ($P < 0.05$). Tape systems deflected an average of 0.42 cm while the other fasteners deflected an average of only 0.28 cm. Tape systems also exhibit significantly higher coefficients of variation than either of the other general joining methods (Table 2). No significant differences were found between glued or stapled units with respect to means or coefficients of variation. Table 4 shows the 95 percent confidence intervals for each technology.

4.3 Tensile Strength

All glue coverages had significantly higher tensile strengths than any

Table 2. Tensile Test Data Summary.

Joining Method	Specimen Width (mm)	Peak Force (N)		Deflection at Peak Force (cm)		Tensile Strength (kN/m)	
		Mean	C. of V.*	Mean	C. of V.*	Mean	C. of V.*
Glued Joints							
Glue 25%		1857	3.1%	0.292	7.4%	15.42	9.2%
Glue 50%	25	1794	3.3%	0.287	7.3%	18.80	4.7%
Glue 75%		1820	2.7%	0.277	2.9%	21.16	4.4%
Stapled Joints							
Staple 0°		1814	5.3%	0.277	8.0%	1.98	14.2%
Staple 15°		1783	5.9%	0.277	5.2%	2.04	11.0%
Staple 30°	38	1882	3.4%	0.272	6.3%	2.13	7.3%
Staple 45°		1705	5.4%	0.287	6.0%	2.58	6.2%
Taped Joints							
Acrylic		1826	6.1%	0.432	31.1%	4.68	11.4%
Paper	25	1923	6.5%	0.427	34.1%	7.17	5.7%
Reinforced Paper		1810	11.4%	0.401	38.0%	6.68	7.3%

*Coefficient of Variation

Table 3. Peak Force (N) 95% Confidence Intervals by Joining Method.

Level	Mean	Std. Dev.
glue 25	1857	58
glue 50	1794	59
glue 75	1820	49
staple 0	1814	97
staple 15	1783	105
staple 30	1882	64
staple 45	1705	92
tape acrylic	1826	112
tape reinforced	1923	125
tape unreinforced	1810	206

Pooled Std. Dev. = 106

of the other fasteners with each increase in glue coverage having significantly better performance ($P > 0.05$). The average glue performance was 18.5 kN/m. The stapled samples had the lowest performance with an average tensile strength of 2.2 kN/m and no significant affect from staple angle. The tape systems were stronger than the stapled samples with an average of 5.3 kN/m. Acrylic tape was significantly weaker than the other tape systems. Using reinforced tape did not significantly improve tensile strength. Table 5 shows the 95 percent confidence intervals for each technology.

Table 4. Deflection at Peak Force (cm) 95% Confidence Intervals by Joining Method.

Level	Mean	Std. Dev.
glue 25	0.292	0.022
glue 50	0.287	0.021
glue 75	0.277	0.008
staple 0	0.277	0.022
staple 15	0.277	0.014
staple 30	0.272	0.017
staple 45	0.287	0.017
tape acrylic	0.432	0.134
tape reinforced	0.427	0.146
tape unreinforced	0.401	0.152

Pooled Std. Dev. = 0.080

Table 5. Tensile Strength (kN/m) 95% Confidence Intervals by Joining Method.

Level	Mean	Std. Dev.
glue 25	15.42	1.42
glue 50	18.80	0.89
glue 75	21.16	0.93
staple 0	1.98	0.28
staple 15	2.04	0.22
staple 30	2.13	0.16
staple 45	2.58	0.16
tape acrylic	4.68	0.53
tape reinforced	7.17	0.41
tape unreinforced	6.68	0.49

Pooled Std. Dev. = 0.675

5.0 CONCLUSION

The results of this study showed:

1. Superior strength for tensile load to failure and breaking load for glued joints followed by stapled and taped joints.
2. Reinforced taped joints showed the highest box compression strength followed by glued joints covering 25% of the overlap or mating area,

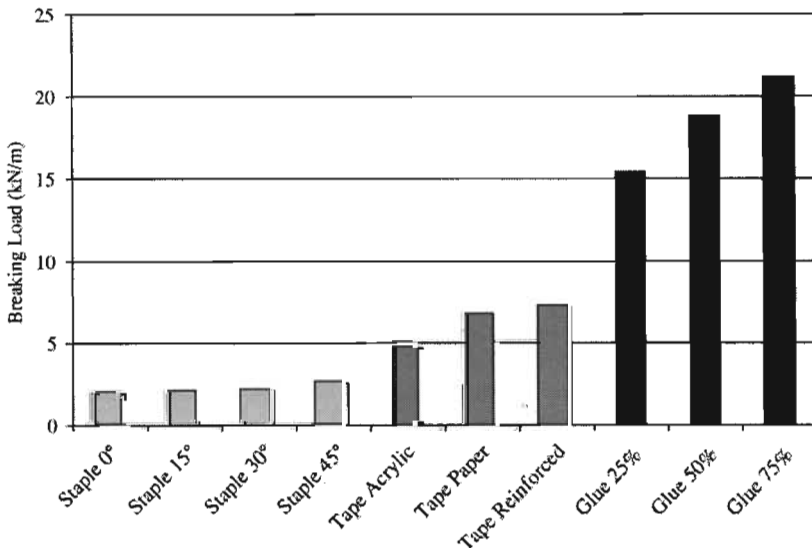


Figure 6. Breaking Load (kN/m) Comparison for all Sample Types.

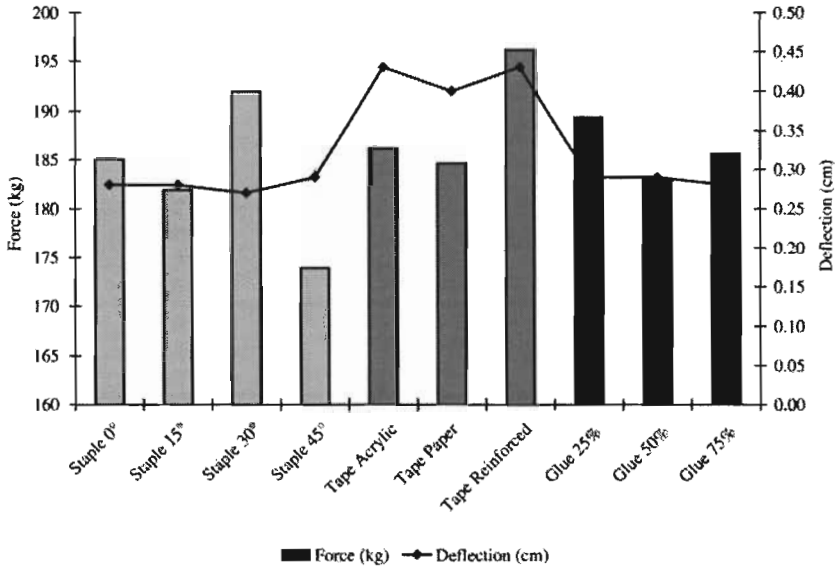


Figure 7. Compression Strength of Boxes with Different Types of Manufacturer Joints.

and stapled joints applied at 30 degrees offset from the direction of depth of the box.

3. This study suggests that boxes with glued manufacturer's joints can offer better containment during shipping and handling.
4. Caution should be exercised when relying on taped joints for deflection performance.

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