Cloud Publications
International Journal of Advanced Packaging Technology
2013, Volume 1, Issue 1, pp. 22-29, Article ID Tech-179
ISSN 2349 – 6665, doi 10.23953/cloud.ijapt.3

Research Article **Open Access**

Recycled Cardboard Comparison

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Publication Date: 15 October 2013

DOI: https://doi.org/10.23953/cloud.ijapt.3

Editor-in-Chief: **Dr. Siripong Malasri**, Christian Brothers University, Memphis, TN, USA

(This article belongs to the previously presented work at Healthcare Packaging Consortium at CBU, USA)

Abstract Three tests were conducted to determine the relative strengths of virgin and recycled cardboard. Edge crush tests were performed to measure the maximum force per inch to crush the walls of a cardboard box. Burst tests were performed to determine the pressure required to rupture the side of a cardboard box. Compression tests were used to determine the behavior of cardboard under a crushing load. All tests were performed according to TAPPI protocols at standard and extreme environmental conditions. Results showed that both recycled and virgin materials exceeded industry specifications at standard conditions but that the performance of both were severely degraded at extreme conditions with the recycled material showing the greatest degradation.
Keywords *Recycled Material; Virgin Material; Environment*

1. Introduction

The use of recycled cardboard has gained wide acceptance in the packaging industry where sustainability has become a priority of consumers. However, recycling cardboard can have a negative impact on the strength properties of the material. The purpose of this experiment is to determine the effect of recycling cardboard at varying environmental conditions.

For this experiment, three tests were conducted to determine the strength of virgin and recycled cardboard. Edge crush tests (ECT) were performed to measure the maximum force per inch to crush the walls of a cardboard box. Burst tests were performed to determine the pressure required to rupture the side of a cardboard box. Compression tests were used to determine the behavior of cardboard under a crushing load. All tests were performed according to TAPPI standards at standard and extreme environmental conditions.

Industry standards for the testing of the edge crush test, burst test, and compression test of corrugated boxes are set forth by TAPPI (Technical Association of the Pulp and Paper Industry), specifically TAPPI T839 om-08 [1], TAPPIT T807 om-11 [2], and TAPPI T804 om-06 [3], respectively. In these standards, restrictions are set for each testing procedure. In the documents, the appropriate apparatus and procedure is given with its specific uncertainty for the process for each test. The TAPPI standard is set in order for multiple companies to be able to provide and compare universal results. The testing standards are set forth for standard conditions and make no reference to testing at extreme conditions.

A literature search for similar comparisons of recycled and virgin materials was unsuccessful. No previous work was found.

2. Materials and Methods

2.1. Samples

In all, 14 different box sizes were tested. The 14 boxes were split into 7 different categories according to size and material. Each category consisted of two materials, Virgin and 100% Recycled. The nomenclature used in testing and results is the size of the box varying 1 through 7 followed by either “V” for virgin or “R” for recycled.

2.2. Conditioning

Each test was performed at two separate conditions. The first condition was at 73° F and 50% relative humidity. This will be referred to as Standard Condition henceforth. The second condition was at 90° F and 90% relative humidity. This condition will henceforth be referred to as Extreme Condition. All conditioning was performed in a Cincinnati Sub-Zero 32 Environmental Chamber located in the Christian Brothers University Certified Packaging Laboratory.

To condition the samples, the samples were subjected to an initial drying period at 90° F and 10% relative humidity for 24 hours. Immediately following the drying period, the samples were exposed to Standard Conditions for 48 hours. Once the standard samples were tested, the remaining samples were exposed to Extreme Condition for 48 hours and were immediately tested.

2.3. Edge Crush Test

The edge crush test was done in the CBU Certified Packaging Lab using a Crush Tester V5.0 Buchel BV (Figure 1) with jig (Figure 2) specially adapted for edge crush testing. In all, 140 samples were tested, 5 for each box per condition.

The cardboard samples were all cut into two inch by two inch squares. The samples were then conditioned. All tests were loaded into the jig with flutes parallel to the force applied. The sample was then tested until failure, and the maximum force was recorded.

Figure 1: *Crush Tester*

Figure 2: *Jig*

2.4. Burst Test

The burst test was done in the CBU Certified Packaging Lab using a Mullen Burst Tester (Figure 3) specially adapted for burst testing. In all, 140 samples were tested, 5 for each box per condition. The cardboard samples were all cut into six inch by six inch squares. The samples were then conditioned. All tests were loaded under the jaws of the Burst Tester. The jaws were clamped to 100 psi. The sample was then tested until failure, and the maximum pressure was recorded.

Figure 3: *Burst Tester*

2.5. Compression Test

The compression test was done in the CBU Certified Packaging Lab using a modified Gaynes Engineering Compression with a DigiWeigh Model TI-5000E floor scale (Figure 4) specially adapted for compression testing. In all, 2 or 3 box samples per condition. Only categories 1 to 5 were tested due to conditioning constraints. The cardboard samples were assembled using the force of the compression table. All tests were loaded into the compression table. The box was preloaded to a specified force. For single corrugated boxes, category 1, the preload was 50 pounds. For double corrugated boxes, categories 2 through 5, the preload was 100 pounds. The sample was then tested until failure, and the maximum force and deflection was recorded.

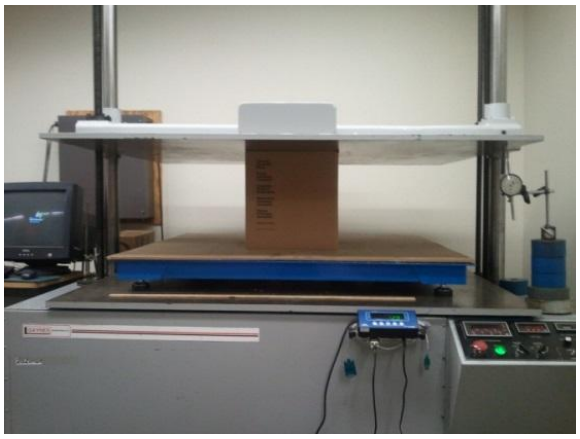

Figure 4: *Compression Tester*

3. Results and Discussion

3.1. Edge Crush Test

Table 1 shows the average results for the samples at each condition. It also shows the industrial strength (determined) ECT listing for each box. The percentage listing is the experimental ECT for each condition related to the industrial listing. Figure 5 shows a comparison of the determined ECT, virgin, and recycled results at extreme conditions.

Table 1: *Results for ECT*

Sample	Determined ECT (lbs/in)	Standard (lbs/in)	Percentage	Extreme (lbs/in)	Percentage
1V	32	42.727	134%	21.564	67%
1R	32	25.782	81%	14.572	46%
2V	48	63.09	131%	30.323	63%
2R	48	55.74	116%	26.155	54%
3V	48	65.09	136%	35.49	74%
3R	48	52.63	110%	24.052	50%
4V	51	65.45	128%	36.714	72%
4R	51	46.745	92%	24.205	47%
5V	48	67.17	140%	30.824	64%
5R	48	48.373	101%	18.354	38%
6V	48	66.78	139%	30.949	64%
6R	48	44.654	93%	18.493	39%
7V	51	73	143%	29.698	58%
7R	51	49.086	96%	15.338	30%

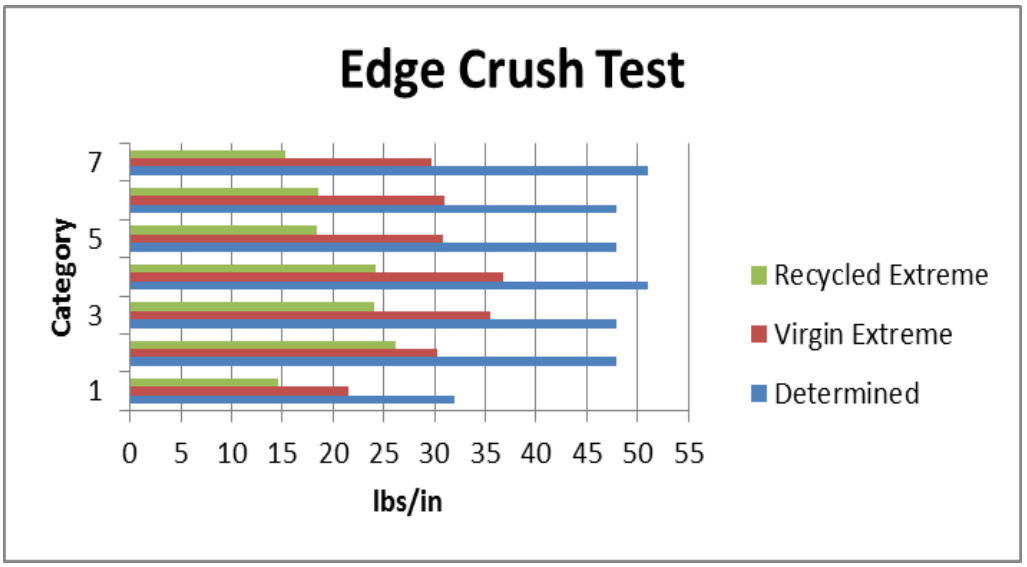

Figure 5: *Results for ECT*

At standard conditions, both virgin and recycled Cardboard matched or exceeded the determined ECT. At extreme conditions, both are reduced below the industrial listings; however, the recycled samples were much more significantly reduced. As seen in Figure 5, the percentages for recycled cardboard are consistently below 50% of the determined ECT while the virgin samples were closer to 65%.

3.2. Burst Test

Table 2 shows the average results for the samples at each condition. The percent change shows the drop in strength between standard and extreme conditions. Figure 6 shows a comparison of the virgin and recycled results at standard and extreme conditions.

Table 2: *Results for Burst Test*

Sample	Standard (psi)	Extreme (psi)	% Change
1V	303.2	205	32.388%
1R	158.4	112	29.293%
2V	439.2	264	39.891%
2R	188.4	150	20.382%
3V	445	238	46.517%
3R	190	148	22.105%
4V	388	330	14.948%
4R	211.8	162	23.513%
5V	443.4	298	32.792%
5R	196.6	140	28.789%
6V	373	278	25.469%
6R	191.2	146	23.640%
7V	458.4	342	25.393%
7R	165	140	15.152%

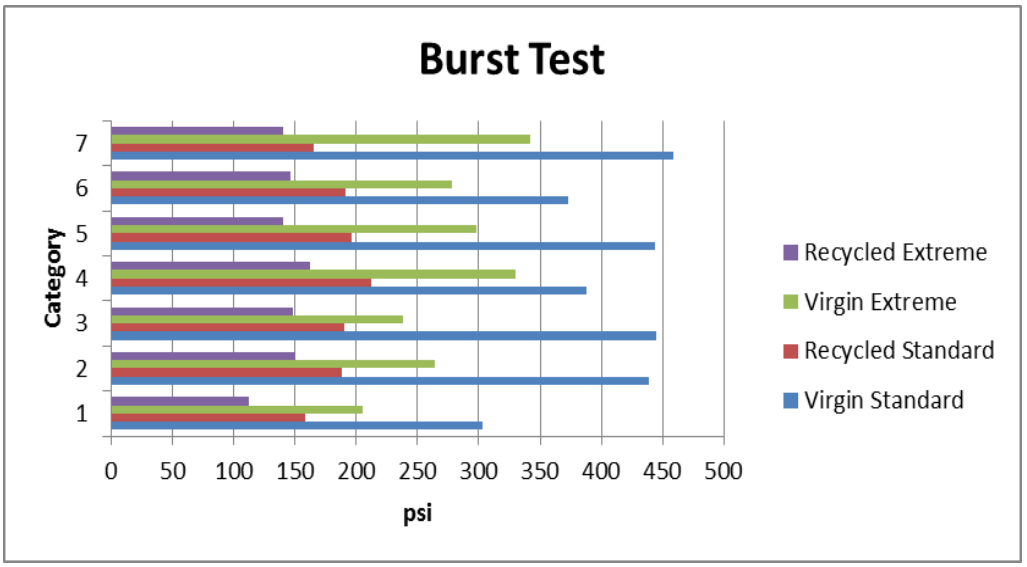

Figure 6: *Results for Burst Test*

At both conditions, virgin material is considerably stronger than its recycled counterpart. Due to its high rupture points as seen in Table 2, virgin cardboard showed a larger percent drop than recycled cardboard. Even with the higher percentage drop, the virgin cardboard at extreme conditions is stronger than recycled cardboard at standard conditions as seen in Figure 6.

3.3. Compression Test

Table 3 shows the average results for the samples at each condition. The percent change shows the drop in strength between standard and extreme conditions. Figure 7 shows a comparison of the virgin and recycled results at standard and extreme conditions.

Table 3: *Results for Compression Test*

Sample	Force (lbs)			Deflection (in)		
	Standard	Extreme	% Change	Standard	Extreme	% Change
1V	906.5	347	61.721%	0.6785	0.375	44.805%
1R	499.5	142	71.572%	0.5005	0.136	72.927%
2V	1622	789	51.356%	1.089	0.843	22.590%
2R	1038	303.5	70.761%	0.2365	0.197	16.913%
3V	1463.5	610.33	58.296%	0.7685	0.622	19.020%
3R	1088.5	358	67.111%	0.297	0.187	37.149%
4V	1521	556.5	63.412%	0.889	0.497	44.151%
4R	798	278.5	65.100%	0.8215	0.615	25.137%
5V	1773	760.5	57.107%	0.707	0.382	46.040%
5R	1208.5	381.5	68.432%	0.382	0.200	47.775%

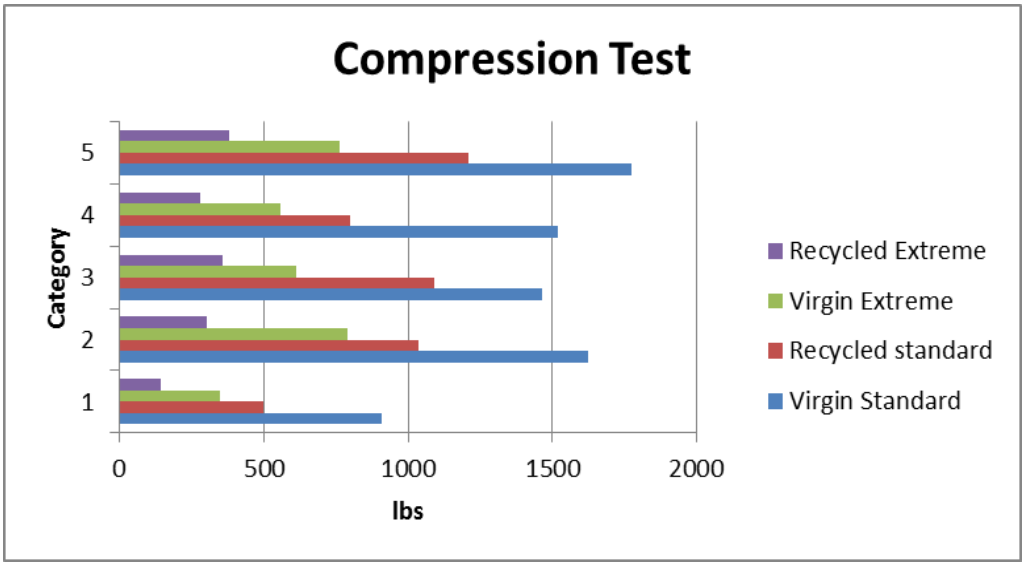

Figure 7: *Results for Compression Test*

In Figure 7, the virgin boxes are stronger at both conditions. Additionally, the virgin boxes show a lower percentage change as seen in Table 3 for each category. This shows the humidity had more of an effect on the recycled boxes.

4. Conclusion

Virgin cardboard tested stronger than recycled cardboard in every test, despite identical industrial strength listings. In extreme conditions, the difference between recycled and virgin cardboard increases. If a company is striving towards sustainability, one option would be to use higher rated recycled cardboard material in place of virgin material.

Acknowledgement

This paper was previously published in the *Proceedings of the MAESC 2012 Conference* (May 2012) as part of the paper entitled “Packaging Analysis.” Use with permission from Christian Brothers University.

References

[1] TAPPI T839 om-08, 2008: Edgewise Compressive Strength of Corrugated Fiberboard using the Clamp Method, Peachtree Corners, GA.

[2] TAPPI T807 om-11, 2011: Bursting Strength of Linerboard, Peachtree Corners, GA.

[3] TAPPI T804 om-06, 2006: Compression Test of Fiberboard Shipping Containers, Peachtree Corners, GA.