

Testing the Suitability of the Waste Packaging Cardboards for External Environmental Conditions to Reuse as Animal Shelter

Emine Erikli^{1*}

¹ Almila Mobilya AŞ, Orcid ID: <https://orcid.org/0000-0002-9760-5094>

* Correspondence: erikliemine1998@gmail.com.tr

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Abstract

Cardboard is known as a cost-effective and most common material for packing products to keep intact during shipping. Consequently, global paper and board consumption reached a total of 408 million tons in 2021 and is expected to reach 476 million tons in 2032. Due to the large size of the furniture in general, the excessive amount of cardboard required for packaging creates a big problem as the cardboard loses its function after shipment and delivery. Thus, the idea was born of reusing cardboard boxes used in product packaging as shelters for street animals.

In the present study, the resistance against outdoor conditions of the waste packaging cardboards which considered to used as stray animal shelter were measured and analyzed with BCT, ECT, and COBB 60 tests. As a result, it has been determined that the stray animal shelters that made of waste packaging cardboard are sufficiently resistant to external environmental conditions.

Keywords: Waste packaging cardboard, reuse, sustainability, durability tests

1. Introduction

Consumers want the products they buy from the internet or the store to reach them without any damage. Based on this, manufacturers pay attention to the packaging of the product they will deliver to the users. The material to be used for packaging should keep the product intact and protected. Considering factors such as usefulness, light weight, cost-effectiveness and recyclability, the most preferred material for this purpose is cardboard. Although cardboard is used in packaging in many sectors, if it is not recycled after losing its function, it directly or indirectly causes environmental pollution and leads to an elevation in carbon emission. Cardboard is known to be a cost-effective and most common material as recyclable and sustainable [1,2]. In this respect, actions related to

recycling in the paper and cardboard sector will contribute to the prevention of climate change and reducing the carbon footprint [3].

According to a market research, global paper and board consumption reached a total of 408 million tons in 2021. Consumption is expected to increase over the next ten years, reaching 476 million tons in 2032. Packaging accounts for the largest share in global paper and cardboard production [4]. According to a study, it was determined that only 70-75% of the 100 billion cardboard boxes produced in the USA every year are taken for recycling [5]. In most developing countries, substantial amounts of cardboard end up in landfills, thus leading to a serious environmental problem [6]. Due to increasing global warming and depletion of resources, more importance should be given to recycling and efficient use of resources.

Besides recycling, the determination of reuse methods for materials that have completed their function has also come to the fore in recent years.

The way to develop a sustainable economic model is through the reuse of materials that complete their function as an economic input [7]. For this purpose, there are many different applications to ensure the sustainability of waste packaging cardboard through reuse [8]. Waste cardboard has been found to be quite easy and safe to use outdoors, as well as having excellent thermal properties [1]. Therefore, one of the notable reuse areas is to create shelter for stray animals. In addition, the shelters made of cardboard can be easily moved to a different location when needed, due to their light weight. The point to be considered here is it should be resistant to adverse weather conditions and damage. In this way, it contributes to the prevention of disease and hypothermia risk by protecting stray animals against harsh weather conditions.

In this study, certain tests will be carried out in order to simulate the use of waste packaging cartons to meet the shelter needs of stray animals. First of all, the pressure resistance of the waste cardboard to be used in the study will be investigated by box crush test (BCT) and edge crush test (ECT). The maximum resistance of the waste cardboard will be determined in accordance with the received data. The strength of the cardboard will be determined by BCT and the deformation behavior will be observed. In the BCT, the sample will be placed in the carton compression machine and force will be applied until the box collapses. This test method being used as a standard to evaluate how long the cardboard box will last during the shipment of the packaged product. In our study, it will help in to predict the durability of the cardboard shelter prototype. The ECT was performed to have information about the resistance of cardboard material to maximum pressure and stacking strength from corners when it rests on its edge. Additionally, COBB-60 test was carried out to determine the water absorbency of the waste cardboard material.

Cardboard is defined as a lightweight and tough material with a significant level of impact resistance [8]. Wood fiber, which is the raw material of cardboard, supports the structure and increases its strength and flexibility. The data obtained from research on this subject helps to prove this opinion in general. In a study, the structures that Japanese architect Shigeru Ban built by recycling cardboard show that they have enough strength and durability to create a cardboard living space [9]. However, cardboard material tends to deform under load and if a long-term structure is to be built, the final durability of this structure should be analyzed [3].

2. Materials and Methods

2.1.Characteristics of Cardboard

In present study, waste cardboard sample that contains BC wave outer paper kraft was obtained from Parteks Paper Industry Inc. The standard tests on the waste cardboard material were carried out in the Parteks Paper Industry Inc. Laboratories. The cardboard material to be used in this study is produced from oriented wood fibers. Thus, its hardness and strength properties are anisotropic. In general, the fiber orientation of the material is symmetrical, and its stiffness properties are considered orthotropic [10].

2.2.Thickness Measurement of the Sample Material

To determine the thickness of the waste cardboard sample, ISO 534 standard test was carried out, and the results were evaluated [11]. The samples were kept in ambient conditions of 23°C temperature and 50% relative humidity for 4 hours, and then the weight measurements were carried out according to the protocol.

2.3.Cardboard Strength Test

2.3.1. BCT (Box Crush Test)

The directional strength value on the cardboard box was tested by BCT method. The test was carried out at 23°C and 50% relative humidity with an LCD screen mounted Devotrans test device. The test gives information about the strength of the waste cardboard box. According to the test results to be taken in this context, manufacturers can make their products stronger and higher in quality. In this study, the values obtained will give information about the deformations that may occur by a physical impact or long-term use of the material to be used as a stray animal shelter. To determine the strength, gradually increasing force was applied to the sample material that placed

between two steel plates and the results were evaluated. The value taken at the spot the box collapsed shows the result of the BCT test.

2.3.2. ECT (Edge Crush Test)

The Edge Crush Test shows the maximum pressure and stacking strength that the cardboard material can withstand when it rests on its edge. This test is the only valid test method for recycled cardboard materials [kaynak]. The compression force to be applied within the scope of the test is applied perpendicular to the direction of the grooves. It is defined as the reciprocal of the applied force per unit width.

The ECT test was performed with a computer controlled Devotrans test device in accordance with the Standards. After the sample was cut properly, it was placed in the hollow part on the bottom plate of the device. A circular saw was used by providing the right angles in the cutting process of the sample. Gradually increased force was applied in order to measure the edge strength with the circular plate located on the upper plate and the results were obtained.

2.3.3. COBB 60 Test

The COBB test is a method that gives information about the water absorbency of cardboard or paper. In this test, the cardboard material was first cut in the form of a disc and measured on a precision balance. The result obtained from the balance was accepted as the starting weight. Then, 100 ml of water was added to the cylinder chamber of the test device and the sample was placed in the chamber so that the surface to be tested contacted the water. The brighter and printed part was chosen as the test surface. The lid was placed on the sample inside the chamber and the test setup was turned upside down. After the sample was kept in this condition for 50 seconds, the mechanism was brought to its original position. Then, the sample was taken from the test device and placed between two blotter papers, with the surface in contact with water facing down. When the excess water was removed the sample was weighed again on a precision scale. The result from the precision balance was recorded for comparison with the first result.

3. Results

3.1. Sample Material Thickness

In the measurements made on the thickness of the samples by the ISO 534 standard protocol, precise results could not be obtained due to the fibrous structure of the paper.

3.2.BCT

Compressive strength is the capacity of a material to withstand loads that tend to reduce its size. The box crush test for the waste cardboard box is used to measure the compression resistance, deformation and stacking ability.

The results of the BCT test depend on different parameters:

- Production of the box
- The size of the box
- Humidity in the box and the environment
- Use of the box before testing
- Presence of any print
- Situation of groove in corrugated cardboard
- Raw material content of the box



Figure 1: Application of the BCT test to the empty cardboard box

In the box compression test, dimensions of the sample were chosen to be $330 \times 265 \times 350 \text{mm}^3$. Then, the sample in the form of an animal shelter was placed between two pressure plates and compressed between the two plates at a constant speed of 12.5 mm/min until the maximum load was reached (Figure 1). When significant deformation on the box was detected, the top plate was returned to its initial position. The result was

observed on the computer screen of the Devotrans test device and was recorded. The maximum force that the box can withstand until it deforms was determined as 4788 newtons (Figure 2).



Figure 2: The BCT results screen

3.3.ECT

The ECT test is related to the stacking capacity of the cardboard box. It is also a test that gives information about the quality of the corrugated cardboard [12]. The main purpose of the ECT test applied in this study is to give information about the in-plane compressive strength of the cardboard. The sample material was cut with a cross-sectional area of 500 mm² and a length of 25 mm. Care has been taken to ensure that there are no knurled or perforated handles that could deviate the measurement in the boxes used while preparing the sample. Then, the prepared sample was placed in vertical position and adjusted to apply a top-down force on the test device (Figure 3). Ambient conditions are set at a temperature of 24°C and a relative humidity of 80%. During the test, a force of 12.5 mm/min was applied to the sample. The maximum force value that the sample could withstand before breaking was recorded (Figure 4). The maximum force applied to achieve this value in relation to the strength of the cardboard is related to the length of the sample, as described before [13].



Figure 3: ECT perform on waste cardboard material.

The test device has a bottom plate that provides fixation and an upper plate that applies the force. The cavity on the bottom plate where the cardboard sample is placed ensures that the force to be applied is in contact with the surface in the most efficient way. The behavior of the cardboard depending on the applied force is displayed as the average force-displacement curve on the graph in the related program (Figure 7).



Figure 4: ECT results screen



Figure 5: ECT test graphic

Stress-strain data was obtained for the characterization of the behavior of the specimen under stress. The maximum applied force on the cardboard specimen was 809 N, resulting in a maximum elongation of 1340 mm, and the corresponding maximum stress value was determined to be 1.618 N/mm². The compression force on the specimen was found to be 713 N, with a compression length of 4 mm. The cardboard specimen experienced a deformation of 16%. The yield strength is 0.004 N/mm².

3.4.COBB-60

As part of the test conducted on waste packaging cardboard, first, the cover of the testing device is opened to place the specimen on it in the form of a disk. By marking around the cover placed on the paper with a pencil, a circular line is drawn, and the shape is obtained by cutting along the marked line with scissors. The resulting circular paper is measured on a precision balance with an accuracy of 0.01 g. The measurement obtained from the balance is considered as the initial weight. Then, 100 ml of water is added to the cylindrical chamber of the testing device. The specimen paper is placed in the chamber in a way that the surface to be tested comes into contact with the water. At this point, the test surface is generally chosen to be the more glossy and printed side. A cover is placed on top of the paper inside the chamber and tightened using a knob to make it secure. Then, by means of a lever located on the side of the testing device, the apparatus is turned upside down. The specimen is kept in this position for 50 seconds, after which the apparatus is returned to its original position. The specimen taken from the testing device is placed between two pieces of blotting paper, with the surface that was in contact with water facing downwards. To remove excess water from the paper, it is rolled twice on a 10 kg paper roll. The paper, from which excess water has been removed, is then weighed again on a precision balance, and the result is recorded for comparison with the initial measurement. Finally, the same procedures are applied to the other side of the specimen

In the initial measurement conducted when the waste packaging cardboard specimen was dry, the weight of the paper was approximately 2090 grams. After performing the COBB-60 test procedures, this value was calculated to be 2443 grams. The COBB value of the specimen was determined by multiplying the difference between the measurements by 100. As a result, the COBB value of the sample was found to be approximately 35.3 g/m².

4. Conclusions

Cardboard boxes are widely preferred in various industries, such as shipping, transportation, etc., due to their lightweight and cost-effectiveness. The use of packaging cardboard aims to protect and preserve products during transportation in the best possible way.

The starting point of our study is to contribute to the environment and sustainability by repurposing cardboard used in furniture packaging into animal shelters after losing its functionality. In this project for stray animals, the durability of the cardboard is essential considering outdoor conditions. Therefore, within the scope of our study, three different tests were conducted to assess the strength of waste packaging cardboard material.

Firstly, the maximum force that the empty cardboard box can withstand was investigated through the BCT (Box Compression Test) and ECT (Edge Crush Test) In BCT test result, the maximum force that the waste cardboard box can resist was detected as 4788 newtons. In this case, data indicating the durability of the animal shelter that will be made available for stray animals has been obtained, showing its resistance to impacts.

In our study, the force-displacement graph obtained from the ECT test shows a lower initial stiffness region potentially caused by the initial compression and crushing of the upper and lower slipping surfaces. According to the results obtained from a study where ECT tests were performed on cardboard with different masses, the material's strength was reported to vary depending on its mass [source]. Additionally, another study conducted using different types of paper materials in ECT tests revealed that different results were obtained depending on the material type. According to the results obtained in the study conducted by McKee and other authors, there is a correlation between ECT (Edge Crush Test) and BCT (Box Compression Test), which provides a correlation between the compression load applied to a cardboard and the load at which buckling occurs. Primarily, compression tests conducted on cardboard boxes have shown that after the structure of the cardboard is deformed, most of the compressive strength concentrates near the edges before deformation occurs. When evaluated together with previous research and the results obtained from our study, it has been determined that the mechanical strength of the waste packaging cardboard material, which is intended to be transformed into a shelter for stray animals, is sufficiently suitable for providing shelter to street animals.

Materials such as paper and cardboard have the capacity to retain moisture, so it is essential for their own moisture content to be balanced with the humidity level of the

environment. The equilibrium moisture content of these materials is related to the relative humidity of the surrounding environment. To achieve this balance, the relative humidity of the environment should be kept around 55%. If the material traps moisture from the environment, the bonds between the cellulose fibers in its structure weaken, and the mechanical properties of the material are significantly affected as a result.[14] COBB test is applied to obtain information about the water absorbency of cardboard or paper. The COBB value corresponds to the mass of water absorbed per unit area under specific conditions. If the COBB value is found to be high in the test results, it indicates that the material has a high water retention capacity. In our study, the COBB 60 test was applied to measure the material's resistance to water and moisture and evaluate how its service life is affected when it comes into contact with water. The data collected shows that the strength of the cardboard is related to its quality and weight. Based on this data, it has been determined that the animal shelter created from cardboard can withstand harsh weather conditions for an extended period. Additionally, it is believed that the strength of the material will further increase if the interior is lined with styrofoam.

Based on the data obtained from our study and the evaluation of existing literature, it has been concluded that waste packaging cardboard with higher weight and quality exhibits greater resistance to outdoor conditions and has a longer lifespan.

References

- [1] Vaccari, M. Environmental Assessment of Cardboard. Master's Thesis, Oxford Brookes University, Oxford, UK, 2008.
- [2] Gibbon, H.; Foerster, F. Structural Engineering and Design in Paper and Cardboard-Approaches and Projects. *Cardboard Archit.* 2008, 7, 95.
- [3] Venkatesan, S.; Afroz, M.; Navaratnam, S.; Gravina, R. Circular-Economy-Based Approach to Utilizing Cardboard in Sustainable Building Construction. *Buildings* 2023, 13, 181. <https://doi.org/10.3390/buildings13010181>
- [4] <https://www.statista.com/statistics/1089078/demand-paper-globally-until-2030/> (Date of access: 14.06.2023)
- [5] Recycling.com. Why Cardboard Recycling Is Crucial to Protect the Earth. Available online: <https://www.ocrecycling.com/cardboard-recycling-crucial> (Date of access: 22 December 2022).
- [6] Ahmad, A.; Rahman, M.; Khalil, A.; Adil, M.; Khan, M.; Efficient Use of Waste Cardboard in Construction Material, *Peşaver*, 2500, 2018
- [7] Lorang, E.; Lobianco, A.; Delacote, P. Increasing Paper and Cardboard Recycling: Impacts on the Forest Sector and Carbon Emissions, 2022, <https://doi.org/10.1007/s10666-022-09850-5>

- [8] Cripps, A. Cardboard as a construction material: A case study. *Build. Res. Inf.* 2004, 32, 207–219. [CrossRef]
- [9] Shigerubanarchitects.com, 2013, 坂茂建築設計 | Shigeru Ban Architects. [online] Available at: <http://www.shigerubanarchitects.com/> [Accessed: 20 Nov 2013].
- [10] Fadji, T.; Berry, T.; Coetzee, C.J.; Opara, L.U.; Investigating the Mechanical Properties of Paperboard Packaging Material for Handling Fresh Produce Under Different Environmental Conditions: Experimental Analysis and Finite Element Modelling, 2017
- [11] ISO 534, “Paper and board – Determination of thickness, density and Journal of Applied Packaging Research 34 specific volume,” 2011.
- [12] Gok, B.; Akpınar, D.; Investigation of Strength and Migration of Corrugated Cardboard Boxes, 2020, 7 (3) 163-168, DOI: 10.17350/HJSE19030000185
- [13] R.C. McKee, J.W. Gander and J.R. Wachuta, “Compression strength formula for corrugated boxes,” *Paperboard Packaging*, vol. 48, (8) pp. 149–159, 1963.
- [14] P.B. Pathare and U.L. Opara, “Structural design of corrugated boxes for horticultural produce: A review,” *Biosystems Engineering*, vol. 125, pp. 128–140, 2014.