Effect of resin content, press time and overlaying on physical and mechanical properties of carton board made from recycled beverage carton and MUF resin

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Abstract: The purpose of this study was to produce "carton board" with the density of 1 g/cm^3 from Recycled Beverage carton (tetra Pak containers) by mixing melamine-Urea formaldehyde resin (MUF) at 3 levels 0%, 9% and 12% with two different pressing times, 10 min and 12 min. Half of the boards were created using walnut veneer layers. Physical and mechanical properties of boards including water absorption (WA), thickness swelling (TS), Modulus of Rupture (MOR), Modulus of Elasticity (MOE), internal bonding strength (IB) and screw With Drawl Resistance were evaluated in all samples according to the EN standard. To characterize effects of any ingredient on physical and mechanical properties, the data were analyzed as a factorial design by SPSS software at 99 confidence level. The results presented that different amounts of press time and resin content did not have particular effect on mechanical properties of the "carton Board", but walnut veneer significantly increased the mechanical properties and reduced the physical properties in all samples. Although samples created without using any resin had better physical properties. The results stated that the Carton Board can be manufactured by mixing Recycled Beverage Carton (tetra Pak containers) with MUF resin or even without any resin. The resulting composite has an acceptable physical strength according to EN standard and walnut veneer can increase mechanical resistance to a higher amount above the standard deal.

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Keywords: Recycled Beverage carton (tetra Pak containers), Carton board, Melamine-Urea Formaldehyde resin (MUF), Walnut Veneer

Introduction

In the late 1970's, recycling was introduced as an important environmental issue, so that in Netherlands, more than 300 companies declared to voluntarily cooperate with the government for recycling issues (Maryse et al, 2005). These days, due to improvements in wood-related industries, in addition to agricultural waste, many other materials such as waste paper or other materials such as gypsum, cement and recycled plastic can be used to produce wood composites suitable for environmental cleanup of non-recyclable waste. In recent years a large amount of waste left from the beverage cartons (Tetra Pak) are found in urban wastes. As in 2006, approximately 313,000 tons of these materials were found in Europe among 12 billion tons of solid wastes (Ayrilmis et al, 2008). This high volume of waste in European Urban heavily polluted the environment (Murathan & Gurum Balbas, 2006). Tetra Pak is now the largest beverage packaging company in the world and has about 80% of world market. Research has shown that in 2007, over 137 billion packets by Tetra Pak products were distributed in different parts of the world (Korkmaz et al, 2009). In Iran, the demand for these cartons is increasing daily and given that these materials are not recyclable, they can contaminate the environment. These beverage cartons, depending on the usage may differ in shapes (Figure 1). The most important reason that the industries cannot recycle these cartoons is the variety of their components including materials such as light density Polyethylene75% (LDPE), aluminum foil 5% and Kraft Paper 20% (Ayrilmis et al, 2008). In Iran these cartons are excluded from the recycling with other non-recyclable waste materials. Nowadays, in developed countries for separating different layers from each other they use thermal pyrolysis (Korkmaz et al, 2009) that due to high temperatures it can reduce some physical and mechanical quality of Kraft paper. These beverage cartons are usually recycled in Europe to be used as a material in the manufacture of

Figure 1: Types of beverage cartons produced by Tetra Pak Company (Tetra Pak©. 2008).

products such as shopping bags, core for paper & Paper board rolls and etc. (Ayrilmis et al, 2008). In these processes separating of three elements (LDPE, Kraft Paper and Aluminum Foil) is ignored and eventually the cartons will be used in products with less important value. Several studies is done in Iran in order to produce some wood composites such as particleboard and Fiber Board using cellulose waste and OCC, but no scientific research is available on the use of Tetra Pak in manufacturing of composites. Rasam (2005) showed that the use of OCC in the manufacturing of fiberboard improved the mechanical properties, but has increased water absorption and thickness swelling. Doosthoseini et al (2007) reported that increasing OCC Fiber compared to spruce wood Fibers from 40 % to 60 %, will decrease bending strength and shear strength significantly in the Particle Board; also Water Absorption and Thickness swelling were significantly increased after 2 and 24 hours immersion in water. Eshraghi et al (2011) Showed that using OCC with percentages higher than 50 compared to Poplar Wood Particle reduced the physical and mechanical strength in Particle board. Doosthoseini and Abdolzade (2009) stated that the use of wood fibers in the particle board surface layers will increase the bending strength compared to using OCC in them. Doosthoseini and Abdolzade (2010) indicated that mixing wood and OCC fibers in the surface layers of Particle Board improve surface quality and reduce the hardness of the boards. Murathan & Gurum Balbas (2006) produced composite Boards by mixing recycled Tetra Pak beverage cartons, polyvinyl acetate (PVA) and Urea Formaldehyde (UF) Resins. The Physical Properties of boards made with urea formaldehyde were better. It also showed that MOR and MOE will increase if the resin amount is increased from 8% to 12%. It also showed that the low density of boards (o.5 g/cm^3) results in poor physical and mechanical strengths and the boards were delaminated in water. Ayrilmis et al (2008) produced panels using Recycled Tetra Pak cartons, and then overlaid them using beech layers and 4 types of synthetic resins including urea formaldehyde, phenol formaldehyde, Melamine formaldehyde and polyurethane.

The results represented that using different resins doesn’t have significant effect on the density of samples, but using polyurethane as an overlay gave away far better properties.

Urea Formaldehyde(UF), Phenol Formaldehyde(PF) and melamine-urea Formaldehyde(MUF) resins have common use for producing wood composites such as particleboard and MDF (Doosthoseini, 2008). Therefore in this research in addition to investigating possibility of self-bonding LDPE in the hot pressing (for Control samples without any Resin), treatment samples were produced using melamine-Urea Formaldehyde (MUF).

Materials and Methods

In this research "carton board" with density of 1 g/cm^3 was produced from Recycled Beverage carton (tetra Pak containers) by mixing the melamine-Urea formaldehyde resin (MUF) at 3 levels 0%, 9% and 12% and two different pressing times, 10 min and 12 min, so that the effects of using or not using resins could be investigated. Recycled beverage cartons used in this study, were supplied as waste from the Iran National Milk Company (Golestan Pegah Co). Melamine-urea formaldehyde resin was prepared using a mixture of 50% each: melamine formaldehyde and urea formaldehyde from Sari Adhesive Company. The prepared Melamine-Urea Formaldehyde resin properties are shown in Table 1.

Table 1: some Properties of Melamine-Urea Formaldehyde resin (MUF) used in the study

Solid content (%)	Specific gravity (g/cm^3)	Viscosity (Cps)	PH(at 25^{o}c)	Gel Time (Sec)
60.5	1.27	42	8.6	49

Methods

Prepared Beverage Cartons Were sectioned (cut) to approximate dimensions of 5 × 5 cm with the handy cutter. Then put in the oven dry at 70 ° C for 24 h (for moisture conditioning), and due to treatment type, resin (9% or 12%) was added using the spray in a rotary blender. For control samples (without resin or 0% resin) blending stage was not performed, so that only LDPE would be used for bonding of carton boards at hot press. The boards were manufactured with dimensions 28 × 32 × 1 cm. Hot pressing Process was performed at temperature of 170 ° C, pressure of 25 Kg/cm^2 and the two different times, 10 and 12 minutes. The type of boards made in this research and their related codes are shown In Table 2. Overlaying process was done using walnut veneer with 1 mm thickness and 0.6 g/cm^3 density. Also 100 g/m^2 Urea Formaldehyde resin was utilized at heat press machine with pressure 25 g/cm^2, temperature 120 ° C in 8 minutes. Physical and mechanical properties were evaluated in all samples according to the EN standard. MOR and MOE of samples were based on the standard (EN 310, 1993) and thickness swelling (TS) and water absorption (WA) after immersions in water (2 and 24 hours) were based on the standard (EN 317, 1993). The internal bonding strength (IB) was performed due to (EN 319, 1993) and the Screw with drawl Resistance was studied due to (EN 320, 1993). The driven data were analyzed as a factorial design by SPSS software and independent and interactive effects of variables on the physical characteristics and mechanical properties were determined using analysis of variance at 99% confidence level.

Table 2: manufactured boards types and their related codes

Board type		Press Time(Minute)	Number of iterations	Resin content (%)
Overlaid with walnut veneer	without veneer			
A11	A1	10	4	12
A21	A2	12	4	
B11	B1	10	4	9
B21	B2	12	4	
C11	C1	10	4	0
C21	C2	12	4	
total -	-	-	48	-

Results

Average amount of physical and mechanical properties of carton board manufactured in this study are listed in Table 3 and the analysis of variances of various factors effects on mechanical and physical properties of samples are shown in Table 4 and Table 5 respectively.

Table 3: Average physical and mechanical strengths of Carton Board made in Study

Properties		Board type											
		C21	C11	B21	B11	A21	A11	C2	C1	B2	B1	A2	A1
MOR(Mpa)		33.1	28.6	28.21	32.74	30.42	27.77	19	18.4	20.1	18.6	21.05	20.28
MOE(Mpa)		5471	4808	5030	5648	4610	4414	2507	2450	2122	2421	2044	2494
Screw with drawl resistance(N)		1199	1427	1240	1566	1284	1407	970	1004	1087	868	832	1007
IB(Mpa)		0.11	0.12	0.097	0.108	0.102	0.108	0.1	0.124	0.103	0.117	0.118	0.118
WA(%)	2hours	3.12	3.02	3.59	4.01	3.88	3.83	2.13	2.1	2.74	2.72	2.56	2.54
	24hours	5.61	5.12	6.7	6.75	6.35	6.24	4.42	3.28	4.36	4.3	4	3.81
TS (%)	2hours	1.34	1.32	1.7	1.68	1.6	1.5	1.05	1.01	1.17	1.21	1.15	1.23
	24hours	1.71	1.87	2.62	2.4	3.45	2.48	1.74	1.5	1.93	2.4	2.1	1.86

Mechanical Properties

MOR & MOE

MOR and MOE are shown at Figure 2. As a result that was obtained, Overlaying boards with walnut veneer result in a significant increase of MOR and MOE in all boards; while other independent ingredient including resin content and press time as well as reciprocal ingredient did not have significant effect on these properties (Table 4).

Internal bonding Strength (IB)

The Internal bonding strength (IB) is shown at Figure 3. According to table 4, none of the independent ingredient including Board type (overlaid or without veneer), resin content and press time and also reciprocal factors did not have significant effect on internal bonding strength of the Carton Board.

Table4: Analysis of variance of Mechanical properties in tested boards				
F Value				
Screw with drawl resistance	IB	MOE	MOR	Source of variation
180.768*	0.853 ns	140.232*	47.34*	Board type(Overlaid or without veneer)(A)
0.126 ns	2.105 ns	4.584 ns	0.036 ns	Resin Content(B)
3.205 ns	0.921 ns	0.432 ns	0.076 ns	Press Time(C)
0.001 ns	1.565 ns	0.029 ns	0.180 ns	A×B
6.679ns	2.146ns	0.087 ns	1.148 ns	A×C
4.598 ns	2.269 ns	0.110 ns	0.807 ns	B×C
0.002 ns	2.195 ns	2.821 ns	5.305 ns	A×B×C
*: Significant at 99% confidence level ns: Not significant at the 99 % confidence level				

Screw with Drawl Resistance

Screw with Drawl Resistance is shown at Figure 4. As a result, Overlaying boards with walnut veneer result in a significant increase of Screw with Drawl Resistance in all boards; while other independent ingredient including resin content and press time as well as reciprocal ingredient did not have significant effect on these properties (Table 4).

Table5: Analysis of variance of physical properties in tested boards				
F Value				
WATS(24Hours)	TS(2Hours)	WA(24Hours)	WA(2Hours)	Source of variation
128.556*	140.903*	132.247*	113.126*	Board type(Overlaid or without veneer)(A)
11.126*	8.384*	6.121*	8.526*	Resin Content(B)
2.853 ns	2.132 ns	1.229 ns	0.329 ns	Press Time(C)
0.526 ns	2.056 ns	1.922 ns	1.187 ns	A×B
0.562 ns	0.235 ns	0.004 ns	0.031 ns	A×C
0.403 ns	0.165 ns	0.046 ns	0.065 ns	B×C
0.020 ns	1.908ns	1.182 ns	1.021 ns	A×B×C
*: Significant at 99% confidence level ns: Not significant at the 99 % confidence level				

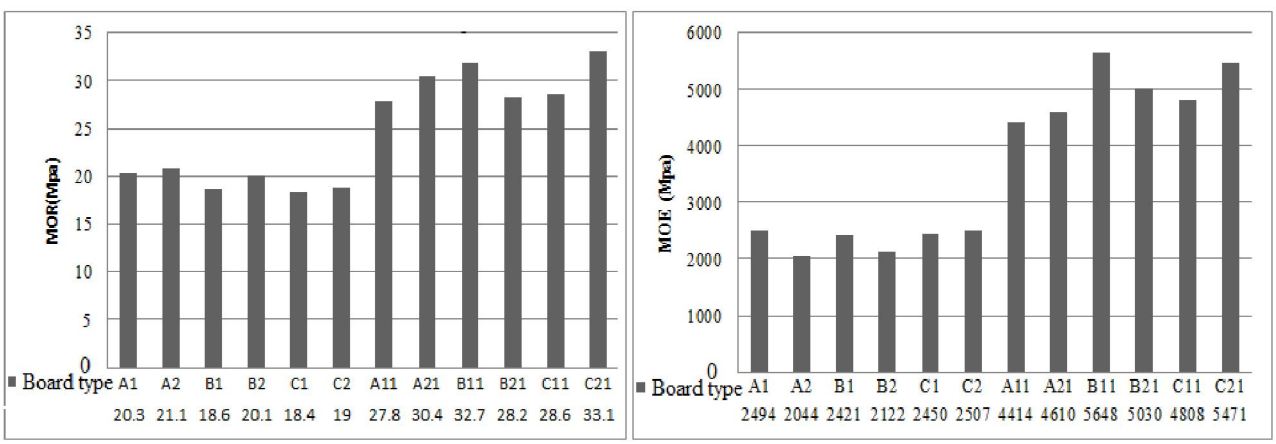

Figure 2: MOR and MOE of Carton Board

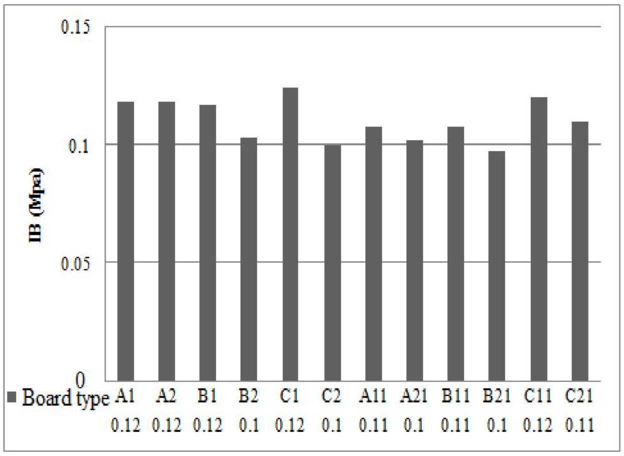

Figure3: Internal bonding strength of Carton Board

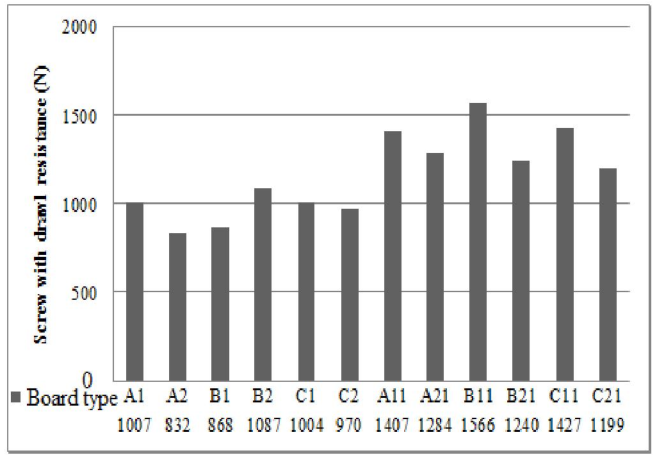

Figure4: Screw with Drawl Resistance of Carton Board

Physical Properties

Water absorption (WA) and thickness swelling (TS) after 2 & 24 hours immersion in water

Water absorption and thickness swelling after 2 & 24 hours immersion in water are shown at Figure 5 and 6 respectively. It is obviously clear that, overlaying boards with walnut veneer result in a significant increase of WA and TS in all boards; It also can be observed that resin content has significant effect on these properties, as Control samples have lower WA and TS than boards manufactured using MUF resin. While pressing time and reciprocal ingredient do not have significant effect on these properties (Table 5).

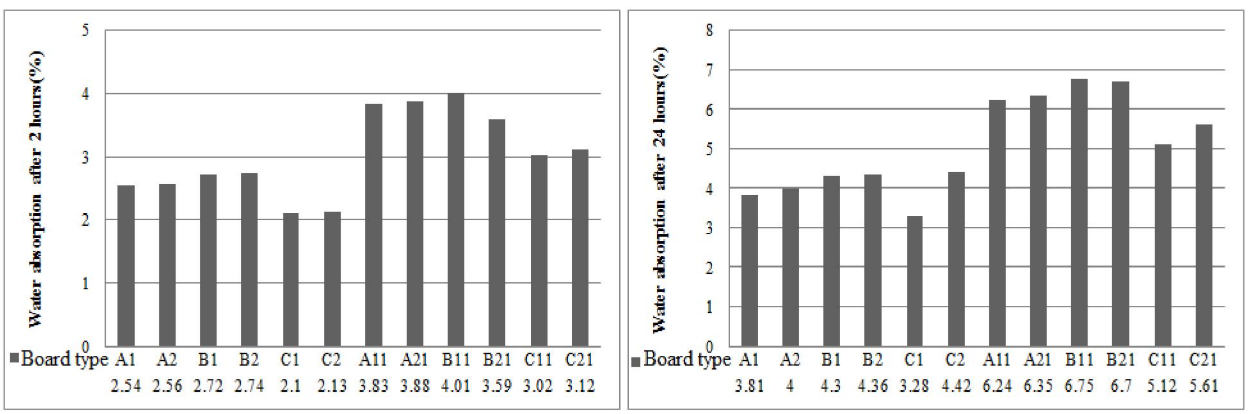

Figure 5: Water absorption after 2 & 24 hours immersion in water

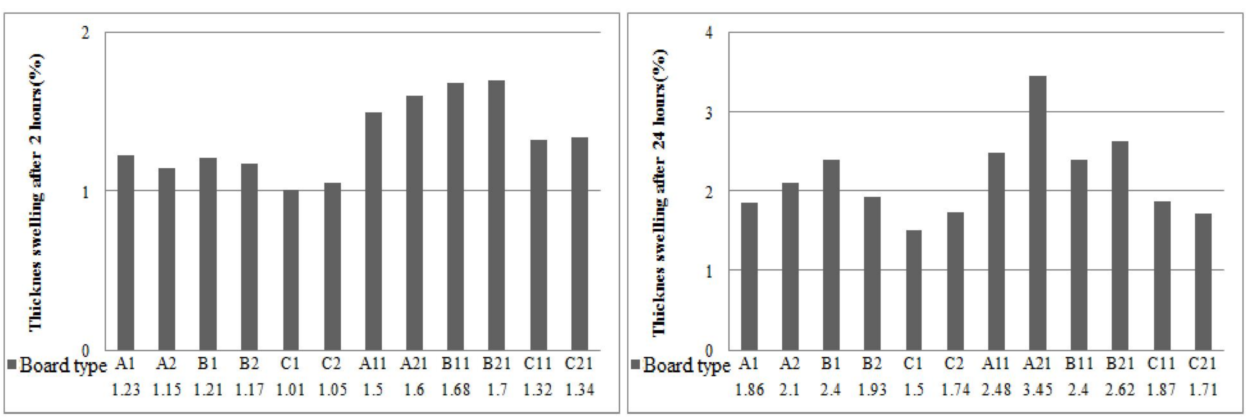

Figure 6: Thickness swelling after 2 & 24 hours immersion in water

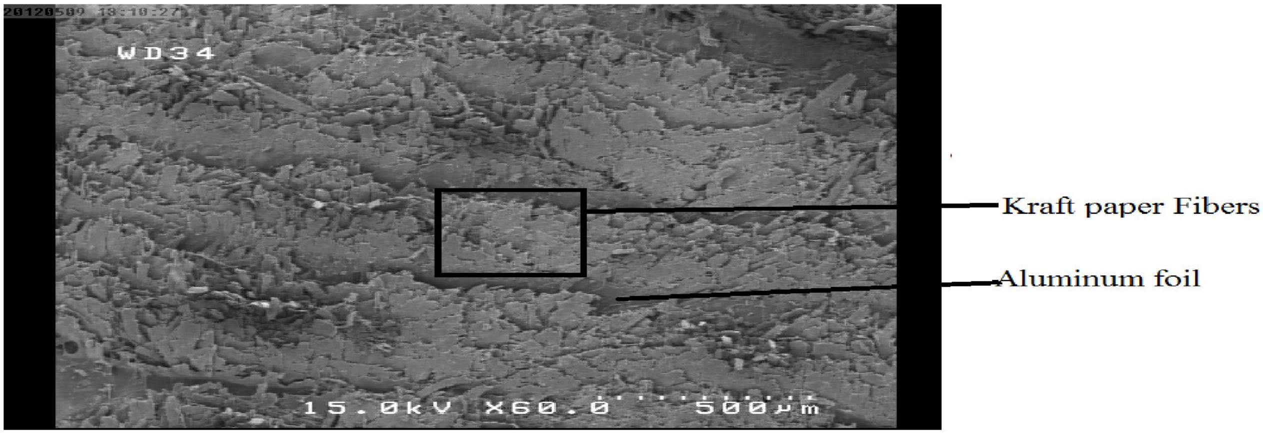

Figure 7: SEM image showing the cross section of the carton board made without resin

Table 7: Some of Carton Boards properties compared to MDF according to EN Standard.

Composite type	TS (%)	IB (Mpa)	Screw with Drawl (N) Resistance	MOE(Mpa)	MOR(Mpa)
MDF	10	0.5	500	2200	28
Carton Board(overlaid)	1.92	0.115	980.33	2717	19.4
Carton Board(without veneer)	2.97	0.115	1332	5171.5	30.7

1. Discussion and Conclusion

As the results showed, the mechanical properties of boards manufactured using MUF resin in different amounts (9% and 12%) didn't differ significantly from Control Samples without using any resin at 99% confidence level. But water absorption and thickness swelling after 2 and 24 hours of immersion in water for Control Samples were significantly lower than other samples using 9% &12% MUF resin. This can be due to low strength of polyamines (melamine-Urea Formaldehyde) against moisture compared to the linear polymer (polyethylene) (Doosthoseini, 2008). Probably Melamine-Urea formaldehyde has no desire to mix with non-polar polyethylene due to the polar structure. On the other hand impervious layers of beverage cartons prevent the resin to exit from boards and contribute to the porosity of the boards. All these factors can increase water absorption and thickness swelling of boards with melamine-Urea Formaldehyde resin compared to Control Samples. As it is clearly shown in Figure 7, the pressing temperature cause polyethylene to melt and distribute in the board matrix (Control Samples). Moreover in different parts of the board, aluminum foils can be seen that may be an important factor in reducing water absorption of carton board wrought with Kraft paper, LDPE and aluminum foil.

On the other hand, the layered structure of beverage cartons causes a reduction in internal bonding strength of all samples. The results showed that overlaying with walnut veneer significantly increased mechanical strengths of the carton board which also based on scientific theories and practical applications can possibly affect the bending properties too (MOR & MOE). To increase the bending strength of wood composites such as particle board, they should be overlaid with wood veneers (DoostHoseini, 2008). Overlaying causes a significant decrease in physical strength in all overlaid samples, and it may be due to higher water absorption and thickness swelling of wood veneers compared to beverage cartons (Ayrilmis et al, 2008). However, based on the results of this study it can be concluded that Carton Board can be made using Recycled Beverage Carton and melamine-Urea Formaldehyde in two different levels: 9% and 12%, and also without using any resin (Control Samples). LDPE can melt in hot pressing process and act like an adhesive in Carton Board. According to Table 3 it is shown that Carton Board has higher physical strength than the value set for some wood composites such as MDF considered in EN standard.

As Table 7 shows, MOR and IB for carton Board without veneer are less than standard deal for MDF. Probably by reducing the cut size of beverage carton from 5 cm to a smaller extent, the IB can be improved. In smaller cuts mat forming of the board can be homogenized and delamination of resulted

Board can be lowered so that delamination of the beverage carton will reduce. That can be the most important factor for reduction of IB in manufactured board. But as it is clear from Table 7, the physical and mechanical strength in overlaid boards, are more than the Standard deals. Properties of Carton board made in this research, compared to other wood composites such as particleboard and Fiber Board made by mixing OCC and wood particle showed that carton board has quite superior physical properties. This is because research has shown that the use of OCC compared to wood particles can cause an intense increase in thickness swelling, even higher than 30% (Eshraghi et al, 2011. Rasam, 2005 & Doosthosseini et al, 2007). Bending properties (MOR and MOE) of Carton board are better than boards made with mixtures of OCC and wood Particles. Average physical and mechanical properties obtained in this study are similar to obtained in another research about using recycled beverage carton for manufacturing card boards in Turkey (Ayrilmis et al, 2008). Generally it can be said that manufacturing Carton boards from Recycled Beverage Carton is more reasonable rather than recycling these materials from municipal wastes; while doing this also reduces pollution. Based on the Iran national standard (number 7416), the minimum deal of MOR for some wood composites, such as fiber board is 15 Mpa (153 Kgf/cm^3). It is clear that the MOR of the carton boards manufactured in this study is higher than the mentioned range. Also due to a very good physical strength, it can be said that the Carton Board can be used both in exterior and interior components such as walls, false ceilings, shelves, boxes, packaging and any other applications that does not require high mechanical strength, although overlaid boards may have acceptable Physical and Mechanical resistances.

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