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Research Article

THE EFFECT OF NUMBER OF WALLS WITH DIFFERENT THICKNESS ON THE PROPERTIES OF THE POLYCARBONATE PANELS

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ABSTRACT

Polycarbonate is a durable, strong, transparent new polymer material. It is used as building material or element because of its properties such as high strength, light transmittance, recycling, lightweight and vapor transmittance. Unlike most thermoplastics, polycarbonate undergo large plastic deformations cracking or breaking so it can be produced with different dimensions and shapes. Polycarbonate panels consist of different numbers of walls with different thickness. Generally, the properties of the polycarbonate panels are determined with all structures of the panels. However, the effect of the number of walls should be determined on the characteristic properties of the polycarbonate panels. Especially transparency and thermal transmittance should be effected by the number of walls. In this study, characteristic properties of the polycarbonate panels such as light transmittance, water vapor transmission, impact and bending strengths, should be tested with different numbers of walls or thickness. Finally, the characteristic properties of the polycarbonate panels are suitable when the number of walls and thickness are low.

Keywords: *Polycarbonate, impact, light transmittance, bending stiffness.*

1.INTRODUCTION

In the construction of naturally lit structures (e.g., green houses, pool enclosures, conservatories, stadiums, Sunrooms, and so forth), glass has been employed in many applications as transparent structural elements, such as, windows, facings, and roofs. However, polymer sheeting is replacing glass in many applications due to several notable benefits.

One benefit of polymer sheeting is that it exhibits excellent impact resistance compared to glass. This in turn reduces maintenance costs in applications wherein occasional break age caused by vandalism, hail, contraction/expansion, and so forth, is encountered. Another benefit of polymer sheeting is a significant reduction in weight compared to glass. This makes polymer sheeting easier to install than glass and reduces the load-bearing requirements of the structure on which they are installed. In addition to these benefits, one of the most significant advantages of polymer sheeting is that it provides improved isolative properties compared to glass. This characteristic significantly affects the overall market acceptance of polymer sheeting as consumers desire a structural element with improved efficiency to reduce heating and/or cooling costs (Maas *et al.*,2013).

The use of polycarbonate can enhance daylighting in architectural design at lower costs and, at the same time, significant energy savings in commercial and industrial applications could be achieved, thanks also to multiwall polycarbonate panels designed for improving thermal performance. Moreover, in these applications, visual connection to outdoors is not as important as the incoming light, which gives a more comfortable environment, and it should be avoided in some situations like industrial areas (Moretti *et al.*, 2013)

Polycarbonates (PC) are a group of thermoplastic polymers containing carbonate groups in their chemical structures. Polycarbonates used in engineering are strong, tough materials, and some grades are optically transparent. They are easily worked, molded, and thermoformed. Because of these properties, polycarbonates find many applications.

Polycarbonate is a durable material. Although it has high impact-resistance, it has low scratch-resistance. Therefore, a hard coating is applied to polycarbonate eyewear lenses and polycarbonate exterior automotive components. The characteristics of polycarbonate compare to those of polymethyl methacrylate (PMMA, acrylic), but polycarbonate is stronger and will hold up longer to extreme temperature. Polycarbonate is highly transparent to visible light, with better light transmission than many kinds of glass.

Over the past few decades, the demand for polycarbonate as a major engineering plastic has increased because they have attracted a significant attention for a range of applications in several industrial fields. Polycarbonate is an amorphous, clear polymer that exhibits three key characteristic properties: toughness, transparency, self-extinguishing characteristic, and heat resistance (Pham *et al*,1997; Madkour,1999; Pham *et al*.,2000; Schnell,1964)

Unlike most thermoplastics, polycarbonate can undergo large plastic deformations without cracking or breaking. As a result, it can be processed and formed at room temperature using sheet metal techniques, such as bending on a brake. Even for sharp angle bends with a tight radius, heating may not be necessary. This makes it valuable in prototyping applications where transparent or electrically non-conductive parts are needed, which cannot be made from sheet metal. PMMA/Acrylic, which is similar in appearance to polycarbonate, is brittle and cannot be bent at room temperature.

Polycarbonate is a high-performing thermoplastic that is widely used in building and construction products, from windows and skylights to wall panels and roof domes to exterior elements for LED lighting. Polycarbonate has a number of qualities that make it useful in these applications – it is lightweight and durable, with high optical clarity, high-impact and high-heat resistance, as well as excellent flammability resistance.

Below are some of the many building applications that take advantage of the high performance of polycarbonate (Bonenfant, 2019; Hedges,2018);

- Polycarbonate can be used in place of glass in a variety of window and skylight applications. Polycarbonate panels and sheets allow natural light to enter a building, and they can also be tinted, reducing the sunlight that reflects inside a building and helping to minimize interior cooling costs in the summer. Depending on the gauge, a typical window- and roof-glazing application using solar-control IR multi-wall polycarbonate sheet can help to reduce interior heat, resulting in energy savings in a temperature-controlled environment.
- From opaque cladding panels to canopies, barrel vaults, skylights, translucent walls and signage, roof domes and louvers, polycarbonate sheet products are designed and available in a wide range of thicknesses, structural strengths and configurations that also meet. Polycarbonate can be formed into a variety of complex shapes using thermoforming, a heat-based thermoplastic shaping technique. Polycarbonate sheet also can be cold-line bent similar to metal. A variety of processes to shape polycarbonate facilitate many building features, from stressed curves for arches to simple paneling.
- Light-emitting diode (LED) lighting is a top choice for illuminating homes and businesses, offering energy efficiency, durability and long life. As an exterior element for LED lighting, polycarbonate plastic is sturdy, and its crystal-like clarity holds up over many years. Other benefits of polycarbonate plastic in LED lighting include heat resistance, transparency, impact resistance, low flammability, and increased energy efficiency.
- Polycarbonate is used in security glazing—strengthening prisons, guard booths, bank teller shields, convenience stores, hurricane shutters, hockey rink surrounds and more. Specifically, polycarbonate's impact strength makes it an excellent choice for security applications, including blast and bullet-resistant glazing. Clear as glass, it also presents an advantage over alternatives such as wire glass and metal screens. When used in a multi-wall format, polycarbonate provides significant insulation, with resulting energy efficiency benefits. When treated with solar control technology, polycarbonate also provides protection from IR radiation and can also increase energy efficiency.
- Polycarbonate is used extensively in sports stadium roofs to protect fans from bad weather – and let the game go on – while allowing in natural light and saving energy at the same time.

Hollow polycarbonate is also often named as a structural polycarbonate, cellular polycarbonate, channel polycarbonate or multiwall polycarbonate. The definition «cellular» is used due to its special internal structure. Air, which is present in the space (cells) between the dividing walls inside of the polycarbonate sheet (called chambers), provides thermal insulation properties, and the existing stiffeners (dividers), ensure a great structural rigidness and flexibility of polycarbonate sheet at the same time.

The unique feature of these glazing products include:

1. They have air spaces within the chamber which provide excellent thermal insulation. This is the reason why they are used in glazing applications where heat conservation is of essence.
2. The dividing walls act as supportive structure which provide a strong structural rigidness and flexibility of the polycarbonate sheet (Lu, 2015).

Cellular polycarbonate hollow sheets offer the higher level of glazing performance where transparency along with high impact strength is of vital importance. They have excellent physical, mechanical, electric as well as hot property which explains their high reputation in buildings and decoration industry. They are sold all over the world, making great contributions to consumer's beautiful life. Their versatility makes them the ideal choice for glazing in hospitals, schools, sporting areas and public infrastructure projects. They are available in transparent & textured finishes.

Cellular polycarbonate panels are used at sunshades for stadiums and bus shelters, lighting for corridors, passages and subway entries, sound and heat insulation for constructions such as houses, canopies for agricultures greenhouses, zoos, PC sheets mainly used for building and decorating materials, greenhouse materials , and the block of insulation materials, wall and roof of greenhouse, department stores , exhibition centers , telephone booth , insulation shield in express ways & highways, office buildings, hotels, villas, stadiums, schools, bus stop, terminals, hospitals, subway entry and exit doors.

In this study, characteristic properties of the polycarbonate panels such as light transmittance, water vapor transmission, impact and bending strengths, should be tested with different numbers of walls or thickness. Therefore, the relationship between the properties of polycarbonate panels and the number of walls should be determined and evaluated.

2.EXPERIMENTAL ANALYSIS

6 different polycarbonate panels are tested. The panels have 9 walls and 40 mm thickness, 5 walls and 10 mm thickness, 5 walls and 20 mm thickness, 6 walls and 40 mm thickness, 6 walls and 30 mm thickness, 5 walls and 16 mm thickness. The experimental tests are linear thermal expansion, light transmittance, energy transmittance, water vapor transmittance, bending and shear stiffness, buckling, sound transmission.

2.1. Determination of Coefficient of Linear Thermal Expansion and Glass Transition Temperature

According to TS 1065-2 1SO 11359-2, 3 rectangular prism samples are prepared with 5 mm width and 5 mm length. The change in the length with the temperature in the sample are measured by settling the samples in the Thermo-Mechanical Analysis instrument which measures the change in the temperature by loading 4 ± 0,1 kPa. The change in the length of the sample is recorded for every temperature. The Coefficient of Linear Thermal Expansion (α) at T temperature, is calculated as K^{-1} and the coefficients are demonstrated in Table 1.

$$\alpha = (dL/dT) \times 1/L_0$$

Lo: The length of the sample at room temperature (μm)

L: The length of the sample at T temperature (μm)

T: Temperature (K)

Table 1. The Coefficients of Linear Thermal Expansion of Polycarbonate Samples

The Number of Walls-Thickness	The Coefficient of Linear Thermal Expansion
9 walls- 40 mm thick	0,0308
5 walls – 10 mm thick	0,0311
5 walls – 20 mm thick	0,0309
6 walls – 40 mm thick	0,0311
6 walls – 30 mm thick	0,0311
5 walls – 16 mm thick	0,0310

2.2 The Calculation of Thermal Transmittance

According to TS EN 674, 400 mm x 400 mm 2 samples are prepared in order to measure the thermal transmittance with the plate method. The upper and lower surfaces of the sample are connected with the deferential thermo-probes and they are settled between the heating plate and the cooling plate. While one surface of the sample is heated with the electricity power, (ϕ_T, Watt), the other surface of the sample is cooled with water. Therefore, the difference in the surface temperature is measured. The thickness (d) of the sample and the area of plate is recorded. At 5 points of the sample, the difference in the temperature is measured. The thermal transmittance of the polycarbonate sample is calculated according to above formula in the regard of TS EN 673, and the results are shown in Table 2.

$$\lambda = (\Phi_T . d) / (2. A. \Delta T)$$

Table. 2 The Thermal Transmittance of Polycarbonate Samples

The Number of Walls-Thickness	The Thermal Transmittance (W/m^2K)
9 walls- 40 mm thick	7,1
5 walls – 10 mm thick	1,9
5 walls – 20 mm thick	5,6
6 walls – 40 mm thick	7,1
6 walls – 30 mm thick	6,5
5 walls – 16 mm thick	4,1

2.3 The Light Transmittance

According to TS EN 14500, at first, the thickness of the samples is measured and then the samples are settled in the spectrophotometer. The absorption amount of the opal samples is recorded by transmitting 500-550 nm wave-length light through every sample. According to these absorption amounts, the percentage of the light transmittances are determined. Therefore, the samples are aged artificiality by holding under 400 W UV lamp for the specific time according to TS EN ISO 4892-2. After the artificial ageing, the absorption amount and the light transmittance of the samples are measured again and the results are demonstrated in Table 3.

Table 3. The Light Transmittance of Polycarbonate Samples

The Number of Walls-Thickness	The Light Transmittance (%)	The Light Transmittance After Artificial Ageing (%)	The Difference in Light Transmittance the artificial ageing Transmittance After Artificial Ageing (%)
9 walls- 40 mm thick	90	85	5
5 walls – 10 mm thick	77	74	3
5 walls – 20 mm thick	77	72	5
6 walls – 40 mm thick	82	81	1
6 walls – 30 mm thick	81	80	1
5 walls – 16 mm thick	77	73	4

2.4 Total Solar Energy Transmittance

According to TS EN 410, the total solar energy transmittance is measured with spectrophotometer. T, the amount of the reflection, is measured by the spectrophotometer to determine the total solar energy transmittance. At first, the amount of reflection of the samples are recorded under 20 W light and then the amount of reflection is recorded after the samples are held under 400 W UV lamp in the regard of TS EN ISO 4892-2. The total solar energy transmittance is calculated with the difference between two reflections and the amount of the reflections and the coefficients of shading are shown in Table 4. The coefficient of shading is calculated as the ratio of the total solar energy transmittances of the polycarbonate samples and 3 mm thick glass.

Table 4. Total solar energy transmittance and the coefficient of shading of polycarbonate samples

The Number of Walls-Thickness	Total Solar Energy Transmittance (%)	Solar Direct Transmittance-T_e (%)	Coefficient of Shading
9 walls- 40 mm thick	87	83-91	1,01
5 walls – 10 mm thick	72	68-76	0,84
5 walls – 20 mm thick	73	71-75	0.85
6 walls – 40 mm thick	87	84-90	1,01
6 walls – 30 mm thick	87	84-89	1,00
5 walls – 16 mm thick	72	71-74	0,85

2.5 Water Vapor Transmission

According to TS EN ISO 12572, 3 polycarbonate circular samples for every type are cut with 80 mm diameter. The thickness of the samples is chosen according to the production of the firm. $CaCl_2$, the humidifier, is put in the bowls which has the same diameter as the samples and then the samples are settled in the mouth of the bowls without spaces. The dimension between the sample and $CaCl_2$ should be 15$\pm$5 mm. The circumstance of the samples is covered with the paraffin. After the bowls with the sample are weighed in the analytical scale, the bowls are put in the closet with 23$\pm$0,5°C and 93$\pm$3 relative humidity. The samples are weighed every day at the same time. When the measurement of weights becomes constant, the test is finished. The resistance factors of the water vapor transmission of the samples are calculated according to the difference in the weights in the time and demonstrated in Table 5.

Table 5. The resistance factors of the water vapor transmission of the polycarbonate samples

The Number of Walls-Thickness	The resistance factors of the water vapor transmission ($gr/mm^2.h.Pa$)
9 walls- 40 mm thick	62
5 walls – 10 mm thick	19
5 walls – 20 mm thick	48
6 walls – 40 mm thick	32
6 walls – 30 mm thick	33
5 walls – 16 mm thick	35

2.6 The Mechanical Resistance and the Deformation Behavior

According to TS EN 16153, at least 3 samples are prepared according to the cutting directions in the standard. For the x-axis loading, the samples are cut parallel to the levels whereas for y- axis loading, the samples are cut perpendicular to the levels. The samples are tested with 3- points bending test and loaded according to the cutting direction. The distance between the supports is chosen as 200 mm. The samples are loaded in the attitude to x and y axis. The maximum force and the deformation are recorded and the deformation behavior for x and axis is calculated according to below formula. Also, the shear stiffness through y-axis is calculated.

$$B_x = \frac{F_x \cdot {L_x}^3}{48 \cdot s_x \cdot b}$$

B_x : The bending stiffness in x-axis

F_x : The maximum force in the attitude to x-axis.

L_x: The distance between the supports

s_x : The deformation at 0,6 min.

b: The width of the sample

$$B_y = \frac{F_y \cdot ({L_{y1}}^3 - L_{y1} \cdot {L_{y2}}^2)}{48b \cdot (s_{y1} - s_{y2} \frac{L_{y1}}{L_{y2}})}$$

B_y : The bending stiffness in y-axis

F_y: The maximum force in the attitude to y-axis

L_{y1} : The distance between the supports at first measurement in y-axis

L_{y2} : The distance between the supports at second measurement in y-axis

s_{y1} : The deformation at 6 min at L_{y1}

s_{y2} : The deformation at 6 min at L_{y2}

b: The width of the sample

$$S_y = \frac{F_y \cdot \left(L_{y1} - \frac{L_{y1}^3}{L_{y2}^2}\right)}{4b \cdot \left(s_{y1} - s_{y2} \frac{L_{y1}^3}{L_{y2}^3}\right)}$$

S_y : The shear stiffness in y-axis

F_y : The maximum force in the attitude to y-axis

L_{y1} : The distance between the supports at first measurement in y-axis

L_{y2} : The distance between the supports at second measurement in y-axis

S_{y1} : The deformation at 6 min at L_{y1}

S_{y2} : The deformation at 6 min at L_{y2}

b : The width of the sample

In Table 6, the bending stiffness in x and y-axis (B_X, B_Y) and the shear stiffness in y-axis (s_Y) is demonstrated.

Table 6. The bending stiffness (B_X, B_Y) and the shear stiffness (s_Y) of polycarbonate sample

The Number of Walls-Thickness	B_X (Nm^2/m)	B_Y (Nm^2/m)	s_Y (Nm^2/m)
9 walls- 40 mm thick	1093	1115	1,13
5 walls – 10 mm thick	599	230,8	1,47
5 walls – 20 mm thick	1166	137	0,81
6 walls – 40 mm thick	788	423	0,47
6 walls – 30 mm thick	780	390	0,48
5 walls – 16 mm thick	880	168	0,84

Also, the bending and shear stiffness of the polycarbonate samples are measured after the artificial ageing. The results are shown in Table 7.

Table 7. The bending stiffnesses (Bx, By) and the shear stiffness (sy) of polycarbonate sample after artificial ageing

The Number of Walls-Thickness	B_X (Nm^2/m)	B_Y (Nm^2/m)	s_Y (Nm^2/m)
9 walls- 40 mm thick	874	746	0,86
5 walls – 10 mm thick	607	514	2,22
5 walls – 20 mm thick	1332	410	1,65
6 walls – 40 mm thick	1229	946	1,22
6 walls – 30 mm thick	1208	931	1,17
5 walls – 16 mm thick	976	463	1,93

$$M_b = \frac{F_b(L - L_c)}{4b}$$

F_b: The maximum buckling force

L: The distance between the supports

L_c : The distance between the loads

b: The width of the sample

The buckling moment is calculated before and after the artificial ageing (Table 8).

Table 8. The mechanical resistance of polycarbonate samples

The Number of Walls-Thickness	Buckling Moment (Nm/m)	Buckling Moment After Artificial Ageing (Nm/m)
9 walls- 40 mm thick	22	36
5 walls – 10 mm thick	35	50
5 walls – 20 mm thick	31	55
6 walls – 40 mm thick	26	29
6 walls – 30 mm thick	27	30
5 walls – 16 mm thick	32	52

2.7 Impact Test

According to TS EN 16153, the effect of the impact is tested by the small hard body and large soft body. All the samples are placed on the supports as 40 cm distance with 90°.

In the regard of TS EN 6603-1, in the small hard body test, 250 gr steel ball is fell down on the sample from I meter. The steel ball is fell down on 3 points of the sample. In the standard, these 3 points are outer surface of the sample, the middle and the corner. According to TS EN 1873, in the large soft body, 50 kg bag is fell down on the sample from the specific height. The heights are determined as 0,6-1-1,2-1,6 meter in the standard. The results of both impact test are shown in Table 9.

Table 9. The impact resistance of polycarbonate samples

Impact Test	9 walls- 40 mm thick	5 walls – 10 mm thick	5 walls – 20 mm thick	6 walls – 40 mm thick	6 walls – 30 mm thick	5 walls – 16 mm thick
Small hard body	Damage (no crack or break)	Pass	Pass	Pass	Pass	Pass
Large soft body	Pass	Pass	Pass	Pass	Pass	Pass

According to TS EN ISO 6603-1, the specific weight is fell down on the samples from the specific heights. The impact body should be fell down on the middle of the sample. The impact energy is determined by changing the heights. The heights are between 0,6-1,6 m. The mostly used statistical method is stair method. I kg spherical iron ball is used for the impact testing. The samples are cut as 140 x 140 mm sguare section. The thickness is chosen as the production. The iron ball is fell down ftom the specific heights. The damage is observed visually. In the regards of the different heights, 50 W impact energy is calculated as Joule with below formula.

$$E_{50} = m \times g \times H_{50}$$

E_{50}: 50 % impact energy (J)

m: The constant weight of impact body (kg)

g 'The gravity velocity (9,81 m/s^2)

H_{50}: The height of 50 % impact energy (m)

H_{50} is calculated by below formula;

$$H_{50} = H_a + \Delta H\left(\frac{A}{N} \pm 0.5\right)$$

H_a: The smallest height (m)

ΔH: The change in the height (m)

A: The damaged and non-damaged samples according to the heights

N: The total number of damaged and non-damaged samples

The standard deviation 1s calculated according to change in the heights by below formula;

$$s = 1{,}62\Delta E\left(\frac{NB - A^2}{N^2} + 0{,}029\right)$$

s: The standard deviation

ΔE: The difference in energy

A: The damaged and non-damaged samples according to the heights

N: The total number of damaged and non-damaged samples

B: The damaged and non-damaged samples according to the sguare of heights

In Table 10. 50 % impact energy and the standard deviation is demonstrated.

Table 10. The impact energy and standard deviation of polycarbonate samples in instrumented impact testing

The Number of Walls-Thickness	E_{50} (J)	s(J)	Damage
9 walls- 40 mm thick	5,89	4,07	Small (No crack or break)
5 walls – 10 mm thick	9,81	4,07	Pass
5 walls – 20 mm thick	5,23	5,04	Pass
6 walls – 40 mm thick	9,16	5,04	Pass
6 walls – 30 mm thick	9,11	5,04	Pass
5 walls – 16 mm thick	8,3	4,07	Pass

2.8. Laboratory Measurement of Sound Insulation of Building Elements

According to TS EN ISO 10140-1: Annex D, I m x 40 cm samples are used. 5 constant loudspeakers at different situations are used to measure the sound insulation. The value of the sound from the loudspeaker is measured by the receivers behind the sample. The distance between the receivers, samples and the loudspeakers should be 1,2 meter. The frequency band should be 6 seconds at the 100 Hz and 400 Hz. According to TS EN 717-1, the average of 5 measurements is the value of the sound insulation in Table 11.

Table 11. The values of sound insulation of polycarbonate samples

The Number of Walls-Thickness	Sound Insulation (dB)
9 walls- 40 mm thick	18
5 walls – 10 mm thick	18
5 walls – 20 mm thick	16
6 walls – 40 mm thick	22
6 walls – 30 mm thick	21
5 walls – 16 mm thick	16

3. RESULTS AND DISCUSSION

3.1 Thermal Properties

The coefficients of linear thermal expansion of polycarbonate samples are smaller than the coefficient of linear thermal expansion of pure polycarbonate of which is 0,065. All the coefficients are closer each other so the number of walls do not affect the coefficient.

When the thickness of the sample increases, the thermal transmittance increases. In Polygal technical specification, the results support the relationship between the thickness and thermal transmittance.

The resistance factors of the water vapor transmission of 9 walls- 40 mm thick and 5 walls – 20 mm thick samples are between 50-250 gr/mm^2. h. Pa When the thickness increases, the water vapor permeability decreases.

These polycarbonate panels are suitable to use with the other materials. The polycarbonate materials cannot supply the humidity transfer when the thickness of the panels increases.

3.2 Optical Properties

Before ageing, the percentages of the light transmittance are more than 74 % which is the minimum value of European Union CE standard and the percentages are suitable. After artificial ageing, the difference in light transmittances should be lower than and equal to 5 % for *ΔA* Class according to TS EN 16153. As a result of the measurements, all the samples are *ΔA* Class.

In the regard of the percentages of the total solar energy transmittance, all the polycarbonate samples are "Clear" class. The coefficients of shading support high light transparency.

Polycarbonate panels are counted as the clear material and supply light transmission but under the atmospheric conditions due to the surface deformations the value of light transmission decreases.

3.3 Mechanical Resistance and Deformation Behavior

5 walls with 20 mm thick has the highest of the bending stiffness in x-axis while 9 walls with 40 mm thick has the highest bending stiffness in y-axis. 5 walls with 10 mm thick has the highest shear stiffness.

Except 9 walls with 40 mm thick, the bending stiffness and the shear stiffness of other polycarbonate samples increase after the artificial ageing. Like the deformation behavior, the buckling momentum increases after the artificial ageing. The panels are not affected by the ageing effect.

When the thickness increases of the polycarbonate panels, the small impact deformations occur but generally the polycarbonate panels have the optimum impact strength.

The 5 walls polycarbonate panels have the sufficient tensile strength and buckling moment. The bending stiffness of the polycarbonate panels is high so that the panels should be used mostly in the roof construction.

3.4 Sound Insulation

All the samples are smaller than 27 dB according to DIN 52210-75 and they are counted as the sound insulation materials.

CONCLUSION

As a result of the measurements of the characteristic properties of the polycarbonate samples, this material is the light transparent, clear under the sun-light and protect its color. The coefficient of the thermal transmission is like the polymer based materials. The coefficient of linear thermal expansion is lower. İt is suitable to use with the other polymers and the metals. This polycarbonate is hard and has higher impact strength. The water vapor transmission decreases when the thickness increases. The mechanical resistance and the deformation behavior are high. Except the sample with 9 walls, the bending and shear stiffness of all the samples increase after the artificial ageing. Also, the magnification and reduction factors are used for this result. The polycarbonate samples have the sound insulation. Finally, this characteristic properties of the polycarbonate sample are suitable when the number of walls and the thickness are low.

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