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**CCMC 12536-R**

**CCMC**

*EVALUATION  
REPORT*

DIVISION	13131
Issued	1993-09-10
Re-evaluated	2005-05-30
Re-evaluation due	2006-08-10

## ***The Royal Building System™***

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\* "The Royal Building System™" is a trademark  
of Royal Building Systems (Cdn) Limited

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### ***1. Purpose of Evaluation***

The proponent sought confirmation from the Canadian Construction Materials Centre (CCMC) that "The Royal Building System™" can serve as plastic building system in compliance with the intent of the National Building Code of Canada (NBC) 1995.

### ***2. Opinion***

Subject to the limitations and conditions stated in this report, test results and assessments provided by the proponent show that "The Royal Building System™" complies with CCMC's Technical Guide for Plastic Building System for Housing (NBC), Masterformat number 13131, dated 94-03-01, for one- and two-storey single family dwellings, and provides a level of performance equivalent to that required in:

- NBC 1995, Sections 9.3., 9.4., 9.13., 9.14., 9.15., 9.19., 9.25., 9.26. and 9.27., and Subsection 9.10.16.

Revised Ruling No. 95-01-20-(12536-R) authorizing the use of this product in Ontario, subject to the terms and conditions contained in the Ruling, was made by the Minister of Municipal Affairs and Housing on 10 October 2003 pursuant to s.29 of the Building Code Act, 1992 (see Ruling for terms and conditions).

### 3. Description

"The Royal Building System™" consists primarily of a series of interlocking panels and box connectors that slide together to form the walls, roof and partitions. The system employs various interlocking hollow elements made from a polyvinyl chloride (PVC)-based composite material. These extruded elements are interconnected by means of sliding joints. The elements are assembled to form the walls, both interior and exterior, as well as the roof of the building. The building system consists mainly of a roof assembly, roof beams, floor assembly, wall assembly, foundation walls and connectors. The structural analysis and design are based on the NBC 1995 and on an extensive testing program. Figures 1A, 1B and 1C represent isometric drawings of typical houses and foundations. Figures 2, 3 and 4 represent detailed drawings of the RBS4 (100 mm) and RBS6 (150 mm) panel elements and box connectors, and a cross-section of the RBS8i (200 mm) insulated foundation wall.

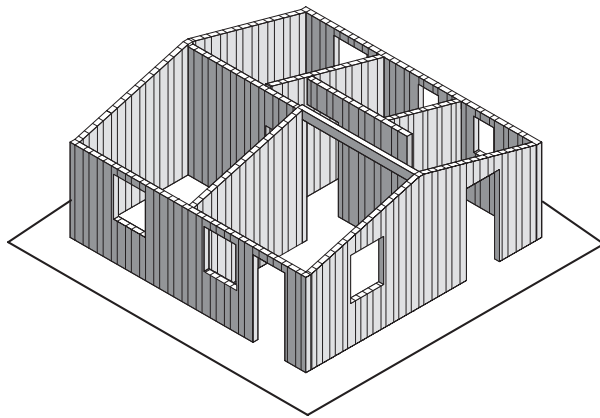


Figure 1A. "The Royal Building System™"  
(One-storey model)

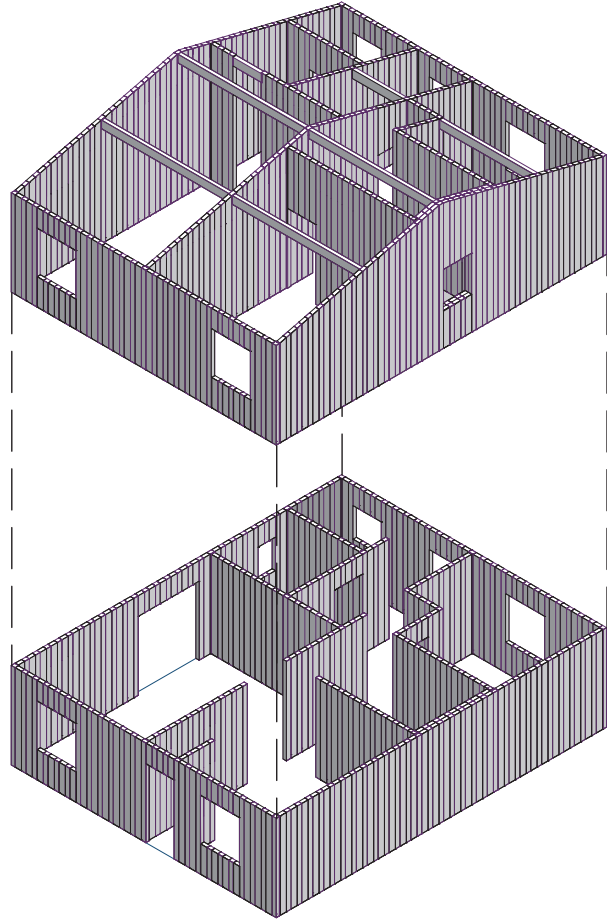


Figure 1B. "The Royal Building System™"  
(Two-storey model)

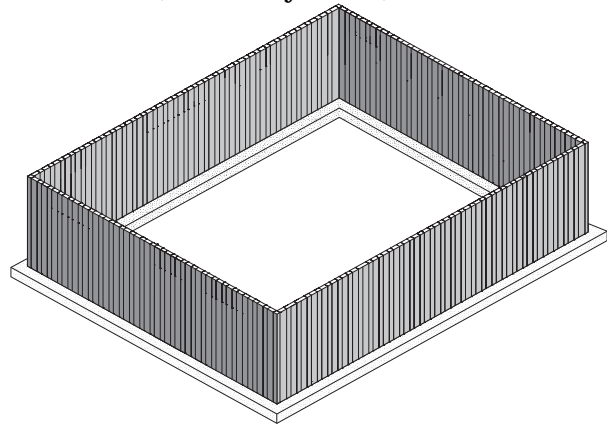
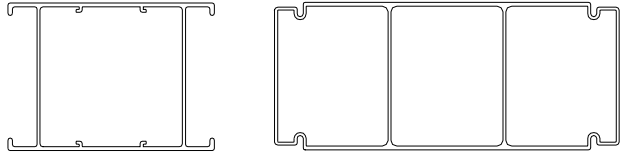
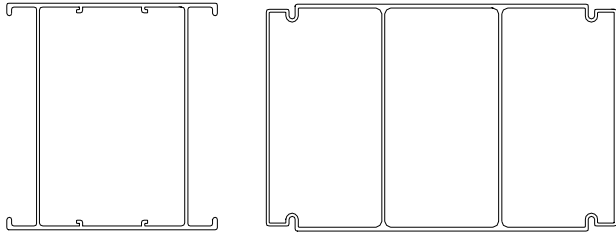


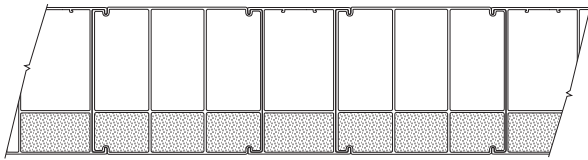
Figure 1C. "The Royal Building System™"  
Foundation (for one- and two-storey  
houses)



**Figure 2. RBS4 (100 mm) Box Connector and Panel Element**



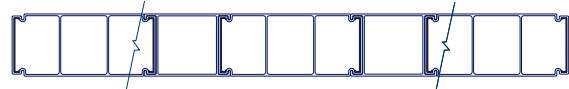
**Figure 3. RBS6 (150 mm) Box Connector and Panel Element**



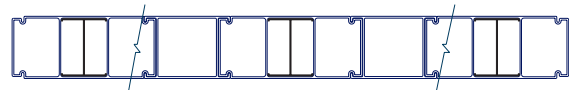
**Figure 4. Cross-section of the RBS8i (200 mm) Insulated Foundation Wall**

### Roof Assembly

The roof assembly is composed of 100 mm panel elements and 100 mm box connectors. The joints between the panel elements and the box connectors are sealed with silicone caulking. The roof assembly is supported by and connected to the exterior walls and roof beams. The behaviour of the roof assembly is set by the temperature of the roof under load and by the duration of the load. The effects of temperature and load duration are not independent and their combined effect has been studied. The roof assembly is stiffened with a cold-formed steel channel section at one side of every roof panel element (i.e., 333 mm on centre [o.c.]). The cavity of the roof panels is filled with a Type 3 pre-formed mineral-fibre insulation that has a thermal resistivity (RSI) of 28/m. The assembly is also covered with 89 mm of Type 4 extruded/expanded polystyrene insulation board and a Noryl™ plastic tile, which provides a sunscreen. An aluminum insert was developed to fit inside the roof panels to suit some of the higher load conditions and longer spans that are being considered. Figure 5 indicates the roof assembly types. The values for the roof assembly are shown in Table 1.



S33-C (with steel stiffeners)



I100-C (with aluminum insert)

**Figure 5. Roof Assembly**

**Table 1. Factored Resistance Values - Roof Assembly S33-C and I100-C<sup>(1)(2)</sup>**

Property		Units	S33-C	I100-C
Factored Resisting Moment ( $M_{x_f}$ )	LL <sup>(3)</sup>	kN·m/m	2.56	4.24
	WL	kN·m/m	2.40	3.91
Factored Shear Resistance ( $V_{x_f}$ )	LL	kN/m	> 8.27	6.81
	WL	kN/m	> 7.75	6.31
Elastic Stiffness (Elx)	LL	N·mm <sup>2</sup> /m	86.8 x 10 <sup>9</sup>	71.7 x 10 <sup>9</sup>
	WL	N·mm <sup>2</sup> /m	81.4 x 10 <sup>9</sup>	66.2 x 10 <sup>9</sup>

Notes to Table 1:

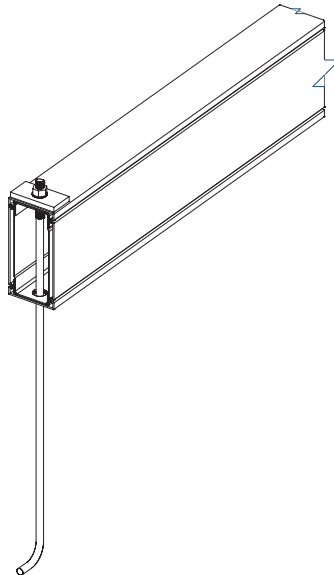
- (1) Values calculated for I100-C conform to CSA standard CAN3-S157-M83, "Strength Design in Aluminum." Values calculated for S33-C conform to CSA Standard S136-94, "Cold Formed Steel Structural Members."
- (2) The strength and stiffness of the box connector and panel members of the roof assembly are affected by load duration and temperature. The values for these members have been multiplied by a factor of 0.80 for roof live loads and snow loads, and by a factor of 0.67 for wind loads.
- (3) LL denotes roof live load or snow load, and WL denotes average roof wind load.

**Roof Beams**

To support the roof assembly, Royal Building Systems Limited has developed a cold-formed steel section to be used as roof beams in their buildings. The Royal Standard Beam (RSB), 1.60 mm (16 gauge), and the Royal Extra Strong Roof Beam (RXB), 1.98 mm (14 gauge), are fabricated using ASTM A 653 Grade 50 galvanized sheet steel, which provides a good combination of forming and mechanical properties. The roof beam is supported by bearing on the interior and exterior

walls. The RSB was developed to suit the most common loading conditions, and the RXB was developed to suit some of the higher load conditions that are being considered.

Selection of the proper beam depends on the beam span, the tributary area, the loading and the maximum allowable live load deflection of 1/180 of the span. The roof beam is shown in Figure 6. The values for the roof beams are shown in Table 2.



**Figure 6. Roof Beam**

**Table 2. Factored Resistance Values - Roof Beams<sup>(1)</sup>**

Property		Units	RSB	RXB
<b>Section</b>				
Gross Area	(A <sub>g</sub> )	mm <sup>2</sup>	1170	1440
Effective Section Modulus (Factored)	(S <sub>x</sub> )	mm <sup>3</sup>	48.66 x 10 <sup>3</sup>	68.62 x 10 <sup>3</sup>
Effective Moment of Inertia (Specified)	(I <sub>x</sub> )	mm <sup>4</sup>	5.236 x 10 <sup>6</sup>	6.80 x 10 <sup>6</sup>
Mass		kg/m	9.40	11.58
<b>Strength</b>				
Factored Resisting Moment	(M <sub>x<sub>f</sub></sub> )	kN·m	15.10	21.30
Factored Shear Resistance	(V <sub>x<sub>f</sub></sub> )	kN	31.04	63.68
Factored End Bearing Resistance (bottom flange bearing)	(B <sub>b<sub>f</sub></sub> )	kN	7.24	9.68
Factored End Bearing Resistance (top and bottom flanges cast into concrete)	(B <sub>c<sub>f</sub></sub> )	kN	14.48	19.36

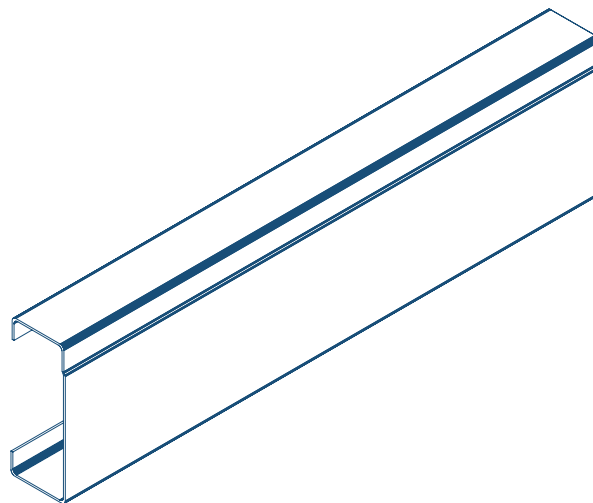
Note to Table 2:

(1) Values calculated conform to CSA standard S136-94, "Cold Formed Steel Structural Members."

**Floor Assembly**

The floor assembly is composed of a 65 mm concrete slab reinforced with welded wire fabric and placed on a steel deck formwork that spans a maximum of 667 mm between floor joists. Royal Building Systems Limited has developed a cold-formed steel section for use as floor joists to support the floor assembly. The Royal Standard Joist (RSJ), 1.60 mm (16 gauge), and the Royal Extra Strong Joist (RXJ), 1.98 mm (14 gauge), are fabricated using ASTM A 653 Grade 50 galvanized sheet steel, which provides a good combination of

forming and mechanical properties. The floor joists are supported by bearing on the interior and exterior walls. The RSJ was developed to meet the most common loading conditions and the RXJ was developed to suit some of the higher load conditions that are being considered. Selection of the proper joist depends on the joist span, the tributary area, the loading and the maximum allowable live load deflection of 1/360 of span. The floor joist is shown in Figure 7. The values for the floor joist are shown in Table 3.



**Figure 7. Floor Joist**

**Table 3. Factored Resistance Values - Floor Joist<sup>(1)(2)</sup>**

Property		Units	RSJ	RXJ
<b>Section</b>				
Gross Area	(Ag)	mm <sup>2</sup>	585	720
Effective Section Modulus (Factored)	(Sx)	mm <sup>3</sup>	24.33 x 10 <sup>3</sup>	34.31 x 10 <sup>3</sup>
Effective Moment of Inertia (Specified)	(Ix)	mm <sup>4</sup>	2.618 x 10 <sup>6</sup>	3.40 x 10 <sup>6</sup>
Mass		kg/m	4.70	5.79
<b>Strength</b>				
Factored Resisting Moment	(M <sub>x<sub>f</sub></sub> )	kN·m	7.55	10.65
Factored Shear Resistance	(V <sub>x<sub>f</sub></sub> )	kN	15.52	31.84
Factored End Bearing Resistance (bottom flange bearing)	(B <sub>b<sub>f</sub></sub> )	kN	3.62	4.84
Factored End Bearing Resistance (top and bottom flanges cast into concrete)	(B <sub>c<sub>f</sub></sub> )	kN	7.24	9.68

Notes to Table 3:

- (1) Values calculated conform to CSA standard S136-94, "Cold Formed Steel Structural Members."
- (2) An independent analysis concluded that the floors meet NBC Part 9 vibrations criteria when designed in accordance with the the manufacturer's approach, which has been ratified by CCMC.

#### Wall Assembly

The wall assembly is composed of interconnected RBS4 (100 mm) or RBS6 (150 mm) panel elements and box connectors. The assembly is reinforced with deformed steel reinforcing 10M and 15M bars (400 MPa grade) and filled with concrete that has a minimum 28-day compressive strength of 20 MPa. The exterior of the wall assembly is covered with

89 mm of Type 4 extruded/expanded polystyrene insulation board and with vinyl siding. The walls vary in height from 2.4 m to 3.9 m and support a combination of lateral and axial loads depending on the specific location in the structure. The values for the wall assembly are shown in Table 4.

**Table 4. Factored Resistance Values - Wall Assembly<sup>(1)</sup>**

Property		Units	RBS4 Value	RBS6 Value
Box Connector and Panel (Flexure)				
Factored Resisting Moment <sup>(2)</sup>	(M <sub>r</sub> )	kN·m/m	4.98	7.96
Concrete (Axial Compression)				
Factored Axial Compressive Resistance <sup>(3)</sup>	(P <sub>r</sub> )	kN/m	488[1-(h/40d) <sup>2</sup> ] (For walls up to 3 m in height)	748[1-(h/40d) <sup>2</sup> ] (For walls up to 4.5 m in height)
Reinforcing Bar (one- 15M bar)				
(Tension)				
Factored Tensile Resistance	(T <sub>r</sub> )	kN	68.0	68.0
Composite Section				
Elastic Stiffness	(E <sub>lx</sub> )	N·mm <sup>2</sup> /m	134.0 x 10 <sup>9</sup>	310.0 x 10 <sup>9</sup>

Notes to Table 4:

- (1) Values calculated are based on laboratory test reports and conform to CSA A23.3-94, "Design of Concrete Structures."
- (2) The strength and stiffness of the box and panel members of the wall assembly are affected by load duration and temperature. The values noted have been multiplied by a factor of 0.80.
- (3) Value must be reduced to account for the slenderness ratio of the wall, based on the wall height.

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**Foundation Wall**

The foundation wall assembly is composed of the RBS8i (200 mm thick) interconnected panels elements and box connectors. The outer 54 mm of the wall elements are filled with a polyurethane foam and the inner portion of the elements are filled with concrete that has a minimum 28 day compressive strength of 20 MPa. When reinforcing is used, it consists of 15M bars

(400 MPa grade), spaced at 667 mm and covered with 35 mm of concrete. Table 5 provides the maximum backfill height for the RBS8i (200 mm) foundation walls, with and without reinforcing for two typical wall heights. The foundation wall does not require an additional drainage layer or dampproofing.

**Table 5. Backfill Heights**

200-mm Foundation Wall	Unsupported at Top	Laterally Supported at Top	
		2490 mm wall height	2743 mm wall height
No reinforcing Concrete 20 MPa	800 mm	1600 mm	1550 mm
15M @ 667 mm (35 mm cover, vertical inside face) Concrete 20 MPa	800 mm	2350 mm	2600 mm

**Connections in General**

“The Royal Building System™” has connection details that are necessary to join the components of the building. The connections include a roof beam anchor, roof assembly connections and wall assembly connections.

**Roof Beam Anchor**

The roof beam bears on the concrete-filled wall assembly. The loads imposed on the roof beam vary with the beam span, the tributary area and the loading. The value for the roof beam anchor is shown in Table 6.

**Table 6. Factored Resistance Values - Roof Beam Anchor**

Property	Units	Value
Factored Uplift Resistance	kN	30.00

**Roof Assembly Connections**

The roof assembly is connected to the wall assembly by a galvanized steel anchor and clip placed in the box sections of the assembly. The roof assembly is connected to the roof beams by

galvanized metal screws and a beam cap. The loads imposed on the connections vary with the assembly span, the connection spacing and the loading. The values for the roof assembly connections are shown in Table 7.

**Table 7. Factored Resistance Values - Roof Assembly Connections**

Property	Units	Value
Eave and Intermediate Wall Anchor Factored Tensile Resistance	kN	4.56
Ridge Wall Anchor Factored Tensile Resistance of Group of Eight #10 x 3/4 screws at 333 mm o.c.	kN	2.22
Intermediate Beam Anchor Factored Tensile Resistance of Group of Four #10 x 1 1/4 screws at 333 mm o.c.	kN	1.91
Ridge Beam Anchor Factored Tensile Resistance of Group of Eight #10 x 3/4 screws at 333 mm o.c.	kN	2.22

**Wall Assembly Connections**

The wall assembly is connected to the roof assembly, as previously discussed and is connected to the foundations by deformed reinforcing steel bars cast into the footing and the

wall. The uplift loads imposed on the reinforcing steel vary with the specific location in the structure. The uplift loads for the wall assembly connections are shown in Table 8.

**Table 8. Factored Resistance Values - Wall Assembly Connections**

Property	Units	Value
Factored Tensile Resistance Load (Depth 160 mm)	kN	7.00
Factored Tensile Resistance Load (Depth 260 mm)	kN	11.40

**4. Usage and Limitations**

- The structural design of the components and the system must be performed by a professional engineer skilled in such designs and licensed to practice under the appropriate legislation. The drawings or related documents shall bear the authorized seal of the professional engineer. For design purposes, the licensed professional engineer must consult the proponent for a more detailed set of design criteria that take into account the effects of radiant energy, cyclic loading, floor vibrations and racking resistance.
- All aspects of handling and installation shall comply with the proponent’s specifications

and instructions as outlined in the Construction Guide for “The Royal Building System™,” dated June 1998.

- “The Royal Building System™” shall not be installed in locations where the wall or roof surface temperature can exceed 85°C (185°F). These conditions are not exceeded in Canada for the white or tan-coloured assemblies used in the system.
- When the cavities of “The Royal Building System™” contain foamed plastic, it shall be separated from the interior of the building by a thermal barrier as described in Article 9.10.16.10. of the NBC.

*Note: This limitation does not apply to the foundation wall assembly as the polyurethane foam in the exterior cavity is separated from the interior by concrete.*

- Gypsum wallboard or any non-flexible finish shall not be supported directly by the roof assembly or the roof beams, unless the deflection limits used in the design are less than L/360 for combined dead and live loads.
- The product must be identified with the following information:
  - proponent’s name or logo; and
  - the phrase “CCMC # 12536-R.”

**5. Performance**

Deloitte & Touche Quality Registrar Inc. provided a certificate of registration to Royal Building

Systems (Cdn) Limited stating that the design, manufacturing and marketing of “The Royal Building System™” complies with ISO 9001:1994. Testing of “The Royal Building System™” was conducted by independent laboratories recognized by CCMC. The test results were compiled and integrated into one document entitled “Product Evaluation Guide, Volume 1, Second Edition,” dated August 1998. Tables 9, 10 and 11 summarize the physical properties, durability, quality control testing and some structural and fire properties obtained for the three-cell panel and the two-way box connector.

With interior climatic conditions of 35% relative humidity (RH) at 22°C ambient temperature and an exterior temperature of -45°C, a thermal analysis demonstrated that the system shows no signs of dew-point condensation at the front or back surfaces of the walls or ceilings.

**Table 9. Physical Material Properties of the Panels, Elements and Box Connectors**

Property	ASTM Test Method	Units	Requirement	Results
Impact Resistance Notched Izod	D 256	J/m ft.-lb./in.	> 53.4 > 1.0	240.3 4.5
Drop Dart Impact At Room Temperature	D 4226	J/m in.-lb./mil	Report value	4893 1.1
Drop Dart Impact At Low Temperature (-30°)	D 4226	J/m in.-lb./mil	Report value	445 0.1
Tensile Strength	D 638	MPa Psi	> 37.7 > 5500	41.9 6023
Modulus of Elasticity	D 638	MPa psi	> 2800 > 377 000	3158 458000
Deflection Temperature @ 1.82 MPa (264 psi) Annealed @ 65°C	D 648	°C °F	> 70 > 158	73.8 165
Coefficient of Linear Expansion	D 696	cm/cm/°C in./in./°F	< 6 x 10 <sup>-5</sup> < 3.3 x 10 <sup>-5</sup>	5.0 x 10 <sup>-5</sup> 2.8 x 10 <sup>-5</sup>
Weatherability	D 1925	Max. YI	Report value	+2.15
Weatherability	D 2244	Max. LH	report value	-0.34
	D 2244	Max. aH		+0.01
	D 2244	Max. bH		+0.92

**Table 9. Physical Material Properties of the Panels, Elements and Box Connectors (cont'd)**

Property	ASTM Test Method	Units	Requirement	Results
Weatherability Drop Dart Impact	D 4226	Min. % Retention	80% of original value	97
Weatherability Drop Dart Impact	D 4226	J/m in.-lb./mil	report value	4848 1.09
Specific Gravity	D 792	-----	report value	1.47
Elongation at Break	D 638	%	report value	127
Elongation at Yield	D 638	%	report value	2.5
Flexural Modulus	D 790	MPa Psi	report value	3537 513 000
Flexural Strength	D 790	MPa Psi	report value	70.9 102 80
Hardness (Rockwell)	D 785	-----	report value	102

**Table 10. Quality Control Testing on Finished Product – Panels, Elements and Box Connectors**

Property	ASTM Test Method	Units	Requirement	Test Results
Wall Thickness	N/A	mm (in.)	report value	2.54 (0.10)
Colour Match	N/A visual	visual	report value	tan, white, grey
Hardness (Shore D)	D 2240		80 ± 5	77
Ash Content	D 229	%	report value	28.7
Shrinkage, 1/2 at 82°C	D 3679	%	Max. 3	1.77
Rate of Burning (mm/10 s)	D 635	mm (in.)	max. 100	0
Drop Weight Impact Resistance at 23°C	D 4495	J/m ft.-lb./in.	report value	533 10
Drop Dart Impact at 23°C	D 4226	J/m in.-lb./mil	report value	4895 1.1

**Table 11. Durability, Water Infiltration, Air Leakage and Fire Properties**

Property	Test Method	Units	Requirement	Results
Accelerated weathering UV-Apparatus, 2000 h	G 154-00	%	>80 retention of original value	100
Water Infiltration	ASTM E 547-86	-----	no water infiltration	no water infiltration
Air Leakage	ASTM E 283-84	l/s/m <sup>2</sup>	0.1	0.076 roof/ 0.020 wall
Flame Spread	CAN/ULC-S102.2	-----	< 150	13
Smoke Development	CAN/ULC-S102.2	-----	report value	75
Roof Covering	CAN/ULC-S107	-----	report classification value	Class A

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John Flack, Ph.D.  
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