Design and testing of annealed glass balustrade panels using a structural PVB interlayer

Wim Stevels
Eastman Chemical Company

Keywords

1=Balustrades
2=Structural PVB
3=Interlayer combination
4=Annealed glass
5=Laminated glass
6=NBN B 03-004

Abstract

Following the introduction of structural PVB interlayers, a number of annealed glass panel configurations were tested under static loads and impact tests according to Belgium norm NBN B 03-004. The results were interpreted against the current norm and the recently published provisional norm. The feasibility of combining different types of interlayers was explored, and its effect on the capability of the configurations to meet requirements was evaluated.
A number of potential application areas were identified for balustrade panels based on glass laminated with a structural PVB alone, or combinations of structural and conventional PVB. The use of structural PVB potentially allows the broadest classification of application area, whereas the combination of PVB types allows the introduction of color functionality into the design.

Introduction

Structural glass balustrades are subject to a complex and dynamic normative framework in Europe. General design principles and applicable loads can be derived from the structural Eurocodes, however a specific Eurocode for glass is still under development [1]. Draft European norms have been proposed for glass dimensioning (prEN16612, prEN13474), but are not implemented yet and glass dimensioning is still subject to national norms. In addition, balustrades are regulated in additional specific norms for these structures in a number of countries such as France and Belgium. Finally, applicable building codes may have an influence on balustrade design. As an evaluation of potential balustrade configurations for all European countries is a very extensive effort, the work reported in this paper focused on Belgium norm NBN B 03-004 [2], Railings of Buildings, and its recently published new draft version prNBN B 03-004 [3]. The new norm is expected to publish within the coming year, if accepted. Recently, some interlayer producers have introduced structural poly(vinyl butyral) (PVB) interlayers to the market that: (a) are markedly stiffer than conventional interlayers [4], (b) reduce occurring stresses and (c), reduce resulting deformations in laminated glass. These structural PVB interlayers are the primary focus of the study, either alone or in combination with conventional PVB types. Finally, tempered glass is widely used in structural laminated glass balustrade configurations, in particular for point-fixed and clamped glazing. However, for uniformly supported systems the use of laminated annealed glass may be considered as stress concentrations are avoided. This would have advantages in costs, logistics and potential avoidance of optical distortions.

Results and discussion

Validation of balustrades under NBN B 03-004 can be executed based on calculation and/or experimentation for static loads and experimentation for impact loads. In this case, balustrade testing occurred experimentally at the Belgium Building Research Institute test center, Limelette, Belgium. A demanding one-side clamped profile system was selected as a test case.
Six different laminated glass panels in glass dimensions 1200 * 1200 mm were prepared fourfold on a commercial lamination line. Configurations prepared were based on two pieces of 8 mm glass, two pieces of 10 mm glass and two pieces of 12 mm glass, all laminated using Saflex® DG41 structural PVB interlayer with a nominal thickness of 0.76 mm to provide three different test specimens, coded respectively 88.2DG; 1010.2DG; 1212.2DG. Also prepared and tested were two pieces of 8 mm glass, two pieces of 10 mm glass and two pieces of 12 mm glass laminated using a combination of a layer of Saflex® DG41 and a layer of Saflex® RB41 PVB interlayers to a total nominal thickness of 1.52 mm, coded respectively 88.4mix, 1010.4mix and 1212.4mix. Prior to testing, these glass panels were mounted in Aluminco® Crystalline® type B (88.x) and type E (1010.x and 1212.x) profiles. These profiles were installed unto concrete according to the profile manufacturer's instructions, as illustrated in Figure 1.

Figure 1 Overview of balustrade testing for thicker configurations (1010.x and 1212.x)

Loads were applied according to the overview in Table 1 for line-, point, and impact loads, with wind loads, if relevant, added as equivalent point loads. An overview of Belgium wind class classification according to NBN EN 1991-1-4 ANB is given in Table 2 (reference heights and wind zones excluded).

	Load type:	Line	Point	Point	Impact
	Location/method	1.00 m	1.00 m	anywhere	EN12600
	Unit	(kN/m)	(kN)	(kN)	(mm)
Building Class	**Description**				
A	Residential	0.5	1.0(1)	0.5	300
B	Office	1.0	1.0	0.5	450
C1-4	Spaces where people gather (2)	1.0	1.0	0.5	700
D	Commercial buildings	1.0	1.0	0.5	700

Table 1 Overview of static and dynamic loads applicable to railings of buildings according to NBN B 03-004
(1) Proposed change to 0.5 kN in prNBN B03-004, Rev 2 Feb 2015
(2) standing crowds C5a&b not included in table

Wind classes	Dynamic peak pressure (Pa) (1)
Wind class 1	544
Wind class 2	693
Wind class 3	815
Wind class 4	950
Wind class 5	1086
Wind class 6	1224
Wind class 7	1364

Table 2 Overview of wind class by dynamic peak pressure according to NBN EN 1991-1-4 ANB wind classes are related to location and height of building, for net wind pressure, table values need conversion using applicable coefficients for local pressure

	NBN B03-004	prNBN B03-004, Feb 2015
Static		
SLS	H/60 (glass) or 20 mm, residual deformation < 3mm	25mm (glass clamped at bottom), residual deformation < 3mm
ULS	residual deformation < H/125 (9.6 in examples)	residual deformation < 10 mm (glass clamped at bottom)
Dynamic	No disengagement of structure	No disengagement of structure
	No fragment that can hurt people	No fragment that can hurt people
	Impact body can't pass through balustrade	Impact body can't pass through balustrade
	Test specimens of specific dimensions can't pass	Test specimens of specific dimensions can't pass
		Post-breakage tempered: 100 N, 10s, 1m

Table 3 Overview of test criteria for railings in buildings

Configuration	NBN B03-004	prNBN B03-004, Feb 2015
88.2DG		A, no wind load
88.4Mix		A, no wind load
1010.2DG	A-wind class 2; B-no wind	A-wind class 3; B-no wind
1010.4Mix	A no wind	A&B no wind
1212.4DG	A, B, C1-4, D-wind class 3	A, B, C1-4, D-wind class 5
1212.4Mix	A no wind	A,B, C1-4, D-wind class 2 max

Table 4 Overview of potential application area for the tested configurations [5]

Whereas care was taken to cover a broad range of test conditions, not every potential combination of configuration and loads were tested for every wind class.
Finally, the test criteria as listed in NBN B 03-004 and prNBN B 03-004 were applied to measured deformations and/or residual deformations. As these are different between the current and the provisional norm, a truncated overview is given Table 3. An overview of the study results is given in Table 4.

Regardless of the norm applied, there is a significant application window for annealed glass configurations based on structural PVB in Belgium, which will become even larger after adoption of the provisional norm, even for these relatively demanding one-side clamped glass configurations. Similar results might be obtained in other European countries, but careful review and or evaluation against applicable code and norm is recommended. Another interesting outcome of this study is that mixed interlayer configurations, e.g. a layer of Saflex® DG41 and a layer of Saflex® RB41 PVB interlayer, might be applied in a number of cases as well. As the physical and mechanical properties of some colored interlayer systems (eg Vanceva® color system) are equivalent to the conventional PVB used and compatible with the structural PVB interlayer used, a broad range of additional design options would then become available. An example of such a mixed color figuration in an installed balustrade is given in Figure 2. The specific interlayer mechanical properties would have to be considered in these scenarios and careful review and or evaluation against applicable code and norm is recommended

Figure 2 Example of use of a mixed colored/ structural PVB in an installed glass balustrade

Conclusions and summary

The introduction of structural PVB's offers interesting new application opportunities in laminated safety glass [5]. These include application of annealed glass in balustrades and/or the introduction of color functionality with these structural PVB's. Validation of the configuration of choice through testing according to applicable code and norm remains key to a responsible glazing practice.

References and notes

[1] M. Feldmann, R. Kasper (2014) Challenging Glass 4 & COST Action TU9095 Final Conference, eds. C. Louter, F. Bos, J. Belis & J-P.Lebet, ISBN 978-1-138-00164-0, p 773.
[2] Belgium norm NBN B 03-004, Railings of Building, 2010
[3] Draft Belgium norm prNBN B 03-004, Railings of Building, 2015
[4] P. Zhang et al. (2015) Shear Modulus measurement of PVB Interlayers and prEN16613, Glass Processing Days, June 2015
[5] Although the information and/or recommendations as may be set forth herein (hereafter "Information") are presented in good faith and believed to be correct at the date hereof, Eastman Chemical Company and its subsidiaries and affiliates including Solutia Inc. (hereinafter "Eastman") make no representations or warranties as to the completeness or accuracy thereof. Information is supplied upon the condition that the persons receiving same will make their own determination as to its suitability for their purposes prior to use. In no event will Eastman be responsible for damages of any nature whatsoever resulting from the use of or reliance upon Information or the product to which Information refers. Nothing contained herein is to be construed as a recommendation to use any product, process, equipment or formulation in conflict with any patent, and Eastman makes no representation or warranty, express or implied, that the use thereof will not infringe any patent. No representations or warranties, either express or implied, of merchantability, fitness for a particular purpose or any other nature are made hereunder with respect to information or the product to which information refers. The data presented is derived from samples tested. Results are not guaranteed for all samples or for conditions other than those tested. Data and its respective measured, calculated or estimated single number ratings is for glass panels only – glazing installed in frames may differ significantly in performance.

Platinum sponsors

DOW CORNING

kuraray

SentryGlas®
IONOPLAST INTERLAYER

waagner biro

Gold sponsors

Quanex building products

EASTMAN

Eckersley O'Callaghan

Merchandise sponsors

EASTMAN

Everlam GmbH

Heraeus

The conference is supported by the following trade fairs and associations:

glasstec
INTERNATIONAL TRADE FAIR FOR GLASS
PRODUCTION • PROCESSING • PRODUCTS
21–24 OCTOBER 2014
DÜSSELDORF, GERMANY

GGF
Glass and Glazing Federation

GlassBuild AMERICA

GIMAV
Italian Glass Processing Machinery and Accessory Supplier's Association

NGA
NATIONAL GLASS ASSOCIATION
National Glass Association

VITRUM

GANA
GLASS ASSOCIATION OF NORTH AMERICA

abravidro
Associação Brasileira de Distribuidores e Processadores de Vidros Planos

NÜRNBERG MESSE