

Durability Assessment of Gypsum Boards with Glass Mat Reinforcement Used in Light Facade Systems

Mauricio M. Resende¹, Douglas C. Meirelles²,
Gustavo R. Boriolo³ and Luciana A. Oliveira⁴

¹ Institute of Technological Research of State of São Paulo – IPT, Building Technological Center – CETAC, and São Judas University, mresende@ipt.br

² Saint-Gobain Brasil, douglas.meirelles@saint-gobain.com

³ Saint-Gobain Research Brasil, gustavo.boriolo@saint-gobain.com

⁴ Institute of Technological Research of State of São Paulo – IPT, Building Technological Center – CETAC, luciana@ipt.br

Abstract: *Gypsum boards with glass mat reinforcement are used in light weight facade systems. These boards were recently brought to the Brazilian market. Therefore, there are few studies and little practical knowledge of their performance over time, mainly concerning to durability. The gypsum boards manufacturers set that these boards always need to be coated, however they can be exposed to natural conditions during the construction site period. A study is necessary to evaluate the feasibility of using these boards in Brazil, since the exposure conditions relating to humidity, temperature and solar radiation are different from Europe and North America. The aim of this paper is to show the approach used to evaluate the durability of the gypsum board with glass mat reinforcement, and also show the test results. In order to establish the durability approach, standards were adopted, as well as the functional performance concept. In addition, the tests considered that such boards would be used on the facade and should behave similarly to other boards used in facades in Brazil, such as fiber cement boards. Thus, mechanical tests were done in steady state, saturated and after aging in cycles of immersion, drying and heating. Other evaluations were made on gypsum boards applied on exposed walls. The results showed that even the board strength decreases after the accelerated aging cycles, the final value remains in an acceptable level. In addition, boards applied on exposed walls for 12 months have been presenting a good performance; meaning no cracks neither detachments, even though the follow-up still needs to be maintained longer.*

Keywords: *Gypsum Boards with Glass Mat Reinforcement, Durability, Performance, Aging.*

1 Introduction

Gypsum boards with glass mat reinforcement¹ were recently brought to the Brazilian market and it has been used in light weight facade systems². There are no Brazilian standards concerning these boards, however, there are American and also European standards (ASTM C1177, 2017 and EN 15283-1, 2009) and some publications relating to moisture resistance

¹ Gypsum boards with mat reinforcement are composed of set gypsum plaster core reinforced with inorganic fibers which are arranged in a woven or non-woven mat to form flat rectangular boards. Admixtures, fillers and fibers dispersed in the core may also be present (definition of EN 15283-1, 2009).

² Site of construction products in Brazil, available in <https://www.aecweb.com.br/emp/p/usg-brasil_34433_1>

(CMHC, 2007; Randall *et al.*, 2016). Although, these standards and publications, there are few studies and little practical knowledge of the performance of these boards over time in Brazil, mainly concerning to durability requirements. Singh and Garg (1992) have defined the durability of glass reinforced gypsum composite by assessing its behavior in water, in natural weathering exposition and after wetting and drying aging cycles.

The use of glass mat gypsum boards in external facades is recommended only as a substrate to a coating system – whether a Direct Applied Finish System (DAFS) or an External Insulated Finish System (EIFS). Glass mat board manufacturers set that these boards cannot stay apparent, meaning no coating, during their entire service life. However, they may be exposed to natural conditions during the construction site period during one year at most. The boards are used as a component of a facade system. Once assembled in facades, they must contribute to ensure the design life (DL) of the complete system. This is an actual discussion in Brazil, mostly because of the residential building performance standard, ABNT NBR 15.575-1 (2013), set a minimum DL of 40 years for façade systems of residential buildings.

A study is necessary to evaluate the feasibility of using these boards in Brazil, because of the design life requirement set on NBR 15575 and because of the exposure conditions relating to relative humidity, temperature and solar radiation are different among Europe, North America and Brazil. For example the average temperature in South East Brazil is around 23°C and 76% of relative humidity, with an average solar radiation of 18 MJ/(m².dia) (Tiba, 2000, Inmet site – available in < <http://www.inmet.gov.br/portal/>>).

In this context, the aim of this paper is to show the approach settled to evaluate the durability of the gypsum board with glass mat reinforcement for use in facades of multi-story building in Brazil, and also show the tests results. Therefore, this study is related to the durability assessment of the glass mat product (board), does not considering the whole facade system.

2 Research Method

The durability approach settled here is according to ISO 15686-2 (2012) concepts: a) definition of user needs, material requirements and characterization; b) preparation – identifications of aging agents, mechanisms and effects, choice of performance characteristics and evaluation techniques; c) exposure and evaluation – short-term exposure (accelerated exposure) and long-term exposure (field exposure); and analyzing and interpretation. The table 1 shows the durability approach developed to this study based on the authors experience and knowledge.

Table 1. Durability approach developed to this study, based on ISO 15686-2 (2001) concepts.

Stage	Descriptions/ Definitions	Reference
Definitions		
User needs	The intention is to use this gypsum board in facades of multi-story building in Brazil façades in Brazil	Principles set to this work
Performance requirements relating to gypsum board durability	Strength reversability Moisture resistance	CMHC (2007); Randall <i>et al.</i> (2016) and Singh and Garg (1992)

Material characterization	Density, water absorption, dimensional changes due to moisture and bending strength	Characteristic from ASTM C1177 (2017), EN 15283-1(2009) and NBR 15498
Preparations		
Identification of aging agents	Water, solar radiation, hot temperature	Adapted of ISO 19208 (2016)
Mechanisms and effects	Water is the main agent of plaster degradation due to the solubility of the gypsum. By the action of wet-dry cycles of the environment, the gypsum dissolves and precipitates continuously, but the attached crystals are deposited on the surface and do not have the same imbrication of the first formation.	John, V.; Cincotto, M.A. (2017)
c) exposure and evaluation – short-term exposure (accelerated exposure) and long-term exposure (field exposure);	All characteristics were evaluated before and after stress by immersion in water associated to different temperatures (Figure1)	Proposal of this paper. The most tests were carried out considering the NBR 15498

The tests (characteristics evaluation before and after short term exposure) were designed considering that gypsum boards with glass mat reinforcement will be used on the facade and should behave similarly to other boards applied in facades in Brazil, such as fiber cement boards, even they will be coated after at maximum one year (Figure 1). Then, mechanical tests were done in steady state, saturated and after aging (cycles of immersion in water and drying), since the water is the most important aging agent for these boards (Figure 1).

In additional, a field exposure is carrying on since four gypsum boards were assembled on exposed walls it has been twelve months. These walls are in São Paulo city, West region, placed directed to North.

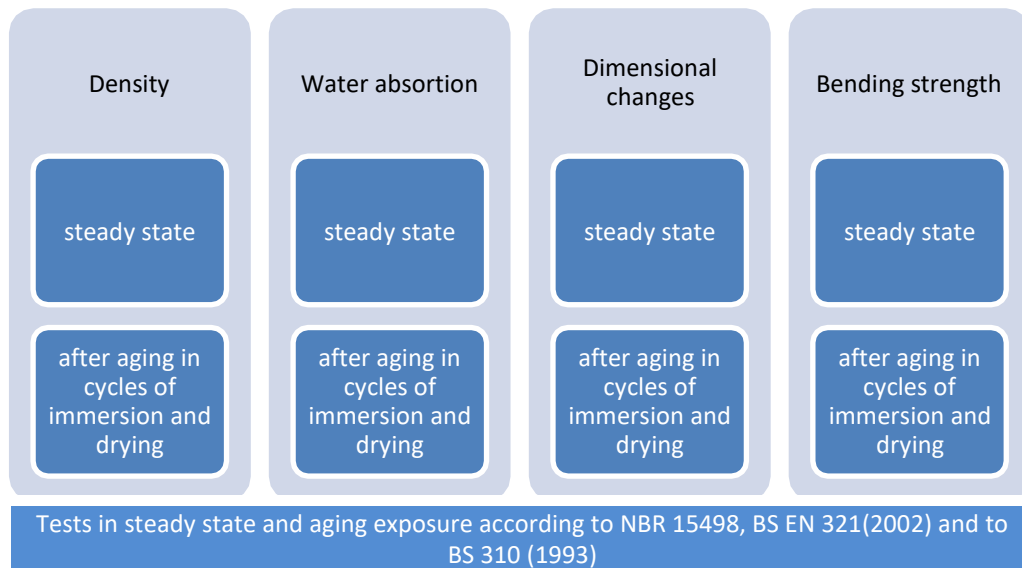


Figure 1. Tests of gypsum boards under stress condition.

The test in normal condition, steady state, means keeping the samples for three days to (20 ± 2) °C and (50 ± 5) % of relative humidity. Two kinds of short aging exposure were carried on: one adopting the fiber cement standard (ABNT NBR 15498, 2016) and the other adopting the OSB board standard (BS EN 321, 2001).

The aging test specified by ABNT NBR 15498 (2016) consists of subjecting the samples to 50 aging cycles. Each cycle consists of the following steps: immersion in water at 20°C for 18 hours and exposure at 60°C for 6 hours. The aging test specified by BS EN 321 (2002) consists of subjecting the samples to 3 aging cycles. Each cycle consists of the following steps: immersion in water at 20°C for 72 hours, then exposure at -12°C for 24 hours and finally exposure at 70°C for 72 hours. At the end of the aging cycles, the samples were conditioned at 20°C and 65% relative humidity until they reached constant mass (equilibrium condition). In the state condition, it determined the flexural tensile strength and the modulus of elasticity of aged and non-aged samples according to BS EN 310 (1993).

3 Results and Discussion

3.1 Density

According to NBR 15498 (2016) samples of gypsum boards were measured and weighed; the average results can be seen in Table .

Table 2. Gypsum boards with glass mat reinforcement densities.

Steady state	After aging in cycles of immersion and drying ⁽¹⁾	Difference between normal and aging conditions
798,6 ± 6,30 g	784,13 ± 19,45 g	14,47g (1,81%)
⁽¹⁾ aging exposure according to NBR 15498		

32 Water Absorption

Moisture content was calculated, according to NBR 15498, using 250x100 mm samples for gypsum board, which are the same sizes of the bending test samples. The results shown in Table 3 are the average of 10 samples at 21°C and 65% RH.

Table 3. Moisture content of Gypsum boards with glass mat reinforcement (average result).

Steady state	After aging in cycles of immersion and drying ⁽¹⁾	Difference between normal and aging conditions
(36,6 ± 0,95) %	(55,5 ± 3,4)%	18,9%
⁽¹⁾ aging exposure according to NBR 15498		

In additional, the moisture content tested according to EN 15283-1 (standard for Gypsum boards with fibrous reinforcement), is around 4%, which means these boards is Type H1, with reduced water absorption rate.

33 Dimensional Changes

The dimensional changes relating to width and length were tested using 250x100 mm samples for gypsum board, which are the same sizes of the bending test samples. The results shown in Table are the average of 10 samples.

Table 4. Dimensional change in width and length.

	Steady state	After aging in cycles of immersion and drying ⁽¹⁾	Difference between steady and aging conditions
width	1,15 %	1,23%	0,08%
length	0,26%	0,18%	0,08%
⁽¹⁾ aging exposure according to NBR 15498			

34 Bending Strength after Immersion and Dry

The bending strength according to NBR 15498 (2016) was tested using 250x100 mm samples for gypsum board. The results shown in Table are the average of 10 samples.

Table 5. Bending strength results before and after short term exposure.

Requirements	Steady state	Saturated condition – immersion in water for 24hours	Steady state, after aging in cycles of immersion and drying**	Saturated condition, after aging in cycles of immersion and drying
Bending strength Longitudinal direction (MPa)*	7,9 ± 0,5	4,7 ± 0,4	5,9 ± 0,2	2,6 ± 0,2
Bending strength Transversal direction (MPa)*	6,0 ± 0,8	4,3 ± 0,5	4,5 ± 0,6	2,2 ± 0,2

* the samples were removed from the gypsum board considering longitudinal and transversal direction

** at the end of the aging cycles, the samples were conditioned at 20°C and 65% relative humidity until they reached constant mass (equilibrium condition).

35 Bending Strength and Modulus after Immersion, Freezing and Heating

The bending strength and modulus of gypsum board was tested using 250mmx50 mm according to BS EN 310 (1993), in steady conditions and after short aging exposure, that was based on BS EN 321 (wood board) as showed in Table 6.

Table 6. Average results obtained from the characterization of gypsum board according to BS EN 321.

Requirements*	Steady state	Steady state, after aging in cycles of immersion freezing and heating **	Variation (%)
Bending strength (MPa)	7,11 ± 1,26	6,03 ± 0,9	-18%
Modulus of elasticity (GPa)	2,65 ± 0,3	2,02 ± 0,4	-19%
* the samples were removed from the gypsum board only considering the longitudinal direction			
** at the end of the aging cycles, the samples were conditioned at 20°C and 65% relative humidity until they reached constant mass (equilibrium condition).			

The variation between the results of the physical characteristics of gypsum board mat reinforcement in steady state and after aging exposure were under 20%; density was almost zero, water absorption was around 18% and dimensional changes were around 0,08%. Relating to bending strength, the results in the saturated state were greater than 50% of the results in the steady state. The ratio of bending strength in the transversal by the longitudinal direction was greater than 70%, both in the steady and saturated state. These bending strength results meet the NBR 15498 specifications. Once considering a severe condition, the bending strength in saturated state after aging was 50% of the bending strength of the saturated boards in steady state. Relating to the exposure to wetting / freezing / heating cycles by BS EN 321, it can be seen from the analysis of Table 4 that both the bending strength and the modulus of elasticity after the aging cycles presented values above 80% of the initial values.

36 Long-Term Exposure (Field Exposure)

Gypsum boards mat reinforcement were installed in two walls structured by steel frame, forming a wall of 2400 mm wide x 2400 mm length. After 12 months of exposure, no significant occurrences (no cracks neither detachments or wraps) were found on the boards.

4 Conclusions

This paper shows an approach to evaluate the durability of gypsum boards mat reinforcement used in the facade, considering water as the main aging agent, since the board may have contact with rainwater and solubilize the plaster. Then, tests were made to evaluate the physical and mechanical characteristics of these boards under normal condition (steady state) and after aging, cycles of immersion in water and drying. It was assumed that glass mat gypsum boards should behave similarly to other facade sheets, such as fiber cement and wood boards. For this reason, it was adopted the aging exposure methods indicated in both standards.

Concluding, the tests results show that the difference between physical characteristics before and after aging is less than 20%. Regarding to the mechanical characteristics, the bending strength losses after aging were on average less than 50%. However, after conditioning under normal conditions there is a resistance return, the strength after aging, at steady state, is similar to the resistance in the initial saturated state (table 5). Concerning the natural exposure, the boards have been providing good results, even though the follow-up still needs to be maintained longer.

ORCID

Maurício Marques Resende: <https://orcid.org/0000-0001-6496-0762>

Douglas Meirelles: <https://orcid.org/0000-0001-5203-0365>

Gustavo Boriolo: <https://orcid.org/0000-0001-5201-2191>

Luciana Oliveira: <http://orcid.org/0000-0001-6772-3252>

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