Relationship between the Deterioration of Multi Story Buildings Facades and the Driving Rain.

Relación entre la deterioración de fachadas en edificios de varios pisos y la lluvia dirigida.

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Abstract

In order to evaluate the behavior of facades in relation to driving rain, as well as the influence of the architectural elements in front of the deterioration, were calculated in this work the monthly directional driving rain index (dDRI-m) and the amounts of driving rain wall index (I0) to the city of Goiania, Brazil. Was performed a study of case over staining on facades through visual inspection and photographic record of buildings rendered with mortar and paint finish, with more than 12 story and construction aged 10 or under, located in the same city. Samples were collected on facades regions with stains for microbiological analyzes. As a result, it was found that facades of the same building are subject to different levels of moisture and deterioration, fact established by the correlation between the staining observed in the studies of case and the dDRI-m and I0. The stains, often described as dirt, showed the presence of microorganisms: filamentous fungi, phototrophics and actinomycetes.

Keywords: Facades; Driven Rain, Deterioration.

Resumen

Con la finalidad de evaluar el comportamiento de fachadas en relación a la lluvia dirigida, así como la influencia de los elementos arquitectónicos en la deterioración, fueron calculados en este trabajo los índices de lluvia dirigida direccional mensual (ICDd-m) y las cantidades de lluvia dirigida sobre pared vertical (I$_0$), para la ciudad de Goiânia - Brasil. También fue realizado un estudio de caso de manchas en fachadas por medio de inspección visual y registro fotográfico de edificios recubiertos con mortero y pintura, con más de 12 pisos y con 10 o menos años de construcción, localizados en la misma ciudad. De las muestras colectadas en regiones de las fachadas con manchas, fueron realizadas análisis microbiológicos. Como resultado, se constató que las fachadas de una misma edificación están sujetas a diferentes niveles de humidad y deterioración, hecho comprobado por la correlación entre las manchas observadas en los estudios de caso y los índices ICDd-m y I$_0$. Las manchas muchas veces descritas como suciedad, presentan microorganismos del tipo hongos filamentosos, actinomicetos y fototrofos.

Palabras clave: Fachadas; Lluvia dirigida, Deteriorio.

INTRODUCTION

Multi-store buildings are a reality in different countries of the world, along with the problems with their facades durability. Nevertheless, there are few studies about pathological manifestations due to climate impact over this type of building. The durability of buildings facades can be directly related to weathering. Insulation, condensation, wind, and rainfall are climate elements that contribute to the deterioration process and affect the durability.

Rain is as one of the main sources of humidity for buildings, causing severe maintenance damages (CHOI, 1999). Besides comprehension of climate's elements, understanding the impact that geometry and arrangements of the parts involved in a facade can provide before climatic aspects (rain, wind, air humidity, and temperature) and urban aspects (dust and pollution) strongly contribute to the building durability. For example, Chew and Tan (2002) studied the occurrence of stains influenced by elements from facades of new buildings located in an industrial pole in the city of Singapore.

Due to the complexity of the problem and to the occurrence of pathological manifestations, researchers from several countries are concerned, trying to establish measurement mechanisms to the effects of rainfall through empirical equations, measurements, testing, and simulations of the phenomenon. One of the ways to understand the phenomenon of the rain on buildings is performed by studies of driving rain (Straube; Burnett, 2000).

Driving rain is the rain given by a horizontal wind speed component, which makes it obliquely fall. The association of wind and rain creates the intensity vector of oblique rain. From the comprehension of the relation between rain and buildings facades, driving rain intensity term starts to restrict to the rain intensity vector component that causes water flow over a vertical plain, definition adopted by CIB – International Council for Building Research (Blocken; Carmeliet, 2004).

Bearing in mind its relevance, researchers have developed works in different countries, trying to outline a driving rain behavior. Hoppestad (1955) conducted the first studies about the driving rain index (DRI) and, during the 60's; CIB has established it as being a product between the average of wind speed and the sum of the rainfall. The indices are of great simplicity and can be calculated from basic data for wind and rain that are available (Bella *et al.*, 2012). This simplicity allowed

Lacy and Shellard (1962) to propose the driving rain index (DRI) as a standard to qualitatively characterize the scalar exposure linked to each site. The scalar procedure is one of the types of procedure and the other being the directional driving rain (Bella *et al.*, 2012).

This index, usually computed annualy as DRI, has led many ountries to obtain maps of driving rain, such as the UK, Normay, Turkey, China, India, among others Bella *et al.*, 2012; Lacy, 1971; Rydock *et al.*, 2005; Sahal, 2005; Sauer, 1987; Chand; Bhargava, 2002). As parameters for classification of buildings and their respective regions in levels of aggression, Lacy (1977) adopts three levels of exposure to driving rain, according to the annual driven rain index (DRI). However, Chand and Bhargava (2002) adopted a fourth level of exposure, which consider the severe conditions of ambience for DRI larger than 11 m²/s (Tab. 1).

Other ways to demonstrate this relation are by directional driving rain index (dDRI) and amount of directed rain in vertical wall (I_0). These methods provide the identification of orientations exposed to bigger and smaller levels of humidity coming from the rain.

Brazil, with all its territorial extension, does not have a map of directional driven rain index, which would be very important for understanding the phenomenon and allow an international comparison of exposure levels. For directional indices, it is necessary to wind direction simultaneously with the precipitation data to estimate the direction that the rain falls. The results obtained predict the amount of driving rain expected for each orientation and thus generate an independent exposure for each possible direction (Blocken; Carmeliet, 2006). The EN ISO 15927-3:2009 established a procedure for the quantitative estimation of various directional indicators of exposure, both on an annual basis (IA) and per spell (IS). To ensure the accuracy of the method, climate data must be recorded at very short intervals, generally by the hour (Boyd, 1980).

Thus, this paper aims to establish a correlation between the facades deterioration by stains of buildings with more than 12 floors and the rain effect, measured through monthly directional driving rain index (m-dDRI) and of the amount of driving rain in vertical wall (I_0). Additionally, the study relates this deterioration with the presence of microorganisms, besides identifying the influence of architectural elements to deterioration.

The relevance of this research also turns to two significant aspects: the lack of studies that create a correlation between driving rain and respective deterioration problems and to the characteristics of residential buildings in Brazil concerning the number of floors. In general, these buildings have more than 12 floors, reaching 30 floors, factor that exposes to higher intensities of wind.

STATE OF THE ART - DRIVING RAIN INDEX

Directional Driving Rain Index (dDRI)

DRI is a semi-empiric method and it is established as the product between the wind speed and the amount of rainfall, according to Equation 1.

$$DRI = V \cdot \frac{P}{1000} \tag{1}$$

Where: DRI = Driving Rain Index (m²/s); V = Average, V = Wind Speed (m/s); and Wind Speed (m/s); and P = Rainfall Total (mm).

From Equation 1, it is possible to obtain the annual driving rain index (aDRI) and directional (dDRI) through monthly, seasonal, or annual averages, which result, respectively, in monthly directional driving rain (m-dDRI), seasonal (s-dDRI) or annual (aDRI). Directional indexes need the wind direction simultaneously with rainfall data to estimate the orientation from which the driving rain is approaching (Bella *et al.,* 2012).

Amount of driving rain in vertical wall (I_0)

To calculate directed rain amount in vertical wall (I_0), several equations are available in literature, based on relations between water deposition rates in horizontal and vertical surfaces. Equation 2 is based on the equal size of raindrop in a certain event of rain and flow of uniform, fixed, and horizontal wind, where the intensity of driving rain passes by a vertical surface.

$$R_V = R_h \cdot \frac{V}{V_t} \tag{2}$$

Where: Rv = Rate of rain in vertical surface (mm/year or season or month); Rh = Rate of rain in horizontal surface (mm); Vt = Terminal speed of raindrop fall (m/s).

Equation 3 is based on the average size of raindrops based on rainfall intensity and final speed of raindrops fall. According to Blocken and Carmeliet (2004), the exponent 0.88 of Equation 3 can be disregarded without significant interference on the results. From the local effects, the average coefficient of driving rain (0.222) of Equation 3 is replaced by coefficients α, originating Equation 4, next.

$$R_v = 0{,}222 \cdot V \cdot R_h^{0,88} \approx 0{,}222 \cdot V \cdot R_h \tag{3}$$

Where: V = Wind Speed (m/s); R_v = Rate of rain in vertical surface (mm/year or season or month); R_h= Rate of rain in horizontal surface (mm); and 0.222 (s/m) = Driving rain coefficient (average value) resulting from the adopted empirical relations.

$$R_v = \alpha \cdot V \cdot R_h \cdot \cos\theta \tag{4}$$

Where: V = Wind Speed (m/s); Rv = Rate of rain in vertical surface (mm/year or season or month); Rh = Rate of rain in horizontal surface (mm); α = Driving rain factor; and θ = Angle between the wind direction and normal line to the wall (degrees).

For Equation 2, the wind direction is considered as perpendicular to the vertical surface in all times and it is like wind and rain fall deflection has not occurred through surfaces.

In the studies carried out in Norway about the driving rain exposure in vertical wall, Rydock *et al.* (2005) used the Equation 5 for establishing the accrued amount of rainwater in vertical surface for each direction. Rydock *et al.* (2005) used Lacy (1965) data as conversion factor, resulting from studies of 75 rain events during 16 years, where they had adopted that 1 m^2/s corresponds to around 0,206 m or 206 mm of directed rain in vertical wall. The sum is taken over all the D angles which represent the wind blowing against the wall, including the sectors θ - 80º a θ + 80º. The main advantage of equation 5 is that the rain load angular distributions obtained are highly accurate in terms of wind direction (Rydock, 2006).

$$I_0 = 0,206. \sum_{D=\theta-80º}^{\theta+80º} R_D . V_D . \cos(D-\theta) \qquad (5)$$

Where: I0 = Amount of driving rain in vertical wall (mm/year or season or month); RD = Average rainfall for D direction (mm); VD = Average wind speed for D direction (m/s); D = Wind direction (degrees); and θ = Angle between the North and the regular direction to the wall (degrees).

RESEARCH METHODOLOGY

The present work was developed in three steps, all of them directed to the climate and buildings of the city of Goiania, state of Goiás, Brazil. The first step aimed to calculate the monthly directional driving rain index (m-dDRI) and driving rain amount in vertical wall (I_0). In this work, the m-dDRI of the months with higher rainfall intensity are presented, which are: January, February, March, November, and December. The second step evaluated the influence of facades orientation on the predispositions to different deterioration levels based on the driving rain, besides analyzing the influence of architectural details on the formulation of stains on the facades of buildings coated with mortar and painting finishing. Therefore, obtaining information about the predisposition to different levels of deterioration between facades of a same building, influenced by the driving rain. The third and last step has the objective of investigating the presence of microorganisms in the stains identified as dirt in facades, arising from the inefficacy of facade elements (windows' dripping pan and platband) in water outflow.

Geographically, the city of Goiania is placed in latitude 16º 41` South, in longitude 49º 17` west and it has predominant humid tropical weather. The region where it is found presents two significant characteristics: the continentality for the distance from the Atlantic Ocean, and the big regularity of the cyclic process of air masses displacements that, associated to other aspects, create a pluviometric regime. Thus, this region has one rainy season (November, December, January, February and March; around 5 months with rainfall over 200 mm per month); a dry season (June, July, and August), besides an intermediate season (April and May and, further, between September and October). The relative humidity follows the variation of the rain cycle during the year, but, while the pluviometric index has an abrupt variation among the months of the year, the relative

humidity presents a discreet variation (Fernandes, 2006). In the sequence, three steps developed in the research are described.

m-dDRI and I_0 Calculation

For the calculation of the monthly directional driving rain indexes (m-dDRI) and the amount of driving rain in vertical plain (I_0), the semi-empiric methods previously presented were adopted. The adoption of this method was based on the significant results found by several authors, such as Chand and Bhargava (2002) and Rydock *et al.,* (2005).

Data Source

The data for the calculation of the driving rain index - DRI were provided by the 10th DISME (Tenth Meteorological District) from National Institute of Meteorology - INMET, as they are relative to the automatic meteorological station located in Jaó neighborhood, in Goiania, positioned in latitude: -16.38º and longitude: -49.13º W, 770 m height. The first records of the station date from May 26th, 2001 and the measures on rain intensity, wind direction, and speed are recorded by udograph, vane, and anemometer, respectively, every hour, so 24 records a day, which ensures accuracy of the results. In the total, 183,960 pieces of data were processed, referent to the hourly measurements of rain precipitation, wind speed and direction from 2002 to 2008. Although this period is apparently small for studies related to hydrology (as you work with recurrence time), it is justified, because it is the exact period of exposure of the buildings facades under analysis.

Data Preparation

In this automatic meteorological station, the rain precipitation data are recorded in millimeters, wind speed in m/s and wind direction in degrees. Thus, it was not necessary the transformation of units to speed and precipitation. However, the wind direction data - recorded in degrees - were transformed in eight directions, each one comprising 45º, which are: North (N), Northeast (NE), East (E), Southeast (SE), South (S), Southwest (SW), West (W) and Northwest (NW).

After the transformation of the wind directions to eight orientations, the observations (wind speed and precipitation) were gathered for the respective orientations, excluding the observations with winds which speed is bellow to 1 knot (0.5144 m/s), once these ones are considered calm winds. When concluded this data grouping step, having as primordial reference the direction of pluviometric precipitation and wind speed, the study performed the calculation of the m-dDRI from Equation1, and I_0 from Equation 5.

Case-studies of the facades staining

Among the pathological manifestations which can also be originated by elements that compound facades, there are stain formations that can be due both to the particulate material released in the atmosphere by pollution sources, and by the occurrence of microorganisms. Visually, it is not possible to differ between both with preciseness; therefore, these formations will be regarded in this step of the study only as stains.

This step of the study has the aim of pointing out the pathological manifestations by the stains formations in the external elements that configure the facades and, mainly, verifying the possible different behavior of facades of a same building in the deterioration process from the circumstances involving them.

Sampling

Initially, 25 multi-floors residential buildings located in the city of Goiania were inspected. These buildings with more than 12 floors were selected because they present a similar typology, being mainly coated with mortar and painting finishing. Thus, photographic records were made regarding stains formation in facades. Further, out of the 25 buildings, 5 that presented similar conditions to conduct a more detailed study were selected. The characteristics of these buildings are on Tab. 2. The conditions fixed for the selection of the five buildings were orthogonality to the cardinal points: N, S, E and W; and lack of "shelter effect".

The orthogonality over all the buildings was necessary for obtaining, in the final result, the reasonable understanding of the each facade's behavior regarding the orientations and driving rain study. Thus, for creating a relation between the levels of deterioration for each facade and its orientation, through a compass, the facades were identified about their orientation, accepting inclinations up to 20° of the building' situation regarding these points.

The "shelter effect" provides a protection by neighbor buildings by the creation of wind blocking barriers and, consequently, to the driving rain (Gandemer, 1975), which led to the restriction of buildings that were, in a comprising way, surrounded by same height buildings. From the point of view of project conception, a same building can present facades with some differences, in other words, with characteristics defined by specificities that compound them, changing the shapes, colors, types of decorative coating, presence or not of balconies, windows amount and dimensions, and others parts.

Stains Percentage Maps

The study adopted a methodology adapted from Gaspar and Brito (2005) that consists on the application of probabilistic analyses for the definition of pathological manifestations occurrences in mortar coatings applied in facades, where the authors attributed percentage values to the occurrence of damages on facades located in the cities of: Lisbon, Alcochete and Tavira, in Portugal.

Thus, maps representing the facades were created, representing the stain percentages found in the facades elements and the orientations about the cardinal points N, S, E and W. "Ghost-like stains" or "spectres" or "fantomes", terms also used by authors, are typical stains from masonry which are formed drawing masonry's bed joints due to thermophoresis, difference on the superficial temperature of the materials compounding the rendering (Logeais, 1989). These stains also can be attributed to differential absorption on substrate before the render setting time due to a difference in porosity of blocks and mortar joints (AFNOR, 2008) and they can be seen between masonry and concrete structure (SNMI, 2010).

Microorganisms Identification

This part of the study performed an evaluation about the presence of microorganisms existing in facades of some of the studied buildings. The facades presented dark stains, and the goal was to identify if they were only stains (by atmospheric pollutants) or if there was also microorganisms in these formations. Thus, the places and sampling method, as well as the procedures for the microbiological analysis are described as follow.

Places for samplings collection

Three buildings were selected for the collection of the material to be analyzed, being sample 1 from building 6, samples 2, 3 and 4 from building 7, and sample 5 from building 8. The places chosen for the samples collection were platbands and the places close to windowsills with dark stains.

Samples 1 and 5 were obtained from surfaces close to the window's ends, with the purpose of verifying if the stains originated from water flow, only described as dirt, also had microorganisms. Sample 1 was collected over the ceramic coating of the facade turned to the North direction, according to Fig. 1 (a), and sample 5 refer to the collection made over the coating in textured acrylic painting of the facade turned to West direction, according to Fig. 1 (b). The selection of the facades was done by the dirt aspect, in other words, facades with bigger proportions of stains were selected.

Fig. 1: *Place of sample 1 collect (a) and place of sample 5 collect (b) (Developed by the authors).*


(A)

(B)

Samples 2, 3 and 4 were extracted from the top region of the building, illustrated on Fig. 2, specifically of platbands having smooth painting finishing. The samples were collected from different orientations, being sample 2 collected from the facade turned to North, sample 3 collected from the facade turned to South, and sample 4 collected from the top region of which

divides the apartments, not having specific orientation because they are located in the middle of the building.

Fig. 2: *Place of sample 1 collect (a) and place of sample 5 collect (b) (Developed by the authors).*

(A)

(B)
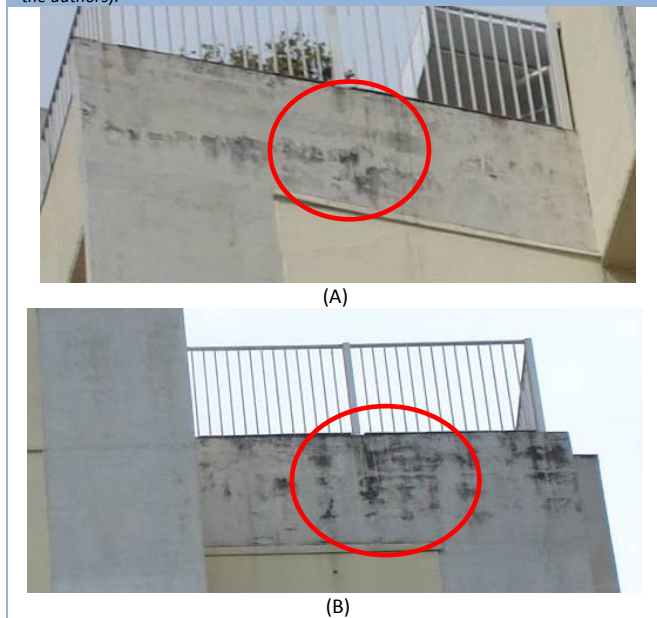
Sampling Method

In the regions defined for sampling, two types of collection were performed. The first sampling, aiming fungi analysis, was performed through toothbrush previously packed in tin foil and sterilized for 15 minutes at 120^oC, under pressure atmosphere, and draught by 48 hours in oven at 80^oC.

After unwrapping, the toothbrush it was moistened in 10 ml of sterile saline (0.85% NaCl) and used to brush the selected area of 2.5 cm diameter using five clockwise movements (Tanaca *et al.*, 2011). The microorganisms were recovered from the toothbrush through an ultrasonic bath (Thornton C/7, T7), for 10 minutes (Shirakawa *et al.*, 2010).

Another way of sampling was through the employment of non-cellulosic adhesive tape, aiming the analysis of phototropics, employing the methodology of Gaylarde and Gaylarde (1999). For such, pieces of adhesive tapes of around 20 cm lengths per 1.5 cm width were adhered over the surface with stains and after that, glued over A4 polyester film.

Microbiological Analysis

For samples collected with the toothbrush, the analyses were made with the suspensions, after being submitted to ultrasound bath, through the inoculation by Spread Plate, in double, of 100 μl of the suspension in Petri dishes containing culture media, Agar Sabouraud Dextrose (Shirakawa *et al.*, 2002). Decimal dilutions were also inoculated. The plaques were incubated at 28^oC, for 72 hours, and the units forming colonies were registered after this period. The adhesive tapes were examined microscopically after inoculated in specific culture media for

phototrophic (Bold Basal Medium) and incubated under room temperature under indirect sun light, for 6 weeks.

RESULTS AND DISCUSSIONS

Directional Driving Rain

The pluviometric system of Goiania is marked by three periods, which can be described in: rainy, little rainy and very dry. The rainy period is characterized by months with precipitation over 200 mm/month (January, February, March, November and December). Tab. 3 shows the annual driving rain indexes.

From the classification proposed by Chand and Bhargava (2002), Goiania is classified with an exposure level of protected region. Fig. 3 presents the monthly directional driving rain (m-dDRI) within the period from 2002 to 2008, for the rainy period. Through the indexes, it is observed a different behavior for the orientations, having higher values in January for N and NW orientations. Fig. 4 results from the m-dDRI average for the rainy months of January, February, March, November, and December, presenting as higher value the NW quadrant (0.37 m^2/s), followed by N quadrant with value equal to 0.33 m^2/s, and with lower value quadrant S (0.13 m^2/s). Fig. 5 presents the average of the driving rain amounts in vertical wall from period from 2002 to 2008. The NW, E, N and W orientations are presented as the most critical, followed by NE and SE facades, and S and SW facades are the less critical.

Through m-dDRI, which demonstrates the amount of incident rain related to the cardinal points, it is noted different behavior of the directed rain for the city of Goiania. By the average of the results, it is found that NW and N orientations receive higher rain indexes and S orientation lower index. Comparing the average of I_0, N, E, W and NW orientations presented higher values in mm/year and S and SW orientations the lower values.

Fig. 4: *Average of monthly directional driving rain indexes (m²/s), January, February, March, November and December, for Goiania in the years from 2002 to 2008 (Developed by the authors).*
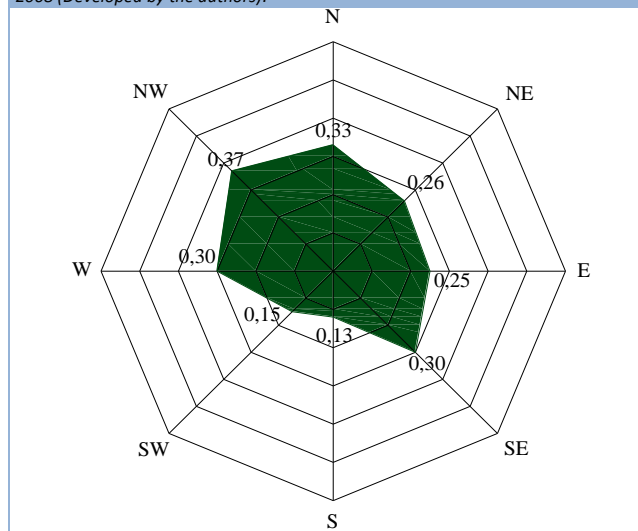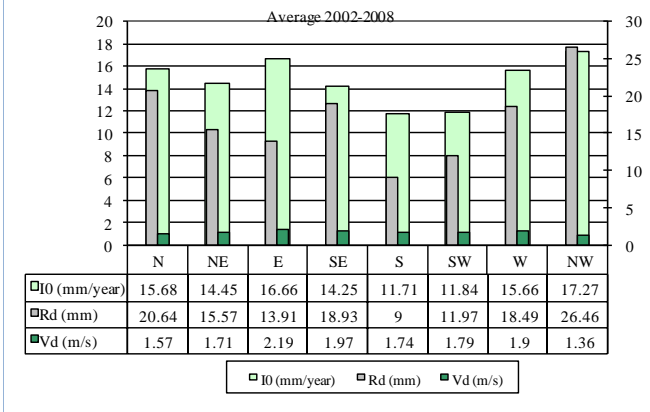
Fig. 5: *Average of the driving rain amounts in vertical wall for Goiania in the years from 2002 to 2008 (Developed by the authors)*

Average 2002-2008

	N	NE	E	SE	S	SW	W	NW
I0 (mm/year)	15.68	14.45	16.66	14.25	11.71	11.84	15.66	17.27
Rd (mm)	20.64	15.57	13.91	18.93	9	11.97	18.49	26.46
Vd (m/s)	1.57	1.71	2.19	1.97	1.74	1.79	1.9	1.36

I0 (mm/year) □ Rd (mm) ■ Vd (m/s) ■

Tab. 1: *Range of exposure to driving rain proposed by Lacy (1977) and Chand and Bhargava (2002).*

Range of exposure	DRI and ranges of exposure by Lacy (1977)	DRI and ranges of exposure by Chand and Bhargava (2002)
Protected	DRI ≤ 3 m^2/s	DRI ≤ 3 m^2/s
Moderate	3 m^2/s < DRI ≤ 7 m^2/s	3 m^2/s < DRI ≤ 7 m^2/s
High	-	7 m^2/s < DRI ≤ 11 m^2/s
Severe	DRI > 7 m^2/s	DRI > 11 m^2/s

Staining in Facades

Fig. 6 shows the maps generated with the staining results in different facades of one of the buildings. These maps were made for all buildings, and Tab. 4 and Tab. 5 present the compilation of the results obtained in these maps. The results without numerical value are relative to the absence of architectural element in that facade. For the buildings 1, 2 and 3, the biggest stains formation happened at facade N platband (Fig. 7), also influenced by the absence of crowning.

Fig. 7: *Stains formed in platbands of Building 3. Facade N (Developed by the authors).*

For stains formed in windowsill (Fig. 8), there were bigger cases on facades S for Buildings 1, 2 and 4. The stains formed over dripping pans occurred in larger quantity on the facades turned to South for buildings 2, 3, 4 and 5, highlighting that building 1

does not have dripping pans. The ghost-like stains occurred in higher percentage for facades S, for mansory walls.

Fig. 8: *Stains formed close to windowsill of Building 5. Facade W (Developed by the authors)*

Microorganisms Identification

Tab. 6 compiled the results obtained in the microbiological analysis performed.

Surprisingly, the presence of phototrophics (organisms that use sunlight as energy source) in three samples taken from the facades was detected. This is the first report in the literature of the obtaining of phototrophic on facades in Brazil. These microorganisms were identified both specific media for the growth of fungi and in particular media for phototrophics.

The growth of microorganisms occurred differently depending on the orientation of facades. For the facades with North orientation, there was a predisposition to the development of photrophics, due to the higher sun incidence and to the humidity of the driving rain, important to the occurrence of certain types of microorganisms. At facades turned to South, there was a stronger trend to fungi appearance, which does not need sun energy for their occurrence. At last, actinomycetes were identified (bacteria with filamentous organization) at the samples obtained over ceramic renderings, and it is a less explored data on the literature, that deserves further studies for confirming this trend with bigger number of samples and in different Brazilian regions.

CONCLUSIONS

Through this work, it is observed that the driving rain exposes facades to different levels of humidity to buildings in Goiania-Brazil. As an example of this remark, we observe that for NO and N orientations showed higher values of m-dDRI for the analyzed months (with values of rainfall above 200 mm/year) and the S orientation showed the lower value. The indices calculated can direct the taking of preventive measures against deterioration of buildings.

In general, it is verified that most of the moisture from the rain can contribute effectively with the staining of facades, leading to deterioration of renderings in less than 10 years. The platbands, regions of facades with more predisposed to

moisture from rain, showed a predominance of staining for the N orientation. However, the facades facing the south orientation showed higher staining in regions of windowsills. This occurrence is explained by the low incidence of rain on these facades, resulting in limited capacity for water cleaning these paraments and giving rise to the so-called washed dirty.

The formation of stains in facades, in most cases, is closely attributed to the presence of the paraments which constitute the building, such as windowsills, drip pans, among many others. Associated with elements of climate and urban ambience, these parts of the building will contribute to the processes of deterioration or staining, showing the strong influence of driving rain. However, the stains can also occur not by the direct influence of the elements of the facades, but directly by the effect of condensation in external masonries, mainly those with lower temperature (south façade, in Goiania-Brasil) throughout the day, giving the fantomes.

It is evident that the discrimination between stains of air pollutants and the growth of microorganisms can only be made based on microbiological analysis. In the case in question, was detected the presence of at least one type of micro-organism in pathological manifestations studied, often described in the literature only as dirt. It was also noted that the influence of weather determines the predominance of the growth of certain microorganisms, such as, for example, the higher incidence of solar radiation, in the case of phototrophics identified on facades N and W. It was also observed that the actinomycetes growth can also arise about ceramic rendering, the fact still unknown to researchers.

Finally, it should be noted that, although the buildings are located in Goiania in a region considered to be protected according to the classification as exposure to driving rain from Chand and Bhargava (2002), there was a loss of durability of facades in less than 10 construction years. This indicates the need for creation of new classifications for the exposure conditions also considering the directional driven rain indexes and for taller buildings (over 40 meters).

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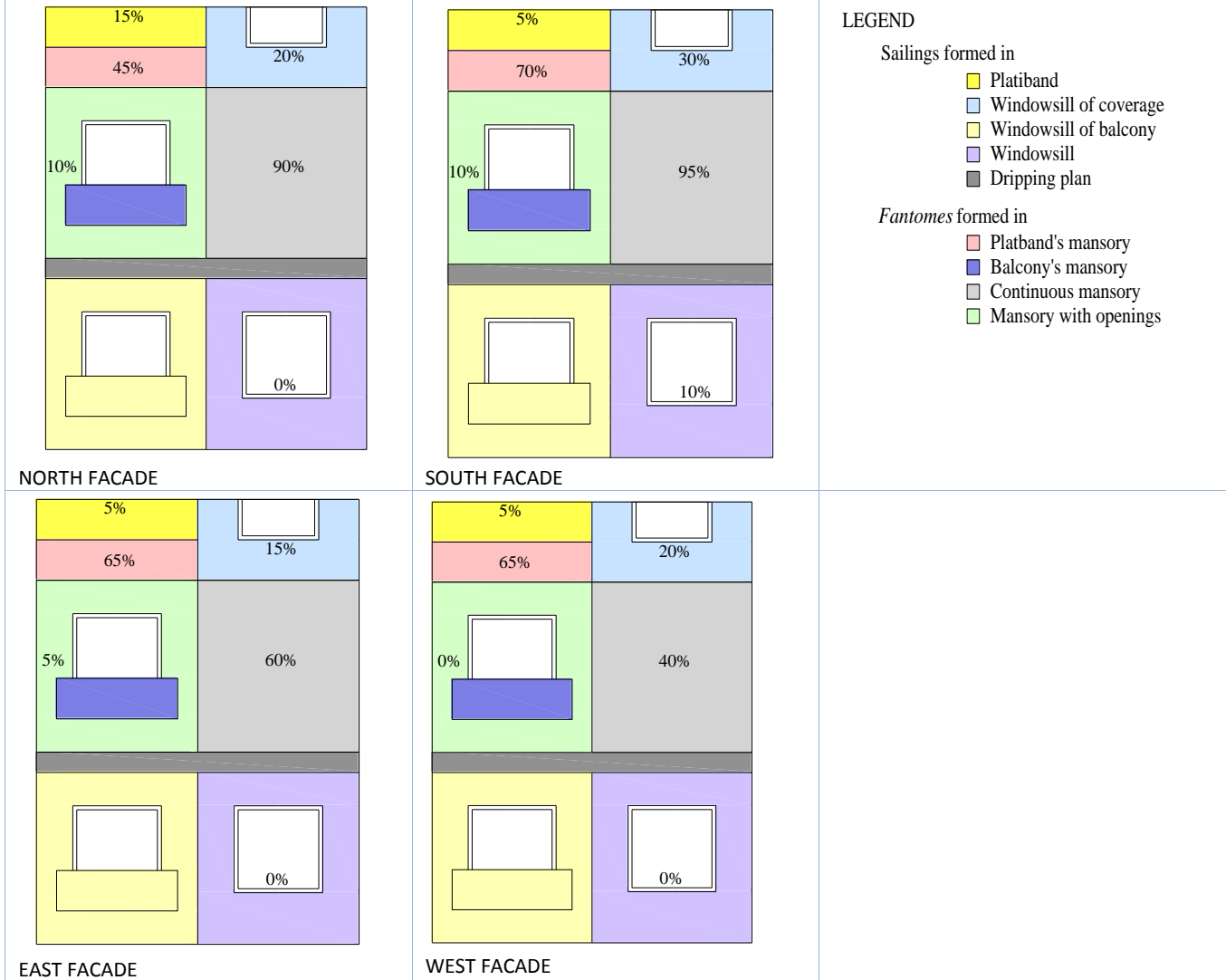
Fig. 3: *Monthly directional driving rain indexes (m²/s) for Goiania, from 2002 to 2008 (Developed by the authors)*
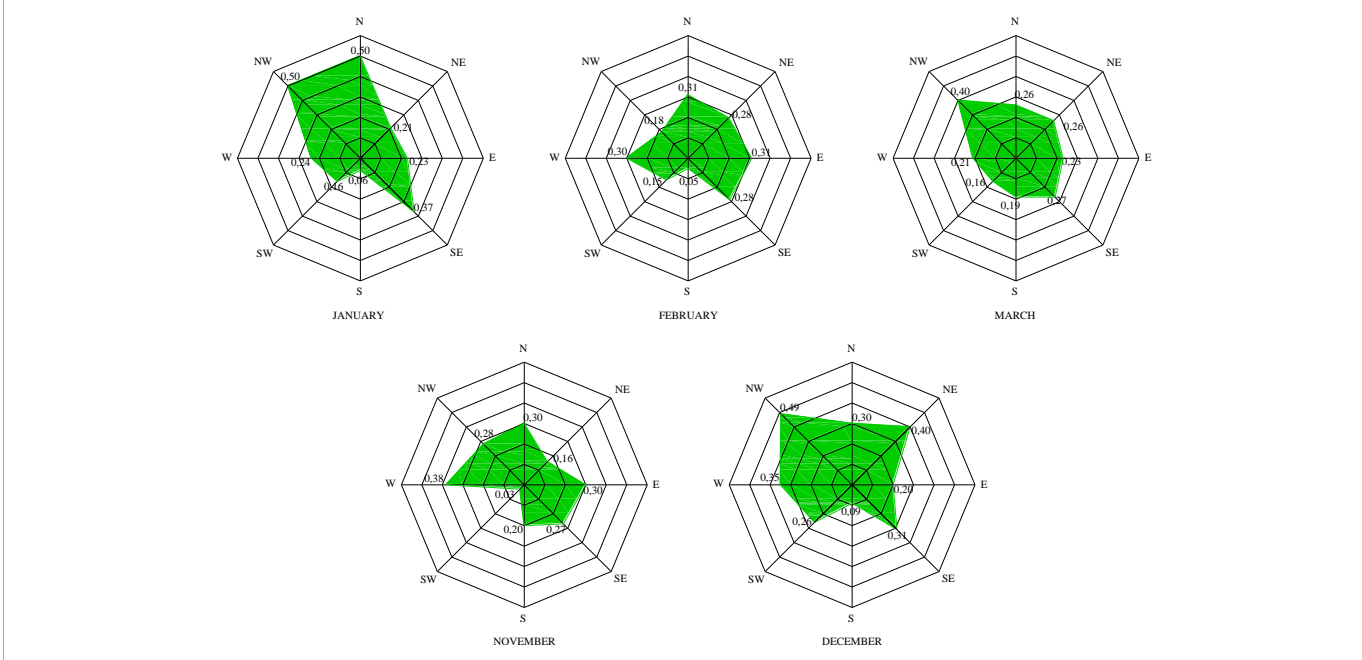
Tab. 3: *Annual driving rain indexes (Developed by the authors)*

Year	Annual rainfall with wind (mm)	Average wind speed (m/s)	Annual Driving Rain Index – aDRI (m²/s)	Ranges of Exposure by Chand and Bhargava (2002)
2002	956.7	2.1	2.01	Protected
2003	1004.2	1.9	1.91	Protected
2004	1236.2	1.5	1.85	Protected
2005	1186.6	1.8	2.14	Protected
2006	1261.9	1.7	2.15	Protected
2007	794.6	1.7	1.35	Protected
2008	1366.2	1.7	2.32	Protected
Average	1115.2	1.8	2.01	Protected
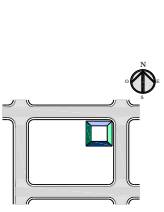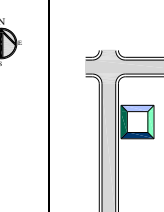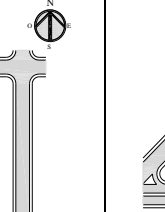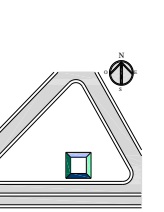
Fig. 6: *Maps of staining percentages of building 1 (Developed by the authors)*

LEGEND

Sailings formed in
- ⬛ Platiband
- ⬛ Windowsill of coverage
- ⬛ Windowsill of balcony
- ⬛ Windowsill
- ⬛ Dripping plan

Fantomes formed in
- ⬛ Platband's mansory
- ⬛ Balcony's mansory
- ⬛ Continuous mansory
- ⬛ Mansory with openings

Tab. 4: *Compilation of the facades staining results (Developed by the authors)*

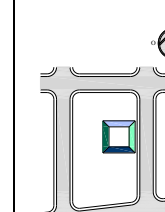| Region	Building 1				Building 2				Building 3				Building 4				Building 5			
	N	S	E	W	N	S	E	W	N	S	E	W	N	S	E	W	N	S	E	W
Staining in platband	15	5	5	5	20	1	1	5	55	5	5	25	5	5	5	5	0	0	0	0
Staining in windowsill of coverage	20	30	15	20	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Staining in windowsill of balcony	-	-	-	-	-	-	-	-	1	0	0	1	-	-	-	-	-	-	-	-
Staining in windowsill	0	10	0	0	1	10	1	0	0	0	0	0	10	30	10	15	40	65	80	100
Staining in dripping plans	-	-	-	-	0	95	5	5	60	100	-	-	30	95	0	70	20	95	25	30
Ghost-like stains in platband of masonry	45	70	65	65	60	80	30	50	35	90	60	65	40	65	40	50	0	0	0	0
Ghost-like stains in balcony of masonry	-	-	-	-	-	-	-	-	70	40	10	50	-	-	-	-	-	-	-	-
Ghost-like stains in continuous walls	90	95	60	40	0	0	0	0	5	10	-	-	-	-	20	25	-	-	0	0
Ghost-like stains in walls with openings	10	10	5	0	0	0	0	1	0	1	0	0	55	60	15	0	0	3	0	0

Tab. 2: *Data from case-studies buildings (Developed by the authors)*

Building	1	2	3	4	5
Figure					
Localization	Latitude: 16°41'31.99" S Longitude: 49°16'30.59" W	Latitude: 16°42'55.49" S Longitude: 49°16'41.65" W	Latitude: 16°41'31.83" S Longitude: 49°16'30.45" W	Latitude: 16°40'42.18" S Longitude: 49°14'15.63" W	Latitude: 16°41'17.26" S Longitude: 49°16'45.43" W
Site plan					
Age of the building	10	6	10	5	10
Number of floors	18	14	15	15	16
Height (m)	54	42	45	45	48
Area of ceramic coating (%)	-	-	2.5	-	4.0

Tab. 5: *Average of the compilation of the results over facades staining (Developed by the authors)*

Region	N	S	E	W
Staining in platband	19	3	3	8
Staining in windowsill of coverage	20	30	15	20
Staining in windowsill of balcony	1	0	0	1
Staining in windowsill	10	23	18	23
Staining in dripping plans	28	96	10	35
Ghost-like stains in platband of masonry	36	61	39	46
Ghost-like stains in balcony of masonry	70	40	10	50
Ghost-like stains in continuous walls	32	35	20	16
Ghost-like stains in walls with openings	13	15	4	0

Tab. 6: *Samples Result (Developed by the authors)*

Samples	Building	Region	Orientation	Decorative finish	Presence of fungi	Presence of phototrophics	Presence of actinomycetes
1	1	Windowsill	North	Ceramic coating	Discreet	No	89 UFC/mL
2	2	Platband	North	Painting	Absence	3.2×10^5 UFC/ml	Absence
3	2	Platband	South	Painting	4.7×10^3 UFC/ml	Discreet	Absence
4	2	Platband	No (top of platband)	Painting	Discreet	1.14×10^4 UFC/ml	Absence
5	3	Windowsill	West	Acrylic texture	Discreet	7.1×10^5 UFC/ml	Absence

UFC=Units Forming Colony