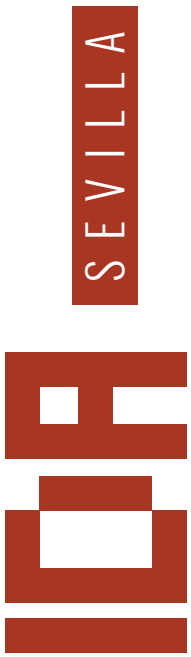
SEVILLA

IDA: ADVANCED DOCTORAL RESEARCH IN ARCHITECTURE



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Antonio Tejedor Cabrera, Marta Molina Huelva (comp.)

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EDITOR
Universidad de Sevilla

COMPILERS
Antonio Tejedor Cabrera
Marta Molina Huelva

DESIGN AND LAYOUT BY
Pablo Blázquez Jesús
María Carrascal Pérez
Daniel Longa García
Marina López Sánchez
Francisco Javier Navarro de Pablos
Gabriel Velasco Blanco

ADMINISTRATION AND SERVICES STAFF
Adoración Gavira Iglesias

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FORMATO

Mesas temáticas
Las mesas temáticas son lugares de presentación de las metodologías y las experiencias de jóvenes doctores y de estudiantes de doctorado procedentes de las diferentes universidades. Son gestionadas por los propios estudiantes de doctorado que generan unas conclusiones para ser debatidas y reelaboradas en la sesión plenaria final. Las sesiones se desarrollan de manera simultánea con la presentación de los *papers* seleccionados en la *call*, organizados en cuatro áreas o líneas temáticas:

1. Tecnologías de la Arquitectura
2. Vivienda, Ciudad y Territorio
3. Patrimonio y Rehabilitación
4. Análisis y Proyectos Avanzados

Taller
El workshop del Congreso se orienta hacia el análisis de los problemas y las necesidades de gestión de los Programas de Doctorado con el fin de extraer conclusiones que pueden ser útiles a las Universidades implicadas. En el workshop participan los coordinadores de los programas de Doctorado en Arquitectura y los representantes de los doctorandos. Son temas de debate: las líneas de investigación, las metodologías, las necesidades organizativas de los programas de doctorado, el Doctorado Internacional y el Doctorado Industrial, y el futuro de la investigación doctoral.

Sesiones Plenarias
Las sesiones plenarias se realizan al inicio y al final del Congreso. En la primera sesión de bienvenida e introducción al Congreso se invita a participar a expertos investigadores del panorama nacional e internacional y a los coordinadores de los programas de doctorado. En la segunda sesión plenaria se propone un debate abierto para la reelaboración de las propuestas extraídas del taller y de las mesas temáticas. Sirve también de clausura con la presentación de las conclusiones finales del Congreso IDA_Sevilla 2017.

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FOREWORD

The Instituto Universitario de Arquitectura y Ciencias de la Construcción (IUACC), in collaboration with the Escuela Técnica Superior de Arquitectura (ETSAS) and the Escuela Internacional de Doctorado (EIDUS) of the University of Seville are pleased to welcome the heads of research from both Spanish and overseas universities, consolidated researchers and young doctoral researchers to the First International Congress of Doctorates in Architecture IDA Sevilla, from 27th to 28th November 2017.

The **IDA_Sevilla 2017** Congress offers a general perspective of doctoral studies in the field of Architecture and its related disciplines: urban planning, heritage, landscape, construction technologies and sustainability. In the new context generated after the elimination of the doctoral programs prior to RD 99/2011, it is necessary to carry out an analysis of the complex panorama that the former programs and the new doctoral programs have drawn up, in order to know in detail both what has been achieved so far, as well as the challenges of the future of advanced doctoral research in Spain, in the European and international context.

The startling changes that are taking place in our society call for a vision of research that is not compartmentalised into traditional disciplines or areas of knowledge. Doctoral research in Architecture must adapt to changes in society and to the sustainable productive needs of territory.

The congress will take place at the Escuela Técnica Superior de Arquitectura de Sevilla, organised in four simultaneous thematic tables, a workshop on the administration of doctoral programs and two plenary sessions.

The **thematic tables** are aimed at young doctors and doctoral students of the different participating universities who will present their experiences and methods of their research - in development or recently concluded. The participation in the thematic tables is carried out through the selection procedure with blind peer review established in the call for papers and through express invitations to the debate. The almost 70 communications have been structured in four thematic areas representative of the PhD programs in Architecture.

The **open workshop** will be held in two sessions with the participation of the coordinators of each of the collaborating programs of the Congress, and professors with extensive doctoral experience. Its objectives are multiple: to discuss the experiences undertaken in the different universities, exchange ideas about the approaches and models applied, address the challenges of internationalization and management, launch the new Industrial Doctorate with companies and public agencies, and so on.

There are two **plenary sessions**: one, a plenary session of introduction to the congress, with the participation of coordinators of national and foreign doctoral programs; and a closing plenary session, with an open debate for the going-over of the conclusions drawn from the thematic tables and the workshop, and the presentation of final conclusions.

We thank the Escuela Internacional de Doctorado of the University of Seville, and the Escuela Técnica Superior de Arquitectura de Sevilla for the support they have provided for the holding of this meeting, which contributes so much to the clarification of the future of doctoral studies in Spanish universities in the face of the great challenge of internationalization and the continuous improvement of the quality of research in Architecture. We also thank those responsible for the participating Doctoral Programs, the Architecture library of the US and all the participants and attendees.

Antonio Tejedor Cabrera
Marta Molina Huelva

Conference Chairpersons IDA_Sevilla 2017
Instituto Universitario de Arquitectura y Ciencias de la Construcción IUACC

PRÓLOGO

El Instituto Universitario de Arquitectura y Ciencias de la Construcción (IUACC), con la colaboración de la Escuela Técnica Superior de Arquitectura (ETSAS) y la Escuela Internacional de Doctorado (EIDUS) de la Universidad de Sevilla, se complacen en recibir a los responsables de investigación de universidades españolas y extranjeras, a los investigadores consolidados y a los jóvenes investigadores de doctorado en el I CONGRESO INTERNACIONAL DE DOCTORADOS EN ARQUITECTURA IDA_Sevilla, del 27 al 28 de noviembre de 2017.

El congreso **IDA_Sevilla 2017** ofrece una perspectiva general de los estudios de doctorado en el campo de la Arquitectura y sus disciplinas afines: urbanística, patrimonio, paisaje, tecnologías de la construcción y sostenibilidad. En el nuevo contexto generado tras la extinción de los programas doctorales anteriores al RD 99/2011 es necesario realizar un análisis del complejo panorama que han construido los programas extintos y los nuevos programas de doctorado, con el objeto de conocer con detalle tanto lo conseguido hasta ahora como los retos que depara el futuro de la investigación doctoral avanzada en España, en el contexto europeo e internacional.

Los vertiginosos cambios que se están produciendo en nuestra sociedad reclaman una visión de la investigación no compartimentada en disciplinas o áreas de conocimiento tradicionales. La investigación doctoral en Arquitectura debe adaptarse a los cambios de la sociedad y a las necesidades productivas sostenibles en el territorio.

El congreso se celebra en la Escuela Técnica Superior de Arquitectura de Sevilla organizado en cuatro mesas temáticas simultáneas, un taller sobre la gestión de los programas de doctorado y dos sesiones plenarias.

Las **mesas temáticas** están dirigidas a los jóvenes doctores y a estudiantes de doctorado de las diferentes universidades participantes que exponen sus experiencias y métodos sobre las investigaciones en desarrollo o recientemente concluidas. La participación en las mesas temáticas se realiza por el procedimiento de selección con revisión por pares ciegos establecido en la *call for papers* y por medio de invitaciones expresas al debate. Las casi 70 comunicaciones se han estructurado en cuatro áreas temáticas representativas de los programas de doctorado en Arquitectura.

El **taller** de puesta en común se realiza en dos sesiones con la participación de los coordinadores de cada uno de los programas colaboradores del Congreso y de profesores con amplia experiencia doctoral. Sus objetivos son múltiples: debatir sobre las experiencias desarrolladas en las distintas universidades, intercambiar ideas sobre los enfoques y los modelos aplicados, abordar los retos de internacionalización y de gestión, poner en marcha el nuevo Doctorado Industrial con empresas y agencias públicas, etc.

Las **sesiones plenarias** son dos: una sesión plenaria de introducción al congreso, con la intervención de coordinadores de programas de doctorado nacionales y extranjeros; y una sesión plenaria de clausura, con un debate abierto para la reelaboración de las conclusiones extraídas de las mesas temáticas y del workshop y la presentación de las conclusiones finales.

Agradecemos a la Escuela Internacional de Doctorado de la Universidad de Sevilla y a la Escuela Técnica Superior de Arquitectura de Sevilla el apoyo que han proporcionado para la realización de este encuentro que tanto contribuye a clarificar el futuro de los estudios doctorales en las universidades españolas ante el gran reto de la internacionalización y la continua mejora de la calidad de la investigación en Arquitectura. Damos los gracias también a los responsables de los Programas de Doctorado participantes, a la Biblioteca de Arquitectura de la US y a todos los participantes y asistentes.

Antonio Tejedor Cabrera
Marta Molina Huelva

Directores Congreso IDA_Sevilla 2017
Instituto Universitario de Arquitectura y Ciencias de la Construcción IUACC

OBJECTIVES

1. Analyze the research lines of the various programs and build a map of doctoral research in Spain with the support of coordinators, tutors / thesis supervisors, doctoral students and young doctors in the disciplines related to Architecture and their related areas.

2. To know the status of doctoral theses in progress or defended in the last three years, selected by means of a call with blind peer evaluation of the doctoral programs participating in the congress.

3. Discuss the structure and university management of doctoral programs in relation to employment challenges, collaboration with the productive sector and national research programs.

4. Exchange experiences with other international doctoral research programs on international mobility management, theses with international mention, co-supervised theses, theses with industrial mentions, etc.

5. No less important, consolidate a national and international network of Doctoral Programs related to Architecture, Urban Planning, Heritage, Landscape, Technologies and related disciplines.

IDA ADVANCED DOCTORAL RESEARCH SEVILLA 2020

LT 1 ARCHITECTURE TECHNOLOGIES

LT 2 HOUSING, CITY AND TERRITORY

LT 3 HERITAGE AND REHABILITATION

LT 4 ANALYSIS AND ADVANCED PROJECTS

FORMAT

Thematic tables
The thematic tables are places to present the methodologies and experiences of young doctors and doctoral students from different universities. They are managed by the doctorate students themselves, who generate conclusions to be debated and reworked in the final plenary session. The sessions are developed simultaneously with the presentation of the papers selected in the call, organized in four areas or thematic lines:

1. Architectural technologies
2. Housing, city and territory
3. Heritage and Rehabilitation
4. Analysis and advanced projects

Workshop
The workshop of the Congress is oriented towards the analysis of the problems and management needs of the Doctorate Programs, with the objective of arriving at conclusions that may be useful to the Universities involved. The coordinators of the Doctorate in Architecture programs and the doctoral students' representatives will participate in the workshop. The following are topics for debate: lines of research, methodologies, organizational needs of the doctoral programs, the International Doctorate and the Industrial Doctorate, and the future of doctoral research.

Plenary Sessions
The plenary sessions are held at the beginning and end of the Congress. In the first session of welcome and introduction to the Congress, researchers from the national and international scene and the coordinators of the doctorate programs are invited to participate. In the second plenary session an open debate is proposed for the going over of the proposals drawn from the workshop and the thematic tables. It also serves as a closing ceremony with the presentation of the final conclusions of the 2017 IDA_Sevilla Congress.

OBJETIVOS

1. Analizar las líneas de investigación de los diversos programas y construir el mapa de la investigación doctoral en España con el apoyo de los coordinadores, los tutores/directores de tesis, los doctorandos y los jóvenes doctores en las disciplinas relacionadas con la Arquitectura y sus áreas afines.

2. Conocer el estado de las tesis doctorales en marcha o defendidas en los últimos tres años, seleccionadas por medio de una *call* con evaluadores por pares ciegos de los programas de doctorado participantes en el congreso.

3. Debatir sobre la estructura y la gestión universitaria de los programas de doctorado en relación con los retos de empleo, colaboración con el sector productivo y los programas nacionales de investigación.

4. Intercambiar experiencias con otros programas de investigación doctoral a escala internacional sobre gestión de la movilidad internacional, tesis con mención internacional, tesis en cotutela, tesis con mención industrial, etc.

5. No menos importante, consolidar una red nacional e internacional de Programas de Doctorado relacionados con la Arquitectura, la Urbanística, el Patrimonio, el Paisaje, las Tecnologías y sus disciplinas afines.

IDA INVESTIGACIÓN DOCTORAL AVANZADA

LT 1 TECNOLOGÍAS DE LA ARQUITECTURA

LT 2 VIVIENDA, CIUDAD Y TERRITORIO

LT 3 PATRIMONIO Y REHABILITACIÓN

LT 4 ANÁLISIS Y PROYECTOS AVANZADOS


IDA
SEVILLA

LT 1

TECNOLOGÍAS DE LA ARQUITECTURA

ARCHITECTURE TECHNOLOGIES / TECNOLOGÍAS DE LA ARQUITECTURA

ENVELOPE'S ENERGY PERFORMANCE OF UNIVERSITIES BUILDINGS LOCATED IN BAHIA – BRAZIL

Santana, Bruno [(1)]; Coch, Helena [(2)]

(1) Architecture & Energy. School of Architecture of Barcelona UPC. bosantana@gmail.com.
(2) Architecture & Energy. School of Architecture of Barcelona UPC. helena.coch@upc.edu.

Resumen: The research elects as its theme the energy efficiency at universities buildings located at different cities of Brazil. Based on the recent Brazilian's university spread, the object of study elected is three classroom pavilion built at different inner cities of Bahia / Brazil (Barreiras, Cruz das Almas and Vitória da Conquista) based upon the same architectural project. It will be evaluated the envelope's energy performance of these three buildings and their thermal impact into the classrooms. The energy analysis carried out until now are based on technical data of these three classroom pavilions, some of them collected *in situ*, and on computational simulations. From this analysis it is possible to point out some envelope's weak characteristics of each building and the major guidelines for a future retrofit.

Keywords: Energy efficiency, Educational building, Retrofit, Hot climate.

1. Introduction

The research elects as its theme the energy efficiency at universities buildings located at different cities of Brazil, all of them distinguished by their hot climates. Based on the recent Brazilian's university spread, the object of study is three classroom pavilions built at different inner cities of Bahia / Brazil (Barreiras, Cruz das Almas and Vitória da Conquista), constructed by 2006-2008 and based on the same architectural project.

This research aims to analyze the envelope's energy performance of this standard project at their different sites. Hence, it will take into account its bioclimatic strategies at different sites, their set up characteristics and the envelope's thermal impact to indoor environment.

Many authors dedicated to energy efficiency in buildings point out vernacular architecture as a source of passive design strategies adapted to each climate (Olgyay, 1963; Givoni, 1969; Serra y Coch, 1995; Lechner, 2000). By the other side, the HVAC systems are so incorporated at buildings and urban lifestyle that the energy efficiency's challenge is the integration of passive solutions with systems that use less energy as possible in order to provide suitable environment conditions into the buildings.

The research establishes as hypothesis that the use of the same architectural project, at different climates, will difficult the energy performance at any of its locations. Kowaltowski (2011) points out that standard design's adaptation to each location, with its different topographies, solar orientations and direction of winds, is the major problem faced by this kind of construction. Orce Schwarz et al. (2012) present a secondary school standard architectural design built at different sites of Argentina, but with the appropriate changes. Measurements and simulations were realized so to guide the necessary modifications in the standard project's bioclimatic strategies and its materials. This experience shows a possible strategy of how to build educational buildings based on a standard project, but adapted to the site's climatic conditions.

In 2009 it was published the Brazilian normative about energy efficiency at buildings that establishes labels for the energy performance: since "A" (most efficient) to "E" (less efficient), considering the eight climatic zones of the country. If applied this normative, it's estimated energy savings from 30%, in cases of retrofit, to 50% for new buildings (Melo et al. 2014).

Regarding to this, some researches focus on constructive solutions to improve the envelope's thermal performance of Brazilian buildings: the use of double-skin façade and its adaptation to the different climatic zones of Brazil (Atem, 2016; Barbosa et al., 2015), which depends on the façades' orientation and the appropriate definition of cavity's dimension in order to provide adequate airflow rates; computational simulations as an evaluation tool for designing envelope's solutions for office buildings set up at hot and humid climate, very common at Brazil's Northeast region (Venancio y Pedrini, 2009). These academic works highlights the façades' thermal loads inwards the indoor environment. In cases of hot climatic zones, avoiding the exterior thermal loads plays an important role as a passive strategy.

This research also looked for bibliographical references dedicated to educational buildings' retrofit at Europe, especially those that aim to reach the nZEB standard (nearly Zero Energy Building). Despite

the climatic differences, these references bring about new technical parameters to the research (Trachte y De Herde, 2014; Gaitani et al., 2015). Furthermore, some academic works dedicated to educational buildings located at Mediterranean region presents similar situations related to avoiding exterior thermal loads, especially the use of natural light and its negative thermal impact during Spring and Summer European seasons (Carbonari, 2012).

2. Methodology

The methodology implemented in this research carried out the following activities: climate description of each city; standard project's technical description; data collection *in situ*, including classrooms' measurements of indoor air temperature; computational model elaboration to simulate the energy performance with the software Designbuilder v.4.5. The measurements and the data collected were used to validate each computational model.
From these validated computational models, it were carried out simulations to evaluate each building envelope and their impact on each classroom's thermal performance

2.1. *Climate description of each city*

The classroom pavilions were built are Vitória da Conquista, Barreiras and Cruz das Almas. The Brazilian building's energy performance normative (NBR 15520/2003) classify these cities at distinguished climatic zones. Their climatic characteristics are:

• Vitória da Conquista: 14º5'S, located at 923 meters above sea level, its climate is characterized by (INMET): annual average temperature of 20ºC; annual average oscilation of 11ºC; annual average relative humidity of 80,8%; annual precipitation of 765 mm; two defined season (summer and winter). It's classified as Climatic Zone 5 by NBR 15.220/2003 (Fig. 1);

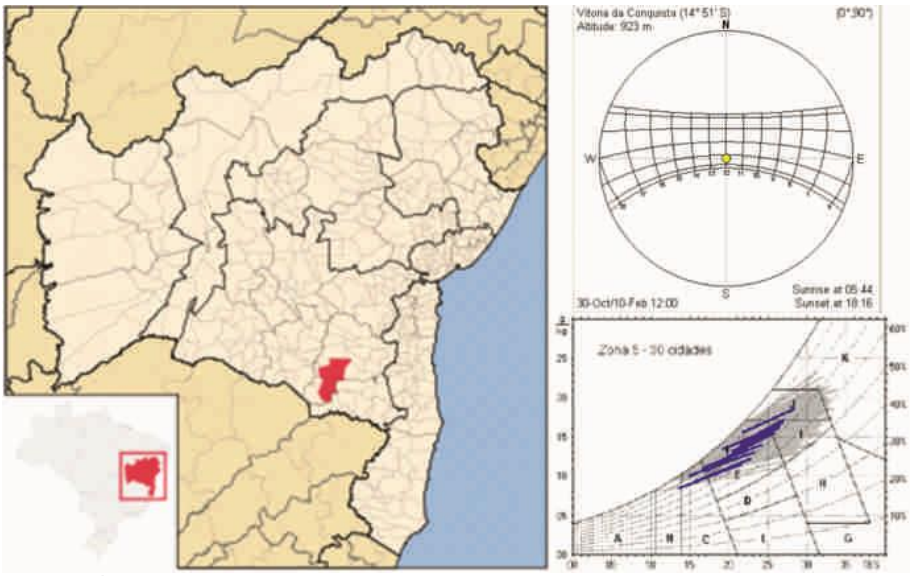

Fig. 1 Vitória da Conquista's location, its stereographic projection and the psychrometric chart of Climatic Zone 5. Source: http://www.ibge.gov.br (access in December/2015); NBR 15.220/2003; Heliodon v. 2.6-01

• Barreiras: 12°S, located at 452 meters above sea level, its climate is characterized by (INMET): annual average temperature of 25ºC; annual average oscilation of 13ºC; annual average relative humidity of 61,5%; annual precipitation of 956,5 mm; without a defined season because it's always hot, but with a dry period between May and September. It's classified as Climatic Zone 7 by NBR 15.220/2003 (Fig. 2).

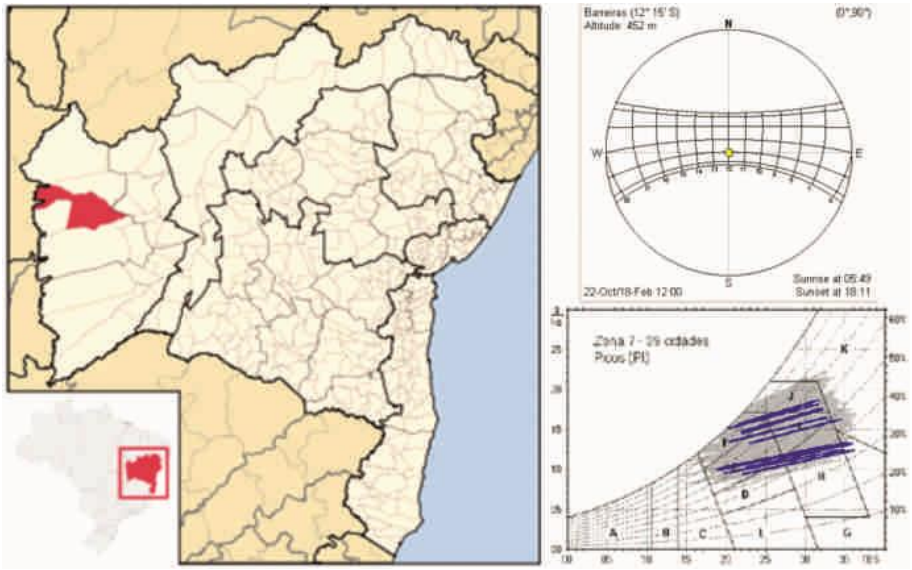

Fig. 2 Barreiras's location, its stereographic projection and the psychrometric chart of Climatic Zone 7.
Source: http://www.ibge.gov.br (access in December/2015); NBR 15.220/2003; Heliodon v. 2.6-01

• Cruz das Almas: 12º S, it´s the city more close to the Atlantic Ocean, located at 220 meters above sea level. Its climate is characterized by (INMET): annual average temperature of 23ºC; annual average oscilation of 4ºC; annual average relative humidity of 83,6%; annual precipitation of 1136 mm; without defined seasons because it's always hot and humid. It's classified as Climatic Zone 8 by NBR 15.220/2003 (Fig. 3).

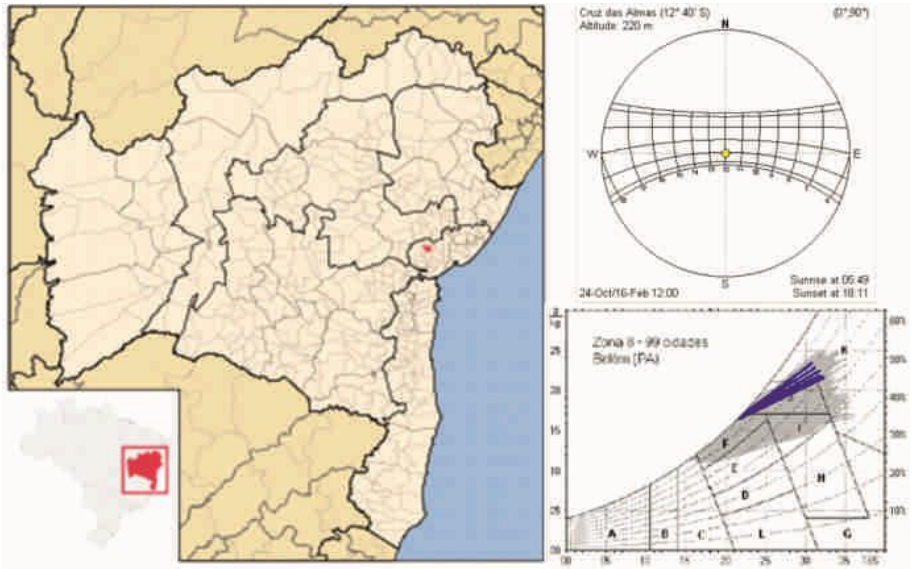

Fig. 3 Cruz das Almas's location, its stereographic projection and the psychrometric chart of Climatic Zone 8.
Source: http://www.ibge.gov.br (access in December/2015); NBR 15.220/2003; Heliodon v. 2.6-01

2.2. *Standard project's technical description*

The standard project used to build the classroom pavilion at Vitória da Conquista, Barreiras and Cruz das Almas is characterized by (Fig. 4 - 5):

• Two-story building with a central block that connects four others blocks (A, B, C, D). The main access, central corridor and administrative offices are located at the central block. The classrooms and the teacher's offices are located at the other blocks. At Vitória da Conquista a library were located at block A's ground floor while it's not built a specific place for this. The building has 4,284.60 m^2.

• The walls are constructed with hollow concrete blocks of 11cm covered with a single layer mortar and painted with clear colors. Its thermal transmittance coefficient is of 2.28 $W/m^2.K$ and its heat capacity is of 1.67 $kJ/m^2.K$. The Brazilian normative indicates that this constructive system has a thermal inertia of 3. Hours approximately. The exterior windows are made of single glass and

aluminum frame without thermal brake, characterized by a thermal transmittance coefficient of 5.70 $W/m^2.K$.

- Its main bioclimatic strategies are: avoid solar gains by exterior windows using louvers in front of each window; provide crossed ventilation in every classroom by locating windows at parallel walls. The use of lattice at blocks' corridor A, B, C and D look for improving the crossed ventilation at classrooms that just have one exterior façade.
- There's a difference between Cruz das Almas' pavilion and the others two buildings: Cruz das Almas' structural modulation from blocks A, B, C and D follows, by one side, the exterior wall and, by the other side, the inner wall between the corridor and the classrooms. At the other buildings the structural modulation follows the exterior walls. So, in these cases the last classroom of each block is larger than those at Cruz das Almas.

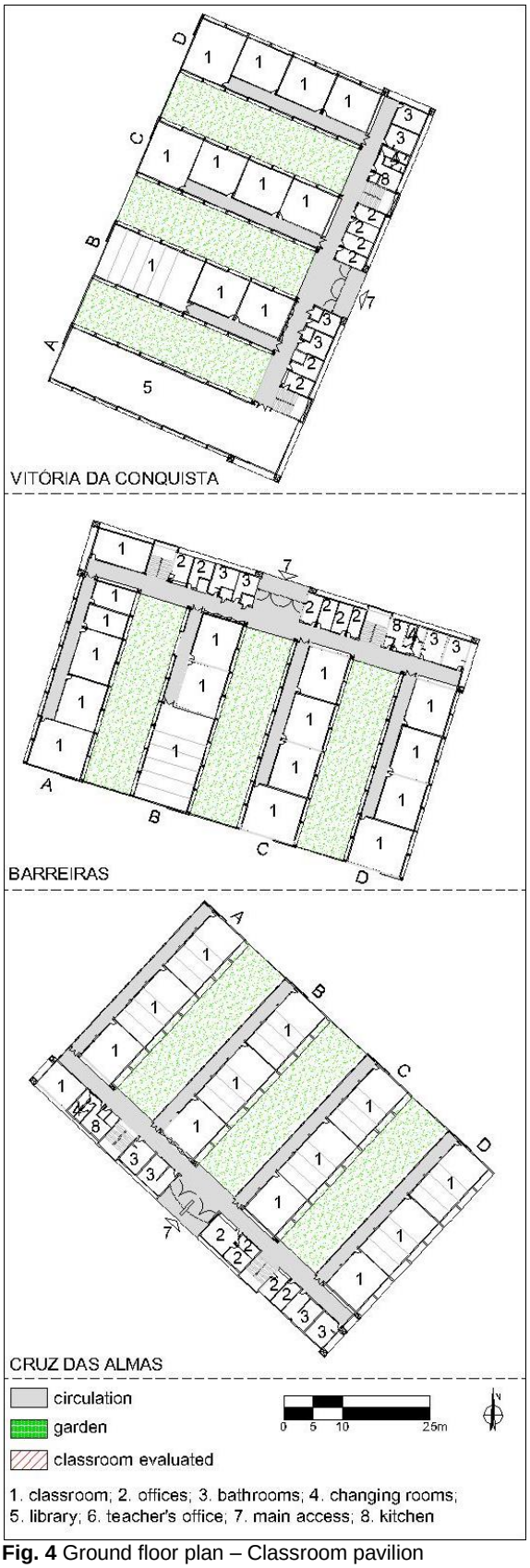

Fig. 4 Ground floor plan – Classroom pavilion

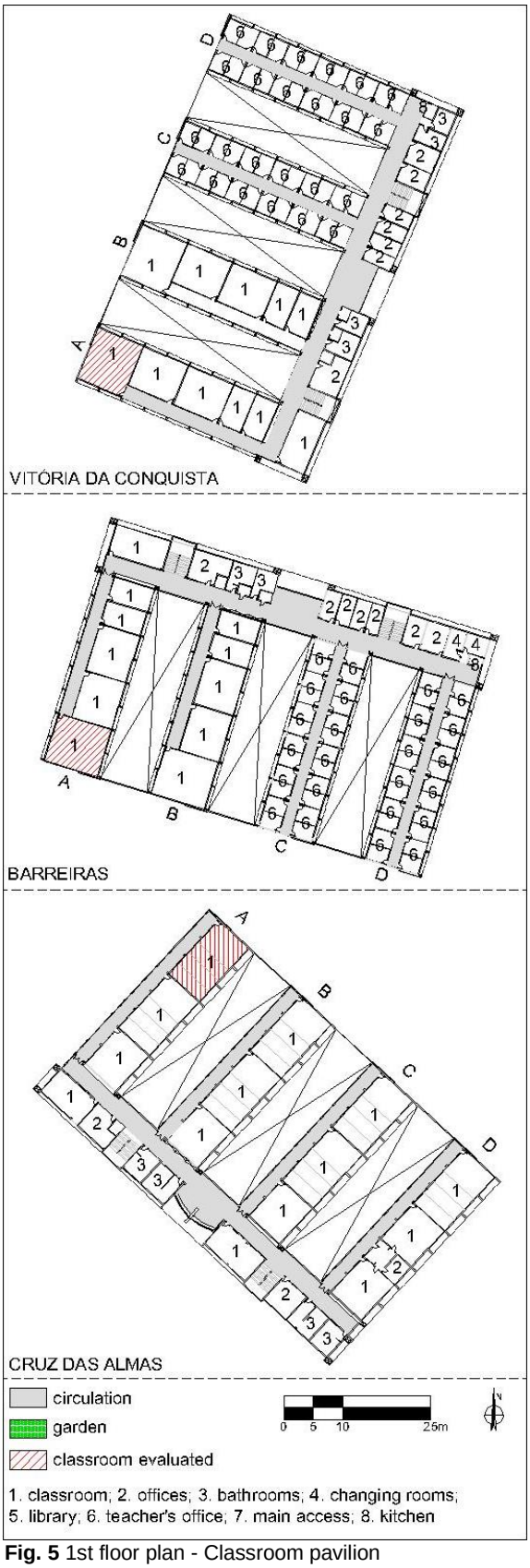

Fig. 5 1st floor plan - Classroom pavilion

2.3. *Data collection in situ*

During August and September/2016 technical visits were realized at the three university campus. The goal was to collect the necessary data about the energy performance of each building and specific classrooms. The period of each technical visit was: Vitória da Conquista, between August 1st and August 9th; Barreiras, between August 22nd and August 30th; Cruz das Almas, between August 31st and September 8th. Unfortunately, there were no classes at Cruz das Almas during these two months because of an employee's strike.
To collect data about the energy performance during the classes, it was asked for the classroom teacher to fill a data sheet filling up: number of students; operation of various equipments (lighting, computer, film projector, HVAC system and its operative temperature, fans, aperture of windows). To measure indoor air temperature it was used a data logger thermometer Testo 174H, placed at 1,20m height. For these measurement were chosen the classrooms more exposed to solar radiation: those ones faced west and located at first floor (Figs. 4 - 5). Moreover, technical data were requested to the infrastructure department of each campus: actualized building plans; technical characteristics of HVAC systems and lighting systems.

2.4. C*omputational model elaboration for energetic simulation*

Based on the collected data, computational models for energetic simulations were elaborated using the software Designbuilder v. 4.5. The initial simulations focused on calibrate the model using the measurements realized as parameter. After the validation of each model, it was simulated the energy performance of each envelope for two periods: one year and a summer typical week, based on the following set up (Table 1).

Table 1. Classroom's simulation set up of each building

	Volume (m^3)	**Infiltration rate (ac/h)**	**Natural ventilation rate (ac/h)**	**Internal loads: occupancy / lighting / equipments (W/m^3)**
Vitória da Conquista	239.00	0.50	0.50	5.26 (7:00h–12:30h); 5.26 (13:00h–18:30h)
Barreiras	239.00	0.50	1.00	5.26 (7:30h–12:30h); 5.26 (13:50h–20:00h) 3.86 (20:00h–22:30h)
Cruz das Almas	260.47	0.50	1.00	4.82 (7:00h–12:30h); 4.82 (13:00h–18:30h)

It's important to highlight some routine conditions that lead to these set ups:

- It was the winter season at Vitória da Conquista during the measurements. So, the windows were generally closed and the HVAC system was always turned off.
- At Barreiras the windows were also generally closed, but by another reason: it was hot and dry. In this classroom, the HVAC was turned on every time it was occupied.
- As there were no classes at Cruz das Almas during the measurements, it was used as reference the occupancy's routines of the others buildings.

3. Simulations analysis

In order to compare the thermal contribution into the classroom of each envelope's element, two groups of energetic simulations were realized: one with monthly and annual periods and the other with a summer typical week. These periods are based on the climatic data of each city and they do not match with summer vacation, between December to February.

Figs. 6 – 8 present the first group simulations. The wall is the envelope's element with the biggest thermal impact into indoor environment. Despite the fact these buildings are located at low latitudes, where the roof generally plays a major role at the envelope's thermal loads, these pavilions have three layers of different materials and two air gaps between the classroom and the roof. So, the thermal gains by the roof are negligible at all sites.

The three graphs highlight the differences between the energy performances of the same building located at distinct sites: while at Vitória da Conquista the flow rate is almost negative during the year, at Barreiras the flow rate through the wall represents the major thermal gain inwards.

The thermal gains by direct radiation through the exterior windows are significant at all sites, although the louvers and the lateral protections existent.

The second group of simulations, during the summer typical week, was chosen because of the extreme conditions faced by the thermal comfort at all sites (Figs. 9 – 11). It is also when the energetic costs rises because of the intense use of HVAC systems.

Based on the Brazilian normative (NBR 16401/2008), the summer temperature range is between 23°C and 26°C. From this, it's possible to affirm that all classrooms' thermal performance go over this parameter. Vitória da Conquista is the less worse situation, where the costs with HVAC system would be lower than the others. It should be emphasized that the wall's thermal load and the operative temperature has similar performances.

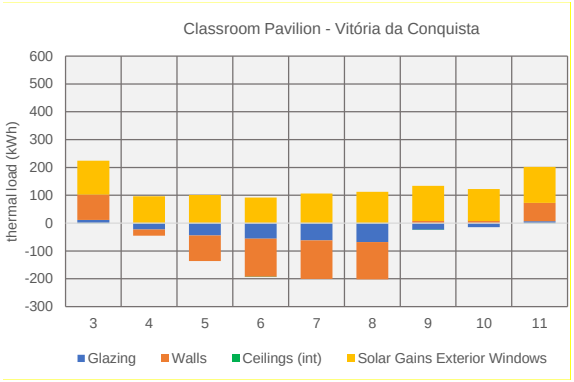

Fig. 6 Monthly envelope's thermal loads
Vitória da Conquista's classroom pavilion

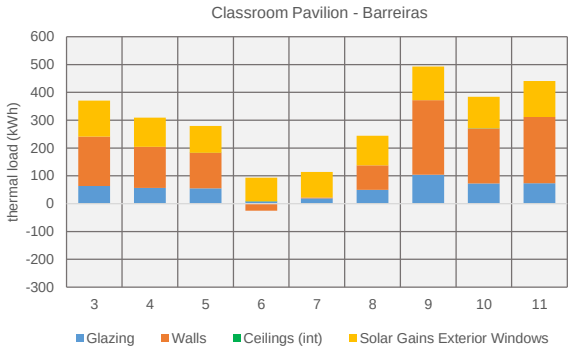

Fig. 7 Monthly envelope's thermal loads
Barreiras' classroom pavilion

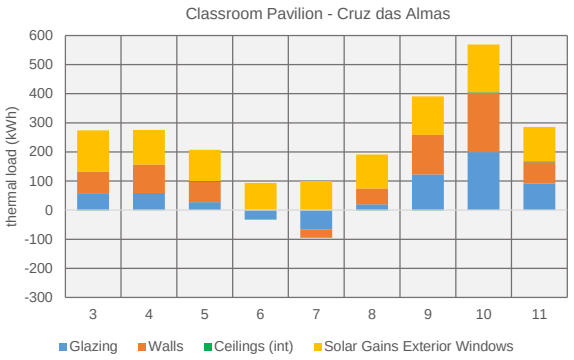

Fig. 8 Monthly envelope's thermal loads
Cruz das Almas' classroom pavilion

Comparing the three cities during the typical summer week, Barreiras presents the higher and the more constant wall's thermal loads. By other side, in all cities the indoor air temperature follows the outdoor air temperature with an approximated delay of 4:30h. For a space dedicated to classes during all day, at Barreiras also in the early evening, the thermal inertia should be greater to avoid indoor air temperature so high.

As Barreiras, Cruz das Almas' indoor air temperature presents a direct relationship with the outdoor air temperature. Furthermore, the operative temperatura lower border is at the limit indicated by the normative. So, any additional thermal load from the envelope should be avoided.

At last, it should be highlighted that all classrooms receives solar gains through the exterior windows.

4. Preliminary conclusions

This research continues realizing computational simulations and evaluating their results in order to present a detailed envelope energy performance's analysis of each building at the end of the doctorate.
However, it's possible to point out some preliminary conclusions:

- The three classroom pavilions were built with orientations that improve the solar gains through walls and exterior windows. About the exterior windows, there were no adaptation of the standard project to each location. Some changes at louvers and lateral protections would avoid these thermal gains;
- The façades' thermal performance are very distinct between then, even at sites with similar latitudes. Therefore, the envelope of each pavilion should be designed to better adapt to each situation;
- This first envelope's performance analysis during summer typical week reveals that should be used different strategies to foster the thermal performance in each case. At Vitória da Conquista, where it's found mild outdoor air temperature, it's posible to avoid thermal gains without structural changes; at Barreiras, the thermal inertia has a major role to avoid the thermal gains because of the high outdoor temperature range; at Cruz das Almas, the thermal inertia is not revelant but it's recommended a ventilated double-skin façade, not just to avoid the thermal gains but also to enable the thermal losses.

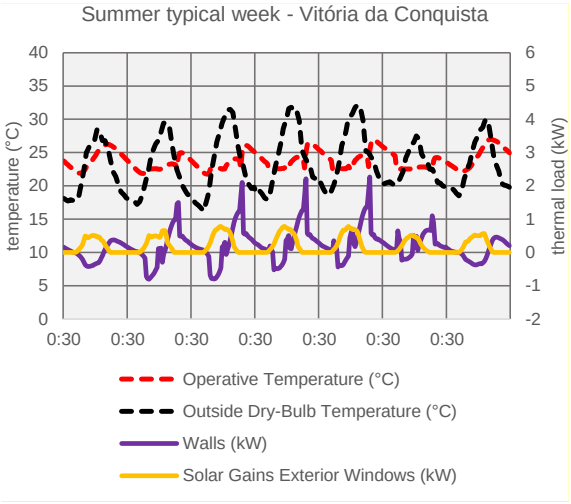

Fig. 9 Summer typical week: thermal loads; operative and outdoor air temperatures - Vitória da Conquista's classroom pavilion

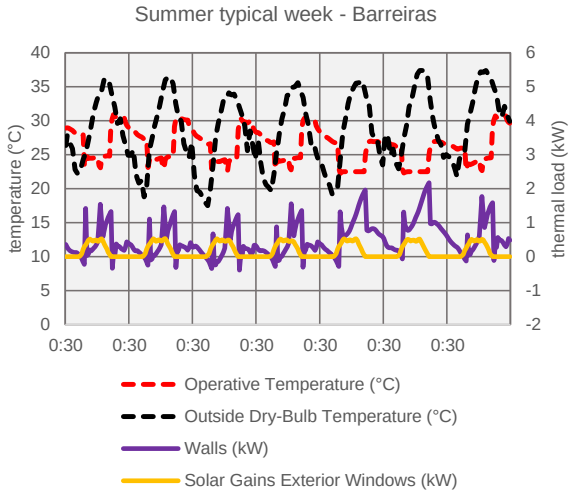

Fig. 10 Summer typical week: thermal loads; operative and outdoor temperatures – Barreiras' classroom pavilion

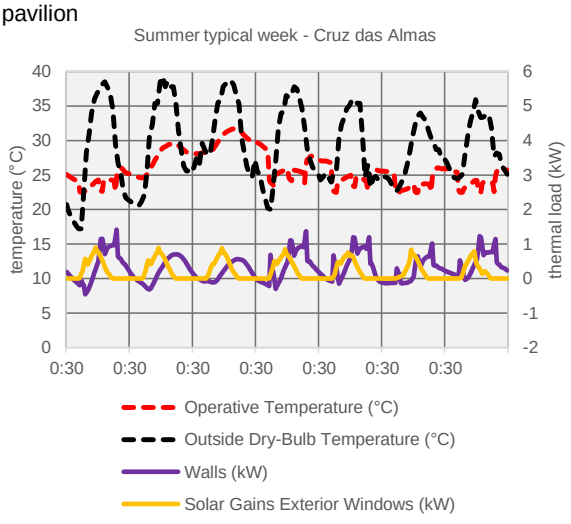

Fig. 11 Summer typical week: thermal loads; operative and outdoor air temperatures - Cruz das Almas' classroom pavilion

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