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Engineering solutions for the social housing, integrated into urban environment

Инженерные решения устройства социального жилья, интегрируемого в городскую среду

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Ключевые слова: гражданское строительство; устойчивое развитие; инфраструктура; энергоэффективность; фавела; окружающая среда

Abstract. Deprived areas integrated into actively developing environment of the modern cities is a burning issue which is being studied in megalopolises of Latin America, Africa and Asia. Diverse controversial issues emerge in the interaction between the city community and inhabitants of the favela. The article deals with the solution for this issue based on the example of interaction between Brazilian favela “Sao Remo” and the University campus of Sao Paulo. Nowadays, this University conducts constant social research to find a suitable integration between both sides of the wall. One of this initiatives was raised in the symposium WC2-2017 which purpose was to elaborate the solution for a social infrastructure to be designed to improve links. Moreover, this infrastructure is sustainable in order to mitigate social, environmental and economic impacts. After an analysis of diverse design strategies, the outcomes were obtained in regard to some technical alternatives which implementation depends on stakeholders’ wiliness to collaborate and understanding to what extent they are ready for compromise.

Аннотация. Неблагополучные районы, интегрированные в активно развивающуюся среду современных городов, являются актуальной проблемой, особенно для мегаполисов Латинской Америки, Африки и Азии. Различные спорные социальные вопросы возникают между городскими общинами и жителями фавелы. В статье рассматривается решение одной из социальных проблем на примере взаимодействия бразильской фавелы "Sao Remo" и университетского городка Сан-Паулу. В настоящее время этот Университет проводит постоянные социальные исследования, чтобы найти подходящую интеграцию между обеими сторонами. Одна из таких инициатив была выдвинута на симпозиуме WC2-2017, целью которого была разработка проекта социальной библиотеки, предназначенной для улучшения связей между университетом и граничащей фавелой. После анализа различных стратегий проектирования было установлено, что наилучшим строительным материалом для данного региона является железобетон, а расположение самой библиотеки должно быть на границе двух взаимодействующих территорий. Реализация данного проекта напрямую зависит от желания заинтересованных сторон сотрудничать и понимания того, в какой степени они готовы к компромиссу.

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1. Introduction

High concentration of poverty and rapid growth of the population within the territory trigger social problems having impact on urban planning of a city. An important example is the “favelas” – Brazilian word to describe a concentration of poor people who live in low quality housing with lack of property rights and primary urban services located in areas geologically inadequate or environmentally sensible [1] – it reflects the extremely unequal economic and social structure of representative cities in Brazil [2]. Most of the citizens who live in favelas are people of lower middle class who cannot afford solutions which housing market offers. From the beginning of 1980 policies of land regulations of the favelas emerged with the focus on urbanizing these areas by using social programs, main public services and relocation from high geological risk [3]. However, due to its rapid proliferation around Brazil and fragmentation of the territory which produces disintegration social [4], nowadays these places have become in spots of lack of participation of the public power and high crime rate, impacting negatively on the people who live there and the surrounding areas. Thus, the urbanization of these places is conceived as a complex integration of the social, environmental and urban spheres [5].

The author [6], through a historical analysis, concluded that the exclusion is main consequence and cause of the expansion of favelas. Moreover, [7–8] affirmed that more than a problem of housing infrastructure, this is a social problem and it should be tackled with integrated programs and promotion of urban planning and inclusive urban management [9]. According to the Secretary of Strategic Affairs of Brasilia DF [10], the lack of integration of these areas with the city deals with two types of consequences: immediate and long-term. The former is the allowance of conditions of illegal activities, segregation, limited presence of the state and guarantee of civil rights and informality, while the latter consequence is opportunities and vision for the future differentiated for the youth and controversial mechanisms for conflict resolution. The secretary recognizes six dimensions to have an effective and sustainable integration: capacity to identify local needs and community action, ability to resolve conflicts, access to public services, economic, physical and symbolic integration and re-signification of the today’s concept of youth conceived in favelas [11].

Different studies have aimed at an inclusive urban management for these sites. Manzione and Antonucci [12] argue that the integration must consider the inclusion of favelas in the mapping of the city and physical and land integration into the formal city. They include also the integration of its inhabitants in the existing social programs and in the discussions on the development ways of the city [13], and of the instruments of planning of the City Statute. Additionally, [5] proposed a model of 5 strategies for the urban requalification of a specific favela in Sao Paulo through the appropriation of interstices and urban interfaces as effective environmental, urban and social infrastructures.

A specific case is the city Sao Paulo, which accounts for the biggest number of favela with more than 15 % (IBGE, 2010) of the population of the city. There is a settled “Jardim São Remo” settlement, with 15 thousand inhabitants, which is a controversial favela because of its contiguous location with the University of Sao Paulo (USP), largest Brazilian public university. However, the land where this favela is situated belongs to the university, but it was historically populated by the inhabitants from Sao Remo. Consequently, as part of this campus, USP is often involved in discussions about the fate of the community [14]. One of the most emblematic and controversial issue which affected the relationship between the community of the campus and the favela was between 1995 and 1997, when the USP built a solid wall with regulated entrance to separate both spaces targeting the preservation of the institute.

Nowadays, sustainability design is one of the main task issues around the world. Each country has its own goals and objectives for the development and preservation of the environment [15–17]. Therefore, the University of Sao Paulo has been working in a sustainable mitigation of the social impacts mentioned. One of its initiatives is the WC2 (World Cities, World Class) Summer Symposium, which took place in 2017 with the focus on integration of the campus community with the people who live in the favela Sao Remo through an infrastructure project. The authors of this paper were involved in the design of efficient and sustainable alternatives of infrastructure throughout the University, which is fenced with the aforementioned wall.

Therefore, the main purpose of this paper is to define the most suitable strategy for the project, which can effectively promote the integration of the USP and the community of the contiguous favela. To archive this goal, the following tasks were solved:

- To consider the main environmental and social factors of the city;
- In the context of detailed consideration of the executed projects to formulate the key factors and main categories for selecting the best solution;

- To choose the most appropriate project, which corresponds to three main categories: location, sustainability, architectures.

2. Methods

The development of this research is based on three different strategies, which are divided in three spheres: location, sustainability and architecture. Those strategies follow common parameters and needs described in the Table 1 and Figure 1, which were consented in the WC2-2017 symposium, hosted by the University of Sao Paulo.

- Localization: this criteria is analysed taking into account the potential social and social impact triggered by setting the construction in the purposed area.
- Sustainability: in this area was technically analysed the materials considered in the architectonic design from the three strategies. Emphasizing the thermal resistance of roof, windows and walls, which are calculated in steady conduction through a constant area plane wall by the Fourier Law. The parameters for resistance for convection indoor and outdoor were taken from the standard IRAM 11601.
- Architectonic: it includes the design and distribution of spaces of each strategy, minding the parameters consented. Autodesk Revit Software and SketchUp program were used to make 3d modeling of the building and topography of the existing area.

Table 1. Parameters of space to be considered

Site area _ around 8.000m²	Sports court (indoors/outdoors) _ 1 or 2
Library _ 1.000m²	Gym (indoors/outdoors) _ 300m²
Multipurpose rooms _ 500m²	Health care facilities _ 500m²
Workshops _ 600m²	Community restaurant _ 300m²
Auditorium _ 500m²	General facilities _400m²
Outdoor arena _ 600m²	Open spaces

Figure 1. General localization of the project

2.1. First strategy

2.1.1. Location

The localization of the infrastructure to be designed remains unchangeable. However, there are some controversial issues which would come out due to the social factor. A demolition of the wall makes it possible to use an informal construction of housing by the population from the favela. Therefore, in order to keep at the same time both a physical border and accessibility, the wall has an open design as described in Figure 3. The access is shown in red arrows with the ease of access for both communities. Moreover, the design takes into consideration the sun going through the wall to the favela.

Figure 2. Localization of the infrastructure for integration of the USP community and Favela Sao Remo

2.1.2. Sustainability

The sustainability of this infrastructure is described in the following aspects: Energy Efficient, Social, Technology and Architecture.

Figure 3. Wall design purposed

The buildings are proposed to be with passive cooling and illumination systems, for that, it is divided in 6 units, which orientation and distribution can guarantee wind flow, sun path and shadows. Additionally, the edifications are suspended from the floor to allow a natural passive ventilation, likewise vertical shading in the façade northwest is meant to allow natural illumination.

The main materials used in this strategy is following described:

- Roof: Green Roof (700 m^2) and Solar Panels (1135 m^2). The former aims an insulation for the ceiling and an open area for pedestrian. The latter aims a solar passive electricity generation, with capacity of 455 solar panels of 1.6mx1m of dimension, producing 200 MWh/year and payback period of 8 years.

- Windows: as the temperature in Sao Paulo is about 28 and 14 °C, a single glass, with blackout curtains systems and brise solei facing in the north is considered in the design.

- Walls: in order to promote a social, environment and energetic integration, the walls are designed with two wood panels with an insulation cavity of cellulose fiber (recycled paper). It is important to notice that the high density of people in favelas carries a high demand of waste to be managed, P. Jacobi [18]. This alternative of recycling can generate opportunities of temporary employment to the surrounding community, which can collect the paper and sell them to the recycling company in charge of the fabrication of this insulation. In fact, as the process of fabrication is not complex and does not require specialized equipment, it can be analyzed the alternative of fabrication inside the campus.

The Figure 4 shows the structure of the purposed and a thermal resistance of 3.10 W/mK is calculated as a thermal parameter in the Table 2. According to this table, the dew point is located in the insulation, which is not a technical problem for its suitable operation.

The social factor as a sustainable factor includes primary services, strategies of promoting inter-community cross-culture interaction. The first mentioned are: water, comfortable indoor temperature, gym and an experimental kitchen, where part of the vegetables harvested in the green roof. The strategies of interaction are trough recreational spaces (Figure 5), balconies, interconnection between buildings and a mobile application to keep up to date to the user.

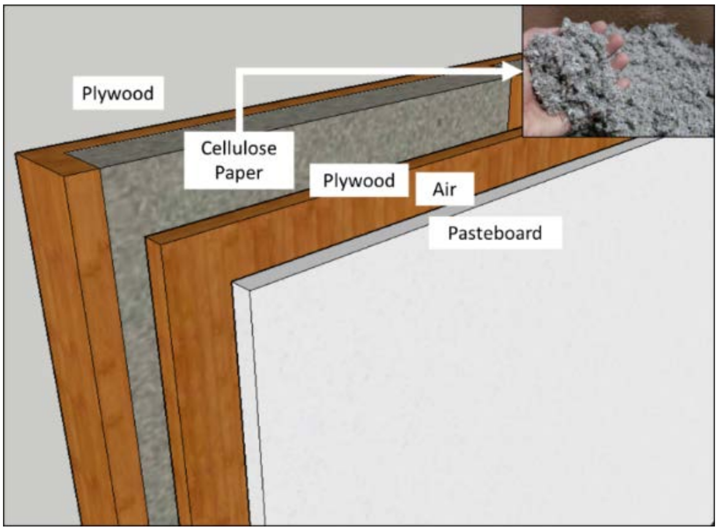

Figure 4. Wall structure for Strategy 1

Table 2. Thermal and Mechanical properties of Wall Strategy 1

Layer	Layer material	Layer thickness [m]	Thermal conductivity [W/m·K]	Specific heat capacity [J/kg/K]	Density [kg/m³]
Indoor					
1	Plywood	0.013	0.130	1600	500
2	**Recycled Cellulose Paper**	0.100	0.040	2020	50
3	Plywood	0.013	0.130	1600	500
4	Air	0.050	0.026	1005	1.25
5	Plasterboard	0.013	0.170	1090	664
Outdoor					

2.1.3. Architecture

Even though the Brazilian law No16.050 of July 2014 (PDE-SP, 2014 [20]) allows as follows: construction of buildings until 8 meters high for this zone, the design ensures the architecture of favelas to remain the same look, so the inhabitants of the surrounding can feel that this infrastructure belongs to this zone. The architecture purposed has no more than 4 floors and is made of brick façade as the surrounding. The library has its own building and it is interconnected with the building for workshops, designed to have a common space for meetings and/or classes lead by volunteers from the University. All buildings are interconnected by bridges as a symbol of integrity and for easy exploring of the facilities. It has an auditorium which north façade works as an outside screen for projection of movies (Figure 4).

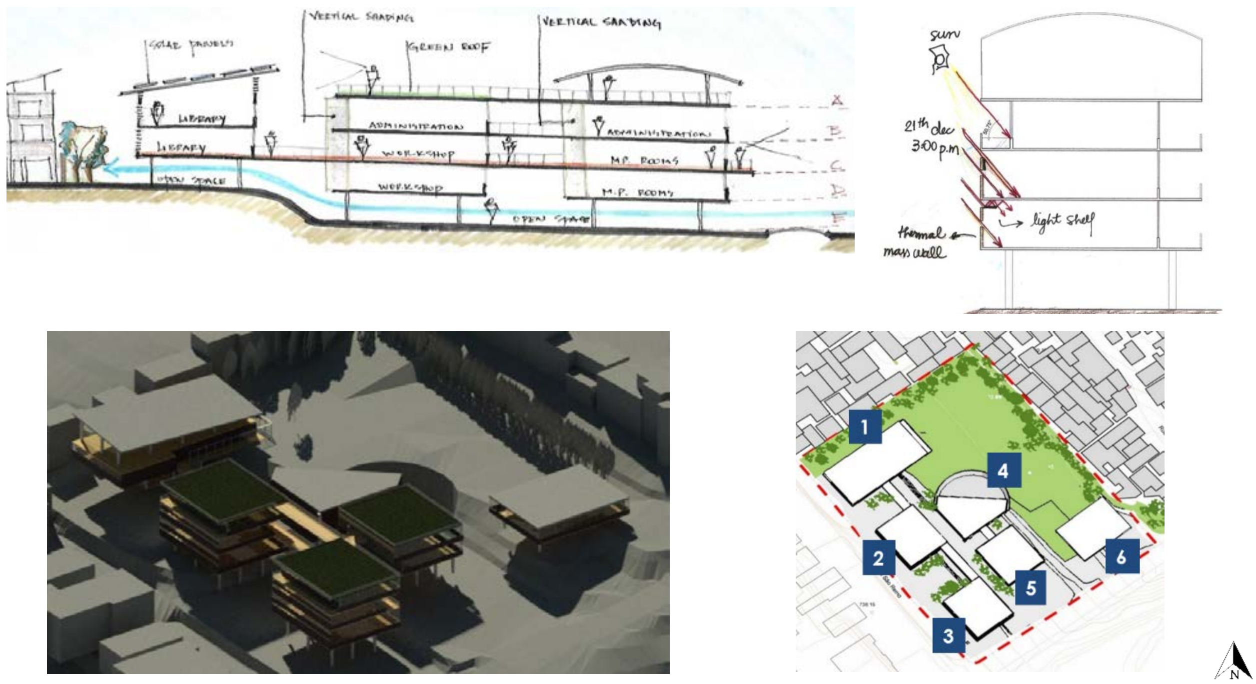

Figure 5. View A-A of buildings and distribution of areas. 1) Library, 2) Workshop + Administration, 3) Multipurpose rooms + Administration, 4) Auditorium + Outdoor arena (cinema), 5) Community Experimental Restaurant and 6) Health Care + Outdoor Gym

2.2. Second strategy

2.2.1. Location

The idea of the second variant is to move the location of future project from the centre of favela to the border (figure 5). This wall separates University of Sao Paulo from the favela. It can be seen in the figure 7 that building has two entrances from the university side and residential district. Therefore, the project brings two different social groups together and every group can feel safely because this territory does not belong to a particular area of USP or favela. The main entrance with the front stair is located in the North-Eastern part of the building.

The building is situated near the soccer field and the volleyball court. Pitches are located in the South-West direction.

Figure 6. Location of the building

Figure 7. Site plan

2.2.2. Sustainability

In this strategy, the selected materials are conventional and commonly used in this region.

In this strategy is highlighted the structures build with concrete due to its high thermal mass. The main construction materials used in this strategy is following described:

Roof: Building has a flat roof with from concrete with a green roof system, which prolongs the service life of HVAC systems through decreased use.

Windows: The use of artificial light is minimized by the opening space on the first floor. The main façade has the single glazing with shading system. Rainwater storage is also located on the top.

Walls: Materials choice for the project is quite simple. Building frame is made of reinforced concrete; northeast side is covered by wooden hinged facade. The south-eastern side of the building is designed into the form of green wall. Plywood is cheap and simple choice for the façade. Reinforced concrete, as the main structure, accumulate cold air during the night and release it throughout the day. Due to this, a comfortable temperature is maintained indoors. The wall structure is presented in the Table 4.

Slabs: Adiabatic cooling integrated into each floor.

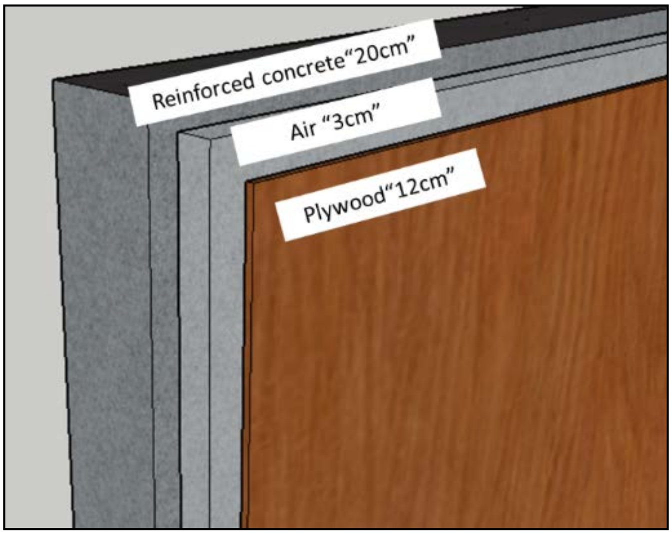

Figure 8. Wall structure for Strategy 2

Table 3. Thermal and Mechanical properties of Wall Strategy 2

Layer	Layer material	Layer thickness [m]	Thermal conductivity [W/m·K]	Specific heat capacity [J/kg/K]	Density [kg/m³]
Indoor					
1	Reinforced concrete	0.200	1.7	800	2500
2	Air	0.030	0.026	1005	1.18
3	Wood panel	0.012	0.130	1600	500
Outdoor					

2.2.3. Architecture

The main idea of the architectural treatment of the building is to connect the University and the favela. Every person, standing from the university side of the building can look through the building and see the favela. And there is the same situation from the other side (Figure 7).

Ground floor is supposed to be an opening space with educational auditorium and restrooms. Two underground levels have a technical room, gym facility, workshop rooms.

First and second floors are supposed to have a library with bookshops and healthcare facilities.

Third floor (last floor) has a community restaurant. It is an open terrace with glass curtain wall and green garden.

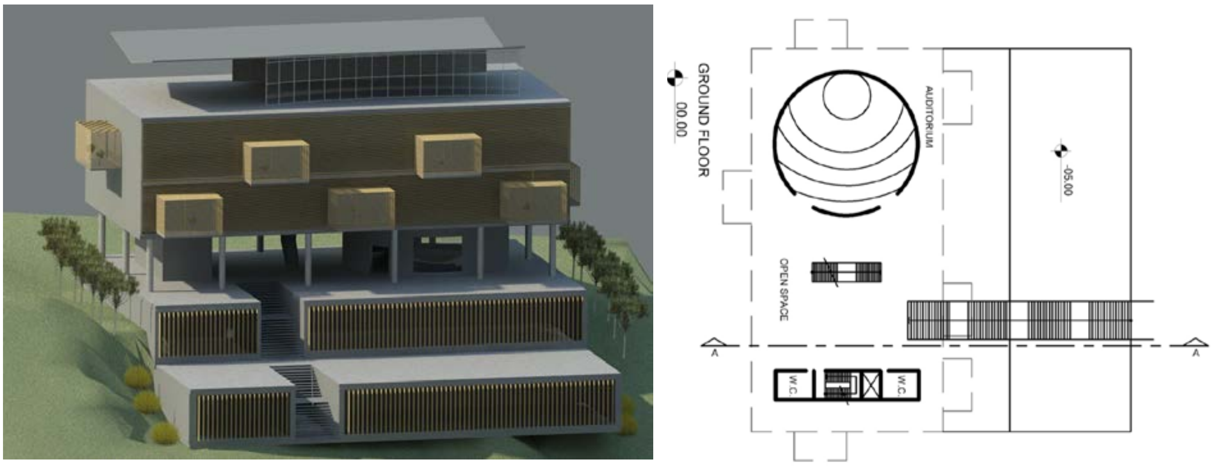

Figure 9. 3D view and Ground floor

2.3. Third strategy

2.3.1. Location

Initially it was suggested for the future building, to locate it within the favela borders which opposed to the main principle of the project to unite the divided parts by destroying the wall. Therefore, it was changed for the place with a more difficult topography but existing as a connecting point for two environments with a city road going along the wall, the university and a public bus stop. New location also gave a possibility to create an interaction between the building project and existing two sport fields found on the other side of the wall (Figure 8).

Figure 10. Initial and changed locations

2.3.2. Architecture

As mentioned, the slope taken into account since changing the location of the project has to be managed in a way to fill the social gaps existing in the society. Thus, the idea of comparing the site to one of the most important philosophical issues – the Maslow's hierarchy of needs – has occurred, and such connection between pyramid has had a response in the process of architectural design (Figures 12). The stories of the center were located in a way that topography allowed to design each section as of approximately 3 m high to form a comfortable space. The ground level (749 m) contains community restaurant separately located on the left side of the plan and an entrance into the community center. There are such rooms as workshop, multipurpose rooms and auditorium included general facilities located respectively are arranged above at the level of 752.5, 755.5, and 758.5 m. The aim of providing places for sport is solved by adding the existing court in favela to the territory of the center uniting these sites. At the top (762.0 m) the library is situated. Open spaces are represented in Figure 11 as terraces on roofs of the building parts, except for the library.

As a result, the concept of the pyramid can be followed. For instance, a community restaurant and a community garden satisfy both psychological part of the basic needs level and psychological needs level itself. On the other hand, Maslow's theory states that motivation to achieve the needs exists but the needs should be particularly ordered - the library, workshop, and auditorium help the favela residents reach the self-actualization level that is on the top of the pyramid.

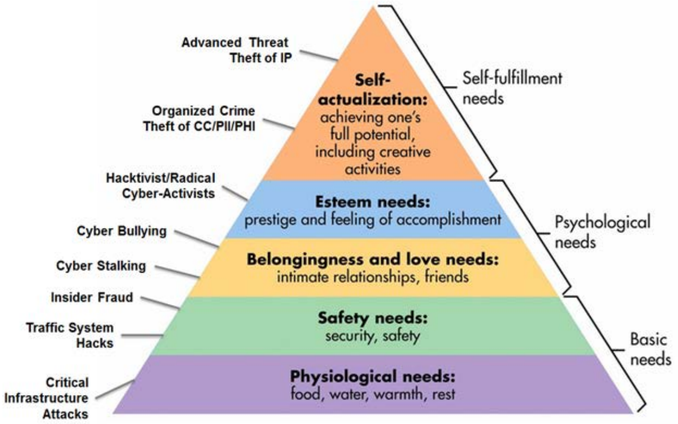

Figure 11. Maslow's hierarchy of needs [19]

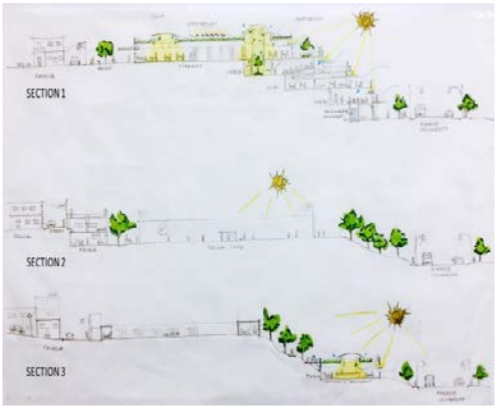

Figure 12. Sections

Figure 13. Sketch of alternative of design No. 3

2.3.3. Sustainability

Due to topography with elevations of about 13 m such sustainable solutions were used:

- Ramps are used to exclude the presence of mechanical and electrical lifts on the territory to reduce electricity consumption;
- Windows: natural light is provided at all levels due to skylights and an abundant glazing and open parts located towards the sun movement (Figure 11); rainwater storage is located on the first level;
- Roof: green roof with installed solar panels and chimney effect is considered as a natural ventilation solution;
- Wall composition: cavity brick wall. Such structure has high thermal mass, keeps comfortable temperature in any season, especially maintains cool temperature in summer. The idea was taken from an Australian research and applied due to the similar climate conditions [20]. The research states that in such structure a large portion of heat can be reflected and radiated back by the exterior surface, so it does not penetrate the internal space (Figure 13). It also was chosen due to its durability, structural capability, fire-resistant and good sound insulation properties, minimal transporting costs.

Table 4. Thermal and Mechanical properties of Wall Strategy 3

Layer	Layer material	Layer thickness [m]	Thermal conductivity [W/m·K]	Specific heat capacity [J/kgK]	Density [kg/m³]
Indoor					
1	Clay Brick	0.250	0.640	880	1600
2	Air	0.100	0.026	1005	1.25
3	Clay Brick	0.060	0.640	880	1600
Outdoor					

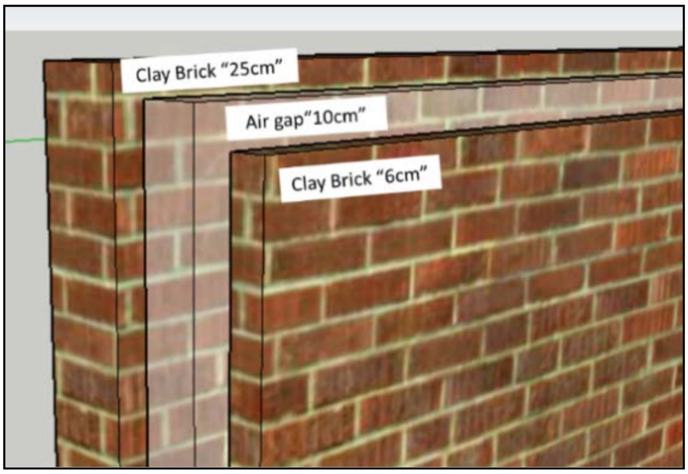

Figure 14. Cavity brick wall purposed for strategy 3

3. Results and Discussion

Based on the projects developed the following results were obtained:

3.1. Location

The best location for the project is between the university and the favela on the border of two territories. (Figure 15). Figure 15 shows the annual wind rose. According to this Frequency Distribution the strongest wind is from Northeast direction. Taking into account this data it is recommended to change the orientation of the main entrance to the Northwest.

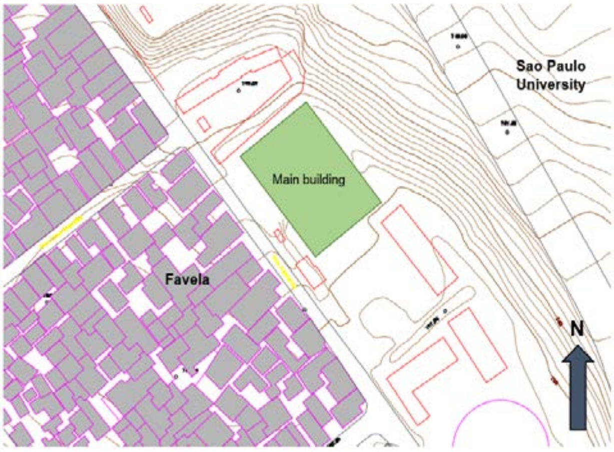

Figure 15. Site view

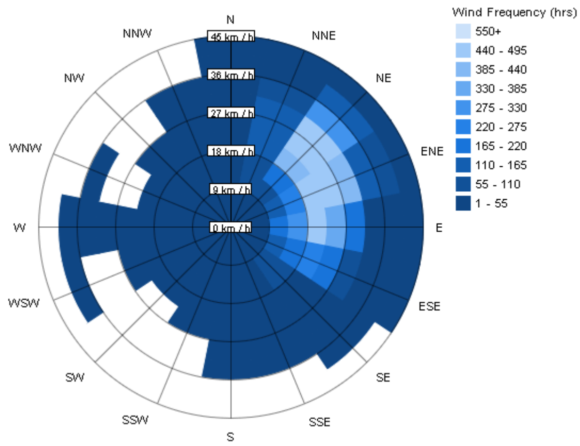

Figure 16. Annual wind rose

3.2 Sustainability

Since the problem in the area is not insulation but the cool temperature inside the building, the assumption is based on average summer temperature. An approximate check of such wall structure was conducted considering the climate of Sao Paulo [23–24] with such initial parameters to provide acceptable thermal comfort conditions indoors:

Humidity: inside – 40 %, outside – 80 %; Temperature: inside – 22 °C; outside – 14 °C.

Table 6. Thermal absorption and thermal resistance of wall strategy 1

Layer	Layer material	Layer thickness [m]	Thermal Absorption β [25] [J/√s·m·K]	Thermal resistance R [m²·K/W]	Temperature °C
Indoor					14.00
Resistance Convection Indoor (IRAM 11601)				0.04	14.07
1	Plywood	0.013	4.19	0.098	14.23
2	Recycled Cellulose Paper	0.100	6.36	2.500	18.34
3	Plywood	0.013	4.19	0.100	18.50
4	Air	0.050	0.29	1.923	21.67
5	Plasterboard	0.013	4.56	0.074	21.79
Resistance Convection Outdoor (IRAM 11601)				0.13	22.00
Outdoor					22.00
Total:			**19.582**	**4.86**	
Internal T °C		22	**External T °C**	14	

Table 7. Thermal absorption and thermal resistance of wall strategy 2

Layer	Layer material	Layer thickness [m]	Thermal Absorption β [25] [J/√s·m·K]	Thermal resistance R [m²·K/W]	Temperature °C
Indoor					14.00
Resistance Convection Indoor (IRAM 11601)				0.04	14.21
1	Reinforced concrete	0.200	368.78	0.118	14.82
2	Air	0.030	0.17	1.154	20.84
3	Plywood	0.012	3.87	0.092	21.32
Resistance Convection Outdoor (IRAM 11601)				0.13	22.00
Outdoor					22.00
Total:			**372.82**	**1.534**	
Internal T °C		22	**External T °C**	14	

Table 8. Thermal absorption and thermal resistance of wall strategy 3

Layer	Layer material	Layer thickness [m]	Thermal Absorption β [25] [J/√s·m·K]	Thermal resistance R [m^2·K/W]	Temperature °C
Indoor					14.00
Resistance Convection Indoor (IRAM 11601)				0.04	14.07
1	Clay Brick	0.250	237.32	0.391	14.77
2	Air	0.100	0.57	3.846	21.60
3	Clay Brick	0.060	56.96	0.094	21.77
Resistance Convection Outdoor (IRAM 11601)				0.13	22.00
Outdoor					22.00
Total :			**294.85**	**4.50**	
Internal T °C		22	**External T °C**	14	

According to the results, the wall No. 1 has the smallest thermal resistance (1.53 m^2·K/W), but the biggest coefficient of thermal absorption (372.82 J/√s·m·K). Whereas air temperature in Sao Paulo never goes below 10 °C. The most important thermal characteristic of the wall is accumulative capacity [26, 27].

Total cost of the wall including material cost and work labor is showed in the Table 9, where the most expensive enclosing structure is structure made of brick.

Table 9. Cost comparison of enclosing structures

Wall type	Strategy 1	Strategy 2	Strategy 3
Cost per m^2	67.87 €	71.98 €	86.45 €

Taking into account the costs and quality of the wall strategies, the most optimal wall for this project will be number two

3.3 Architecture

The best architecture solution is to apply the Maslow's hierarchy of needs. According to this theory, community restaurant and rest rooms have to be in the base of the pyramid, as physiological needs. The library, as a main component should be located on the top of pyramid as well as workshops and auditorium.

All strategies described include sustainable solutions for the project. The first alternative considered passive systems for cooling, heating and illumination, however, as the main variable to be taken into consideration is the social aspect. Its location, almost inside the favela and an open wall can difficult significantly, the security of user from the campus and favela and it is likely to become a spot for illegal actions and vandalism. Furthermore, the use of several time of glazing increases the cost of heating in cold seasons.

With the new location of the second strategy, the aforementioned issue is mitigated, nevertheless, the limited space there, restrict the construction of one unit of building but an integration with both communities is not noticeable due to the wall that it included. Additionally, the material used as a façade, wood, is not recommended because of the high presence of precipitation. The third strategy, which keeps the location of the second, does not considerate a wall fence as a limit. Evidently, this can contribute to informal and illegal construction by the inhabitants of favelas.

4. Conclusions

According to the results of the discussion. the main recommendations were formulated make an optimal design solution in line with three categories:

1. Location: It is important to preserve a physical barrier between the University and favela providing the sufficient system of integration. The best location for the project is between the university and the favela on the border of two territories.
2. Sustainability: The most optimal choice is correctly selected external walls, such as reinforce concrete wall with coefficient of absorption β = 372.82 J/√s·m·K and cost per m^2 = 71. 98 €.
3. Architecture: The most correct space zoning based on the Maslow's hierarchy of needs.

Each of the strategies above has strong advantages which combination results in the most suitable option. Location as stipulated in strategy 2 and 3, pointing out that according to historical backgrounds of this area. It is necessary the keep a physical barrier (fence), however, it should also promote the integration between both communities, as the one designed in the strategy 1. Double façade wall with a cavity in-between to tackle the condensation in the conditions in Sao Paulo is suggested as construction materials with high thermal mass in the strategy 3. Finally, the architecture which must take into account the most important factor – the social one – in order to ensure optimal distribution of spaces according to Maslow's hierarchy.

It is important to remark that the viability and sustainability of this research depend on a pre-social work with the potential users and the responsibility of all stakeholders: Government of Sao Paulo, police, community from the campus and from the influence area of the favela Sao Remo.

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