A BETTER SOCIAL HOUSING FOR MEXICO CITY: EVALUATION OF DESIGN AND INDOOR ENVIRONMENT OF COMMON TYPOLOGIES

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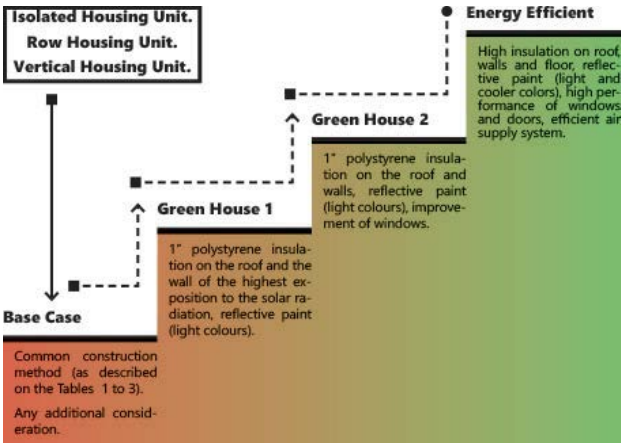

Fig 1: Summary of improvements. Source: Author.

WHICH ARE YOUR ARCHITECTURAL (R)SOLUTIONS TO THE SOCIAL, ENVIRONMENTAL AND ECONOMIC CHALLENGES OF TODAY?

Solutions may need to start on housing and therefore, making them more comfortable and environmental friendly. Research summary

This paper compares thermal comfort in the most common social housing typologies in Mexico City. It is based on a Base Case plus three different improvement's group. They are determined by the most common construction methods in Mexico, the Green Mortgage Program (Mexican programme for sustainable social housing), personal recommendations and the Passive House standards proposed for temperate climates. The approach into the building envelops aims to provide a better IEQ and highlight the actual weaknesses. Therefore, this paper only dwells on Thermal comfort: Temperature and Moisture.

The typologies taken for this study are Row Housing, Isolated Housing and Vertical Housing; which vary from 42 to 52 square meters per dwelling with different designs, but the same architectural programmes. Results are compared and discussed with the use of graphics and tables on the hottest and coldest day in Mexico City. Discussions of the results are presented in just one of the typologies. However, the analysis of the three typologies on the four Study Cases was made and their results presented in a table.

On the analysis of the results can be observed that two Study Cases provide a better IEQ on the three typologies. This suggests that they are the best approaches. Thermal mass and insulation working together prove that it is possible to maintain the thermal comfort range without mechanical supply of heat and/or cooling. The estimated higher cost on the Passive House improvements makes it not accessible for social housing on the Mexican context.

Keywords: Sustainable homes, Sustainable social housing, Cool temperate climate.

1. Introduction

This paper aims to evaluate, through comparison, the thermal comfort of existing social housing in Mexico City and suggest improvements that might provide better and comfortable Indoor Environment Quality (IEQ) meeting standards proposed by The Passive House Institute in Mexico.
The specific tasks realised in this paper include analysis of thermal balance with the help of EDSL Thermal Analysis Simulation Software (EDSL Tas). The investigation uses the following tools in the EDSL Tas Software: 3D Modeller tool, Tas Building Simulator tool and Tas Result Viewer; and in addition, the Office Software package: Excel.
The typologies selected for analysis are based on the most popular social housing units available in the current market in Mexico. These typologies are: Isolated Housing Unit, Row Housing Unit, and Vertical Housing Unit (see [1]). Four study cases are proposed with different building parameters (base case plus three improvement cases). These building parameters are based on the improvements to the building envelope. Variations run from the low energy efficiency (the typical construction method); the standards proposed by the Green Mortgage programme in Mexico; and the Passive House as described in Figure 1.
The operative temperature and relative humidity results are compared during the hottest day and coldest day in Mexico City. These comparisons provide information about the different achievements of different study cases. An analysis of the efficiency in the Mexican market will be required as further work of this investigation to set the affordability of the proposed improvements into the exterior dwelling envelop in the Mexican context. It will be helpful to determinate a real approach that housing developers, architects and engineers should use to achieve a better IEQ without sacrificing the affordability. This research paper only dwells on some of the aspects related to IEQ: temperature and moisture.
IEQ is directly linked to the perception through the senses, and has an effect on the psychology and the mental state of a person. Environmental factors that may change how we realate spaces with our sences. These factors are mainly five: Acoustical quality, Air quality, Lighting quality, Thermal comfort and Ergonomics (dimensions, furniture, spaces) [2]. Although all of them have an impact on the perception and comfort of the IEQ, just the Thermal Comfort (TC) is evaluated on this paper. TC is related to health and comfort perceived in spaces. The Mexican government has established as a comfort range temperatures between 20°C to 25°C and relative humidity from 30% to 70% [3].

2. Methodology

Methodology for this investigation involves virtual simulation tools and analysis software to make the comparisons of the results and evaluate its performance.

2.1 Procedure

The procedure for the investigation involves the following stages**:**

1. Description of the 3 most popular social housing typologies in the current Mexican market, with their actual construction systems and description of the envelop improvements;
2. Creation of 3D Model for each building typology;
3. Attainment of the weather file;

4. Specification of the characteristics of the location, weather, orientation and main internal condition for the building. Same internal conditions are maintained in all the 3 typologies simulation;
5. Specification of the different construction systems used in each study case;
6. Run simulation for each typology and study case;
7. Analysis of the data through comparison of the results for each typology proposed;
8. Conclusions.

2.2 Considerations

The three typologies evaluated in this research were identified and recognised as the most popular typologies on the Mexican market [1]. They are Isolated Housing Unit (IHU), Row Housing Unit (RHU) and Vertical Housing Unit (VHU). A description of IUH typology is presented. The layouts and main characteristics of each typology are shown in Table 1 and Figures 2-4. Construction materials, methods and orientation are also described. The typologies evaluated are presented based on typologies developed by the PECASA Group.

All the internal gains and/or losses are conserved during all the simulation process equally on study cases. There is no modification to the internal layout done, only construction methods are changed the simulations as described in the construction of the study case.

The construction process described is the most common used in the country are shown in Table 2 and described by [CONAVI. 2012] as follows:

- Floor. Reinforced concrete (concrete 2% of steel) of 100 mm thick, polished finish;
- External & Internal Wall. Colour paint, 15 mm concrete : Black Sand (2:1) plaster work, 120 mm hollow brick, 15 mm concrete : Black Sand (2:1) plaster work, White paint;
- Glazing. Clear 3 mm single glazing;
- Door & Window Frames. 3 mm thick and white aluminium 1 1/2” frame;
- Internal Doors. Solid wood door, 130 mm.
- Floor Slab. Reinforced concrete (concrete 2% of steel) floor slab 100 cm of thick. Polished concrete finish.
- Roof. Reinforced (concrete 2% of steel) slab of 120 mm thick, with a 2 per cent slope, “Plasticool” layer colour white.

Typology	Isolated Housing Unit.	Row Housing Unit.	Vertical Housing Unit.
Floor area (m^2).	47.70	51.80	42.00
Glazing ratio back façade (%).	11.21	17.35	35.52
Glazing ratio front façade (%).	36.38	15.15	25.81
Ceiling height (m).	2.40	2.40	2.40
Orientation.	S -N	S -N	S -N
Exposed on (façades).	Four.	Front & back.	Four.

Table 1: Main characteristics of typologies. Source: Author.

2.3 Typology layout

IHU is a single floor house (Figure 2) with a 47.70m^2 total floor area on 90.00m^2 of land area. The treated area is 41.30m^2. The frontal facade has 1 window of 2.25m^2 (11.21% of

glazing). The north side (back side) has a window of $3.8m^2$ and window on the west side of $2.025m^2$ (36.38% of glazing ratio). There is not other House Unit attached to it, so IHU is exposed on its four facades, roof and floor.
The approximate construction dimension is 6.00m wide and 10.50m long. The ceiling height is 2.40 m. Windows and doors have different dimensions and locations as shown on the floor plan. Internal partitions are made of the same materials as the external walls. For purposes of these research this partitions are significant to evaluate the dwelling as a complete building.

	Conductance ($W/m^{2}°C$)		
Building Element	**Isolated Unit**	**Row Unit**	**Vertical Unit**
Floor	25.000	25.000	25.000
External & Internal Wall	1.183	1.183	1.183
Glazing	5.780	5.780	5.780
Door & Window F.	5.882	5.882	5.882
Internal Doors	3.420	3.420	3.420
Floor Slab	-	-	13.660
Roof	13.660	13.660	13.660

Table 2: Construction method. Source: Author.

2.4 Determination of the Housing Cases
The Study Cases with all the considerations mentioned above will be named Base Cases. Exterior envelop improvements are then made to the base case. The first improvement concept (Green House 1) contains all the energy efficiency improvements on the external wall supported by the current Green Mortgage INFONAVIT's programme, even if not all the improvements are supported at the same dwelling [4] and are:

- 1" polystyrene insulation on the roof and the wall of the highest exposition to the solar radiation; and
- Reflective paint (light colours).

Considering the low levels of insulation and the lack of performance windows (isolated frames and double glazed windows) another dwelling concept called Green House 2:

- 1" polystyrene insulation on the roof and all the walls;
- Reflective paint (light colours); and
- Improvement of windows (isolated frames and low-e double glazing).

The building improvements were taken from the standards for tropical climates made for the Passive House Institute [5]. The standards applied on the Energy Efficient House can be summarized as follow:

- High insulation on roof, walls (5.08 cm/2") and floor (2.54 cm/1");
- Reflective paint (light and cooler colours); and
- High performance of windows and doors.

The different improvements are summarized in the Figure 1.

2.4 Geographic and climate characteristics.
Mexico City Metropolitan area, located at the "Valle de Mexico (Mexico's Valley)", is the biggest Metropolitan Area of the country. It occupies around ~1,500 km^2 at a nominal elevation of 2,240 m above mean sea level, and it is bordered on the east and west by mountains that rise 1000 m above the valley floor, the east side with volcanoes that rise up to 5,000 m above the sea level and west side up to 3,952 m above the sea level. Mexico City has a subtropical climate, warm summers and mild winters. Its annual average temperature is 18°C. However, temperatures in summer may rise up to 32°C and in winter may reach -5°C. The rainfall is concentrated between May and

October with an average of 95mm. July is the wettest month (~130mm) and February the driest month (~5mm). Therefore, humidity may rise up to 90%.

3. Results and Discussions.

This section provides a general overview of the simulation results of the different Social Housing Typologies, mainly IUH; evaluation of the Indoor Environment Quality and External Temperature and Relative Humidity. Factors will be evaluated on the hottest day in Mexico City (30th May – 150th day of the year) and coldest day (7th January – 7th day of the year). Results of Isolated Housing Unit are discussed and a summary of all typologies is presented in Table 3 based on analysis made in EDSL Tas [6].

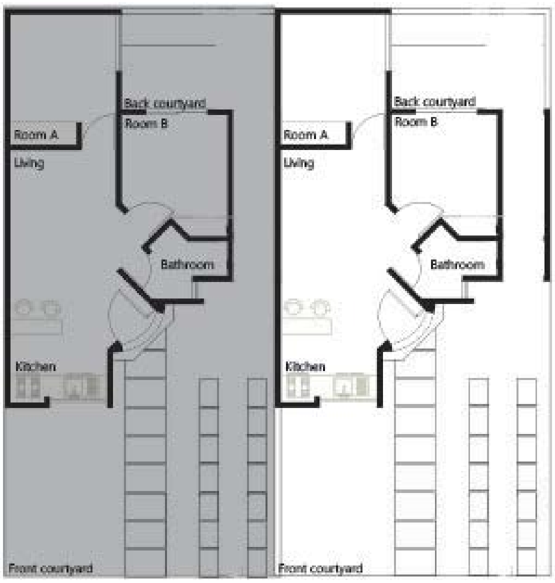

Fig 2: Layout Isolated House Unit. Source: Author based on PECASA Group.

3.1 Isolated Housing Unit (IUH)

On internal temperature analysis (lower and highest) differences in the IHU with the different study cases. The differences between the higher and the lower temperatures in late May in the Base Case is 5.39°C with a time lag of 3 hours; in the Green House 1 is 5.35°C with a time lag of 4 hours; in the Green House 2 is 3.85°C with a time lag of 4 hours; and in Energy Efficiency is 1.85°C with a time lag of 1 hour; and in beginning January is Base Case is 5.06°C with a time lag of 6 hours, in the Green House 1 is 5.06°C with a time lag of 6 hours; in the Green House 2 is 3.04°C with a time lag of 3

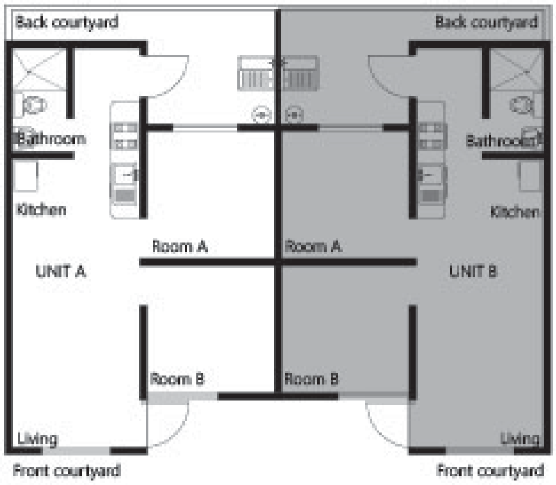

Fig 3: Layout Row House Unit. Source: Author based on PECASA Group.

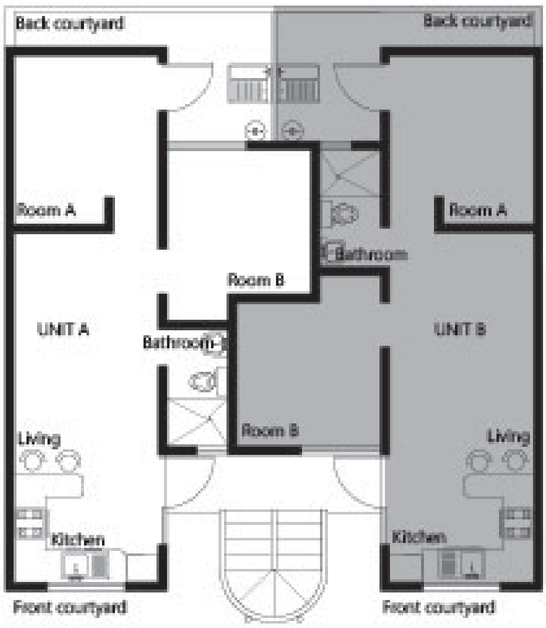

Fig 4: Layout Vertical House Unit. Source: Author based on PECASA Group.

hours; and in the Energy Efficiency is 2.57°C with a time lag of 2 hours. Therefore, results show that the use of thermal mass is also beneficial to maintain the temperature. Thermal mass and insulation were working together in the Green House 2 and Energy efficient cases; as insulation is added to the construction system internal temperatures tend to remain in a lower temperature range. In these cases, the variation in the operative temperatures were reduced considerably, more than 2°C. Insulation as proposed by GMP is not efficient to maintain internal temperatures on the comfort range (20°-25°C).
Temperature increase can be observed in the beginning of January date evaluated. It suggests that with the improvements on the Base Case to the Energy Efficient Case the internal temperature is well maintained, but more over the internal conditions provide additional heat gains which increase the temperature. On late May a cross ventilation can provide enough cooling to keep the four analysed cases within the temperature range, as the building itself permit air flows from the front to the back when all doors are open.
Regarding Relative Humidity differences in the IHU on the different study cases can be seen that environment tends to be dryer and tend to maintain regular RH levels on the analysed days as the different improvements become present. Nevertheless, humidity range is never on the comfort range established by CONAVI (30%-70%). In late May, in the Base Case, the range goes from 39.76% to 95.07%; in the Green House 1 from 39.75% to 95.05%; in the Green House 2 from 37.33% to 85.88%; and in the Energy Efficient from 20.84% to 41.02%. In winter in the Base Case the range goes from 27.83% to 100%; in the Green House 1 from 27.83% to 100%; in the Green House 2 from 23.21% to 93.24%; and in the Energy Efficient from 16.27% to 48.15%. It can be seen that as the improvements are done, the humidity in the air tends to reduce in both days. As the different improvements are simulated; a drier environment is noticed. However, it is not observed any significant variation between the Base Case and the Green House 1. Therefore, IEQ improvement is more likely to be in the cases were insulation is applied in the external building envelop.
Table 3 shows a summary of the results on all typologies and Study Cases.

4. Further work.

An analysis on a real Case Study analysis with the improvements proposed is suggested to compare the results shown here with the real measurements and found if any significant differences between a Low Energy House (Base Case) the Green Mortgage. As well, whenever possible, construction and monitoring of a dwelling with the Passive House standards might be considered to obtain. Moreover, a detailed cost-effectiveness analysis should be made to determinate its impact and affordability on the current Mexican context.

5. Conclusions

The climate of Mexico City is very different for the European climates; therefore the comfort ranges for the Mexican context are suggested by CONAVI (Mexico's National Housing Commission) (20°C-25°C and RH 30%- 70%). In the Mexican situation, the use of a high insulation and high performance on windows and doors represent a higher additional cost, due to most of these elements are not common in the current market.

			Temperature (℃)				Relative Humidity (%)			
Typology	**Day**	**Study Case**	**Max External Temp. (°C)**	**Min External Temp. (°C)**	**Max Internal Temp. (°C)**	**Min Internal Temp. (°C)**	**Max External RH (%)**	**Min External RH (%)**	**Max Internal RH (%)**	**Min Internal RH (%)**
Isolated Housing Unit	30th May - 150 day	Base Case	24.00	14.00	25.95	20.56	88.00	44.00	95.07	39.76
		Green House 1	24.00	14.00	25.95	20.60	88.00	44.00	95.05	39.75
		Green House 2	24.00	14.00	25.52	21.67	88.00	44.00	85.88	37.33
		Energy Efficient	24.00	14.00	29.64	27.79	88.00	44.00	41.02	20.84
	7th January - 7 day	Base Case	24.00	5.40	21.00	15.94	87.00	22.00	100.00	27.83
		Green House 1	24.00	5.40	21.00	15.94	87.00	22.00	100.00	27.83
		Green House 2	24.00	5.40	20.66	17.62	87.00	22.00	93.24	23.21
		Energy Efficient	24.00	5.40	22.86	20.29	87.00	22.00	48.15	16.27
Row Housing Unit	30th May - 150 day	Base Case	24.00	14.00	24.52	18.52	88.00	44.00	91.13	38.61
		Green House 1	24.00	14.00	24.57	18.54	88.00	44.00	90.83	38.51
		Green House 2	24.00	14.00	23.93	18.76	88.00	44.00	82.57	40.10
		Energy Efficient	24.00	14.00	23.86	18.46	88.00	44.00	69.35	37.69
	7th January - 7 day	Base Case	24.00	5.40	23.38	12.76	87.00	22.00	99.26	22.44
		Green House 1	24.00	5.40	23.39	12.77	87.00	22.00	99.26	22.42
		Green House 2	24.00	5.40	23.37	13.61	87.00	22.00	79.41	22.37
		Energy Efficient	24.00	5.40	23.2	12.96	87.00	22.00	63.07	20.9
Vertical Housing Unit	30th May - 150 day	Base Case	24.00	14.00	27.35	22.99	88.00	44.00	26.04	21.35
		Green House 1	24.00	14.00	29.77	22.96	88.00	44.00	26.54	18.76
		Green House 2	24.00	14.00	30.21	24.53	88.00	44.00	21.9	16.90
		Energy Efficient	24.00	14.00	35.08	29.77	88.00	44.00	17.19	14.37
	7th January - 7 day	Base Case	24.00	5.40	21.77	16.5	87.00	22.00	41.08	30.01
		Green House 1	24.00	5.40	23.36	16.08	87.00	22.00	43.36	27.55
		Green House 2	24.00	5.40	24.19	18.85	87.00	22.00	39.2	29.08
		Energy Efficient	24.00	5.40	27.47	23.37	87.00	22.00	28.62	22.46

Table 3: Summary results of all typologies. Source: Author.

However, when they will be available in the Mexican market an effectiveness-cost evaluation is highly recommended. The use of insulation on all the walls results on a better performance than just in the most exposed wall, as proposed by the Green Mortgage Programme. It has proved that insulation just in the most exposed wall can reduce the temperature for less than 0.5 °C. The lack of insulation on the rest of the walls, floor, windows and doors allows heat/cooling gains/losses.

The Green House 2 and the Energy Efficient cases results had the best Indoor Environment. On the actual circumstances high performance elements have higher prices. Thus, the best option is to improve the IEQ through the Green House 2.

A dehumidifier system is highly recommended on all the typologies. Vertical House Unit is significantly drier than Isolated and Row Housing Units. The Indoor Environment is tends to be drier when adding the envelop improvements and Energy Efficient case is the most drier suggesting the use of a humidifier instead of dehumidifier. One of the factors that do not help to the control of Humidity range is the window openings, so in order to maintain a certain internal range is important to keep them close and use ventilation with humidity control system.

6. Acknowledgments

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