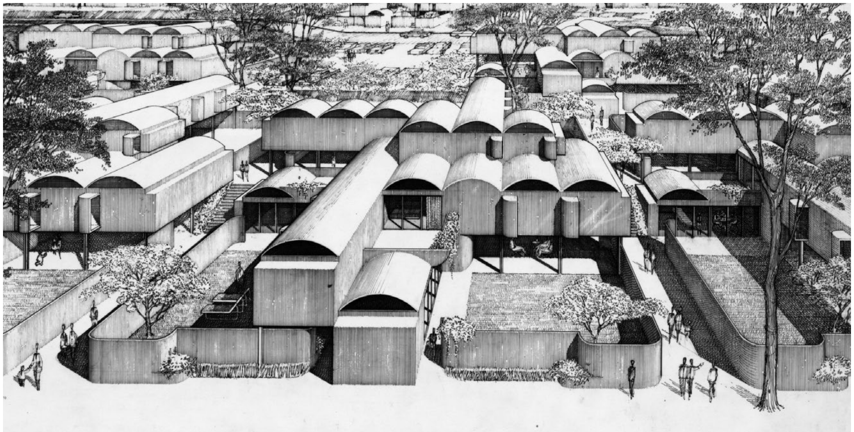
PAUL RUDOLPH
Oriental Masonic Gardens



Latitude _ 41.3° N
Longitude _ 72.9° W

Climate: transition between
Cfa _ Humid Subtropical and
Dfa_ Humid Continental climate

Fig. 1 - View from construction phase

INTRODUCTION

Project name: Oriental Masonic Gardens
Architect: Paul Rudolph
Program: residential
Construction: 1968-1971
Demolished: 1981
Location: New Haven, Connecticut, USA
Site: inner-city
Construction technology: prefabricated, modular

Fig. 2- Axonometric view

The concept of this project is "the mobile home", or, as Paul Rudolph labeled it – "The house of the Twentieth century".

The modularity of the building allows for 148 building units to be built on 4.700 sqm site area.

Fig. 3 - Satellite view

Fig. 4 - Site plan

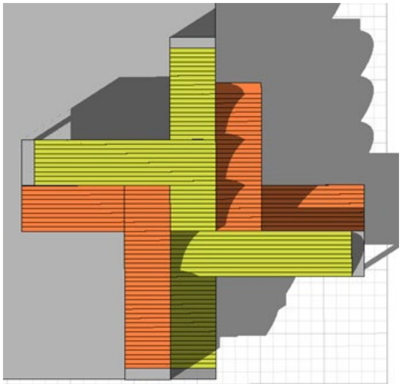


Fig. 5 -*Roof view*

Clusters of four prefabricated mobile units pivoted in pinwheel formation, each unit with its own private entrance and outdoor space.
The arrangement follows a pocket court plan that provides a separate outside space for each family.
A lower module contains living spaces. A second module above it houses two or three bedrooms and it is shifted from the ground floor. The kitchens and the bathrooms are overlapped, the utility core being placed around the junction of the volumes. A third module may be added, parallel to the lowest one, for additional bedrooms.
Each "brick" is formed by 3-4 modules of aprox. 3.6 m by 3.6 m and 3.6 m by 4.6 m, with the maximum length of 18 m, according to the traffic regulations.

Fig. 6- *First floor plan.*

The volumes follows a stacking organization. They are factory assembled with plumbing, wiring and finishes and trucked to the site.

Because of the modularity and mobility of the units, the entire arrangement had the potential to be disbanded and reconstituted.

The openings are also modulated and oriented towards the sheltered outdoor space of each house.

The roof has a curved shape, following the E-W direction.

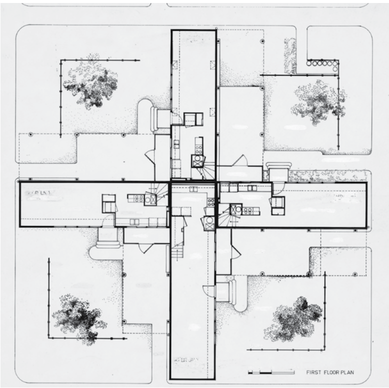


Fig. 7 - *Ground floor plan.*

Fig. 8 - *Photo from the site*

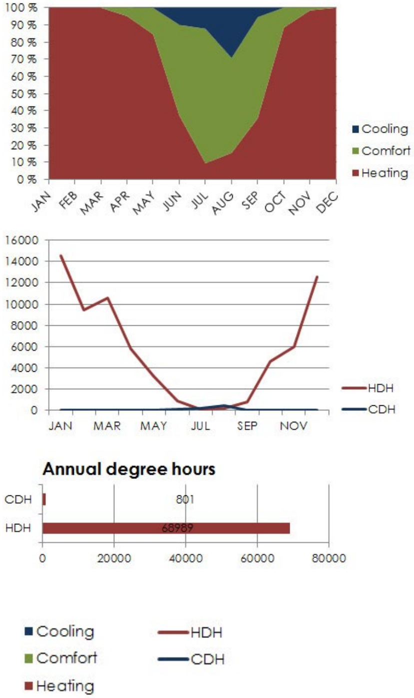


Fig. 9 - *Climate derived data.*

CLIMATE ANALYSIS

New Haven lies in the transition between a humid continental climate (Köppen climate classification: Dfa) and humid subtropical climate (Köppen Cfa), but having more characteristics of the former, as is typical of much of the New York metropolitan area.

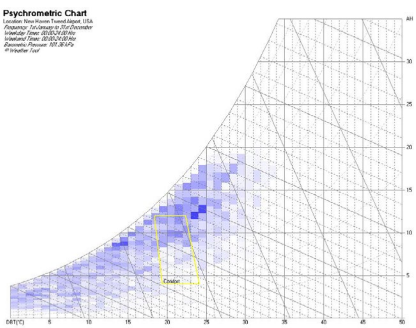
Summers are humid and very warm and winters are cold with moderate snowfall interspersed with rainfall and occasionally mixed precipitation. According to the weather tool, the climate is Cfa - Moist mid-latitude climate with mild winters.

Humid subtropical characteristics are present, with hot muggy summers and thunderstorms. The winters are mild with recipitation from mid-latitude cyclones.

Warmest moth is above or equal 22 C.

During the winter months the heating is required 100% of the time while the cooling is only required for only 30% in a peak month of august. This translates into 86 times more heating degree hours than cooling degree hours.

Fig. 10 - *Psychrometric chart*



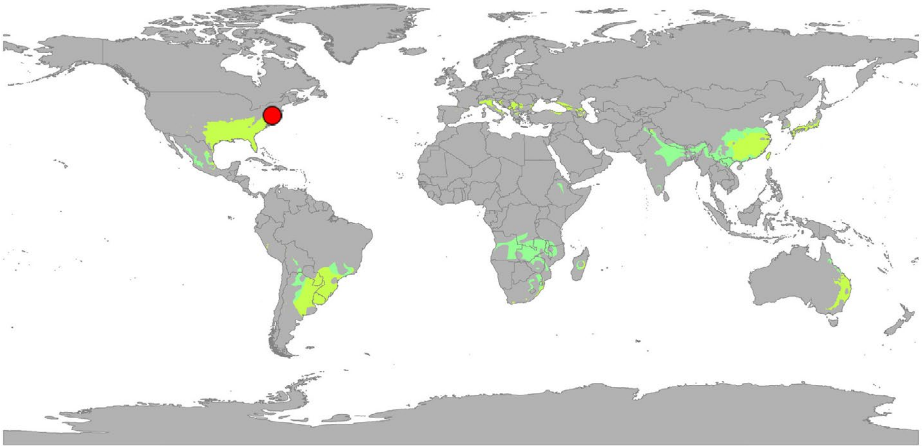


Fig.11 *- Localization of the house in comparison with Cfa Humid Subtropical climate boundaries according to Köppen-Geiger climate classifications.*

CLIMATE FACTORS

Temperature: The temperature throughout the year is below the comfortable range except during the summer season {May, June and July} when it is in the comfortable range. The rest of the year has temperature below the comfortable range. During winters the temperature goes below 0 degree Celsius (January and December). Hence this region experiences sever climate of mostly cool and cold temperature. Snow is common in the winters.

Relative humidity: The humidity levels for comfort levels is between 20 to 80 and the region experiences a fluctuating behavior of the relative humidity which rises to 100 in January and the lowest is 40 in the month of February. The rest of the month has the humidity of around 50 to 60.

Effective natural ventilation speed limit: the speed limit throughout the year is good within the limit of 2.00m/s to 4.00 m/s. There is a fluctuation in the wind speed for every month. Also There are even spells where the speed reaches up to 6.00 m/s.

Annual rainfall: There is rainfall in this region throughout the year with average mean rainfall 90mm.
Wind: throughout the year, the wind direction is North and during the summer time the prevaling wind is from South. The wind is also influenced by the proximity of the Bay.

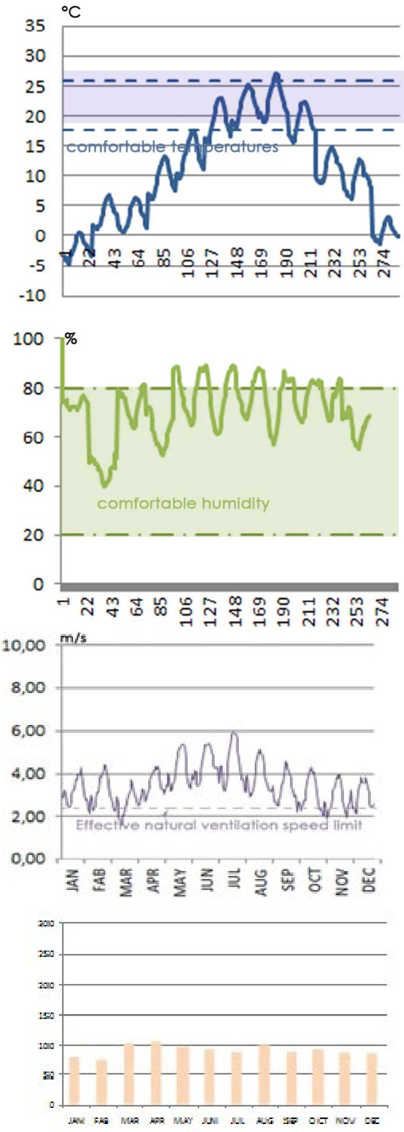


Fig.12 *- Climatic factors*

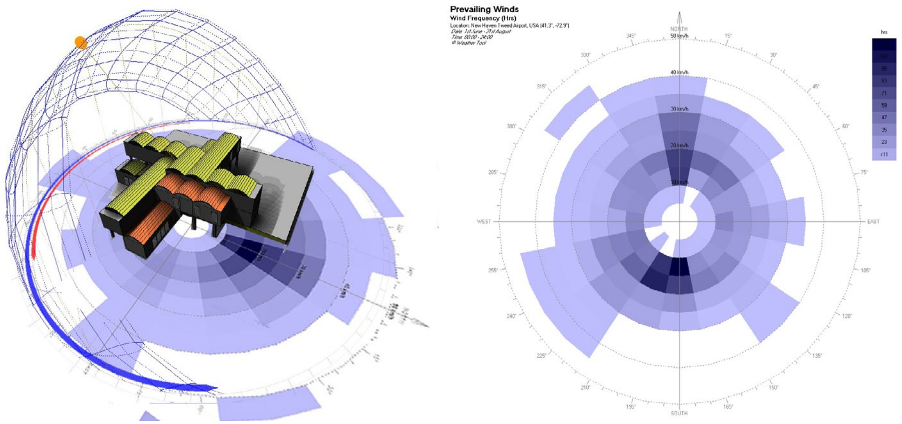


Fig.13 *- Wind selective analysis. Annual and Summer*

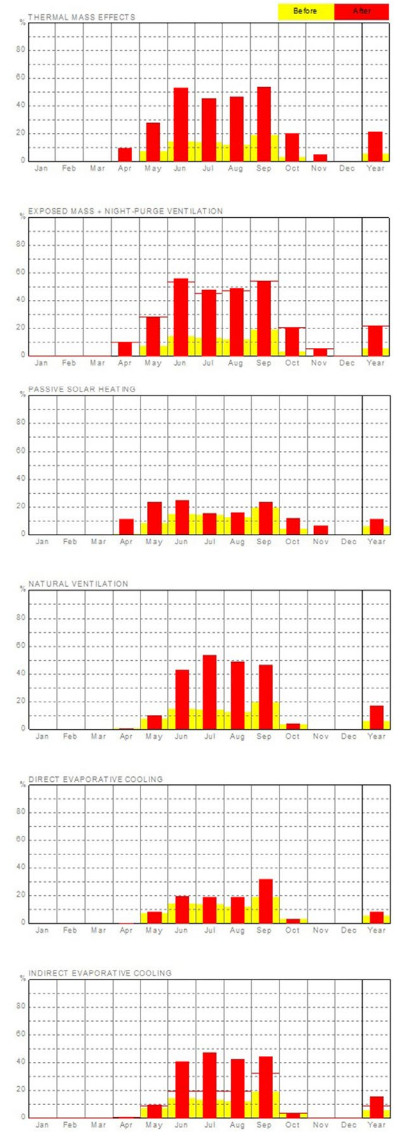


Fig.14 - *Passive strategies potential.*

Fig.15 - *Psychrometric chart analysis*

PASSIVE STRATEGIES FOR COMFORT

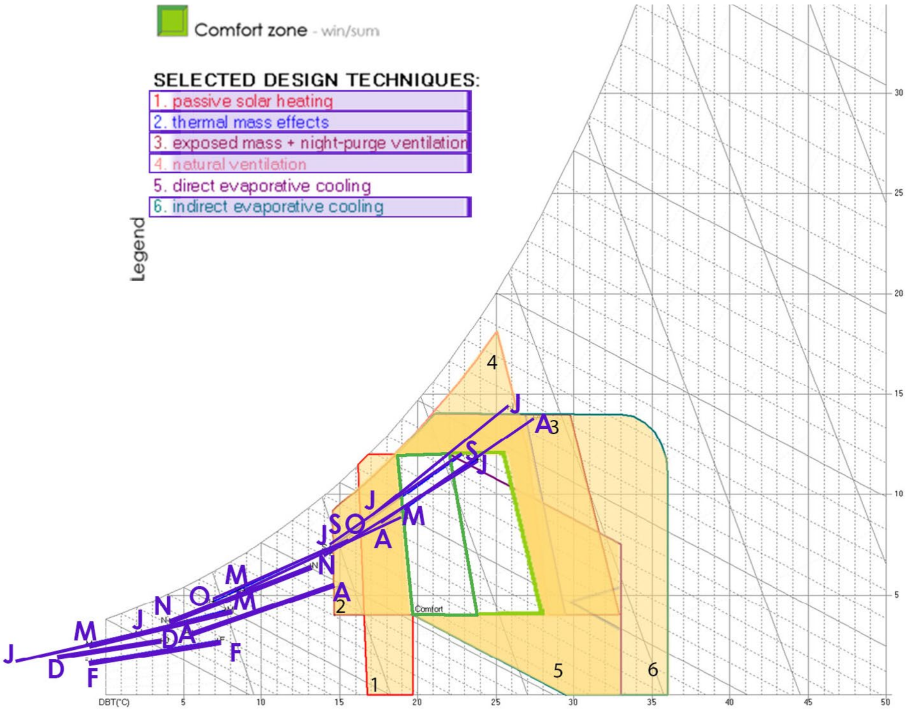
In these diagrams extracted from the weather tool, we can see the different passive strategies for thermal comfort.

The most effective strategies are the Thermal mass effects, the Exposed mass + night ventilation (from April to November) and the Natural ventilation and indirect evaporative cooling (from June to September).

These strategies are effective during the warm months. The rest of the year conventional heating is needed.

Psychrometric Analysis: The diagram shows that temperature experienced in this region mostly falls in the Wet bulb temperature zone throughout the year. Its only during June, July, August and September that the temperature would give comfortable indoor environment.

If we select various design techniques like passive solar heating, thermal mass effects, exposed mass + night-purge ventilation, natural ventilation and indirect evaporative cooling than we would be able to achieve comfort zone for the indoor climate.



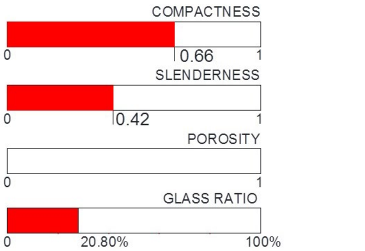


***Fig.16**- Morphological analysis for a 4 module volume-SW first floor*

***Fig.17** - Direct solar radiation*

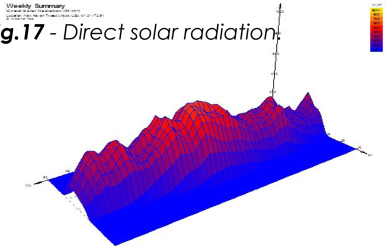


***Fig.18** - Difuse solar radiation.*

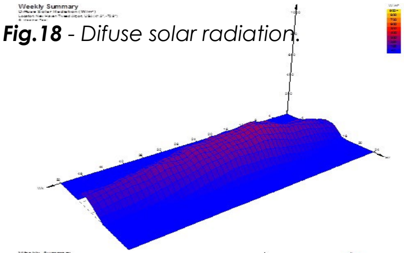


***Fig.19** - Average cloud cover*

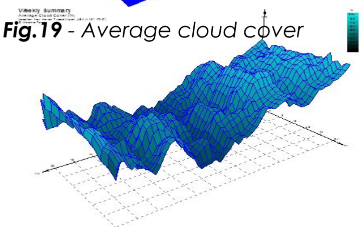
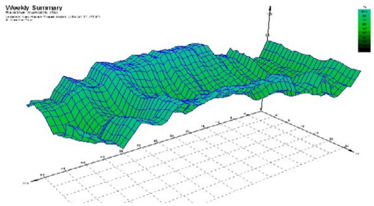


***Fig.20** - Relative humidity*



SOLAR RADIATION ANALYSIS

Looking at one volume of 4 modules, like SW first floor, the compactectness is close to the optimal form for this climate. The glass ration is low.

Indirect solar radiation is relative high throughout the year, with values of more than 600W/mp for 8 hours/day. The indirect solar radiation is also uniform, with a minimum of 200W/mp.

Due to the position in the subtropical climate, both the cloud cover and relative humidity are high. The cloud cover is high especially during the winter months while the relative humidity is higher during the warm months.

Optimal orientation is at SSE and the form has a ratio of 1:1.6. The closest volume is the around floor of the SW cluster.

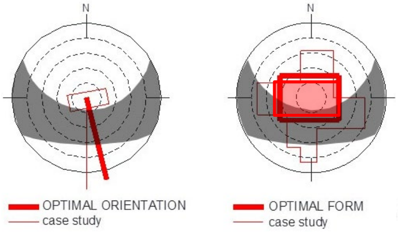


***Fig.21** - Optimal orientation and form*

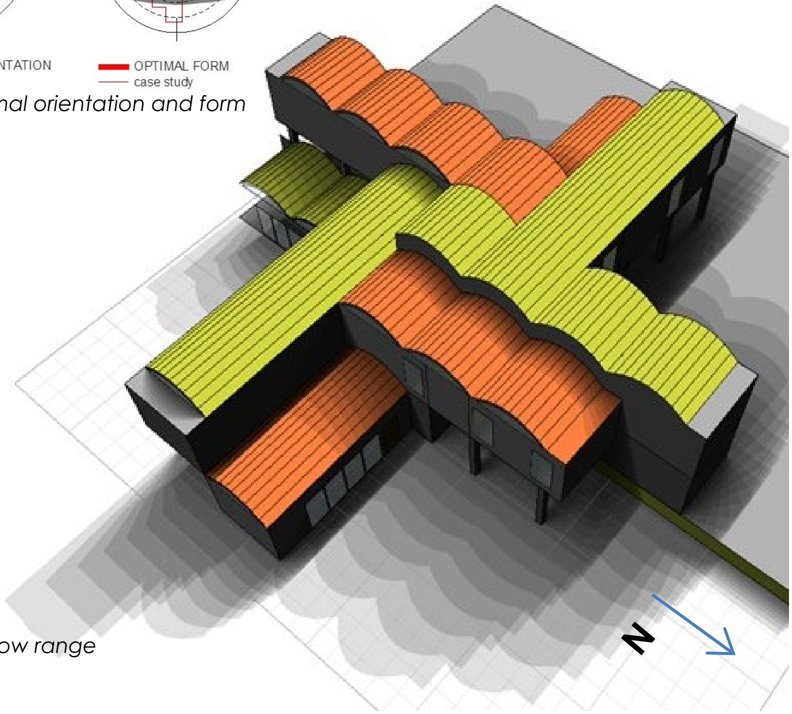


***Fig.22** - Shadow range*

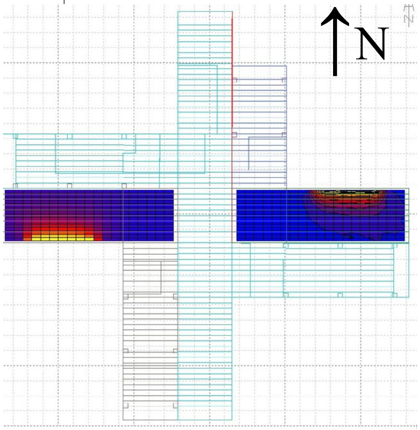


__Fig.23__ - Ground floor_ Light analysis for NE an SW cluster

LIGHT AND SHADE

Using the grid analysis and Radiance we were able to compare again the two clusters and the 4 volumes contained. The measurements were made at 1 m above the floor.
The windows are placed on the same principle, punctual and non uniform on the volume direction.

We can see that the areas near the windows receive much light, aprox. 3000 lx, while the darker parts of the room receive less than 500 lx.

The differences between the clusters are visible on the ground floor. The North volume less light compared to the South volume.

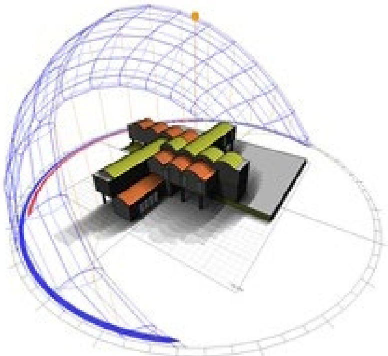


__Fig.24__ - N-E cluster_Shading analysis

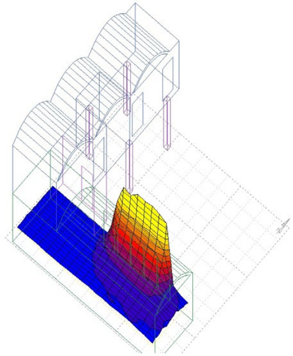


__Fig.26__ - N-E cluster_Ground floor Shading analysis

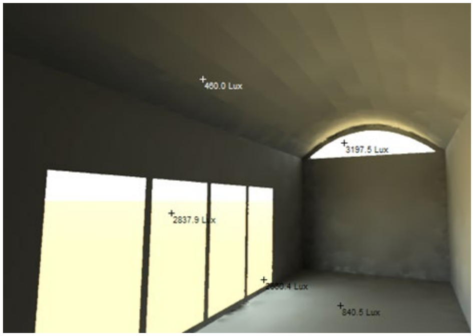


__Fig.28__ - N-E cluster ground floor (living room)
Interior view _ Radiance. Noon.

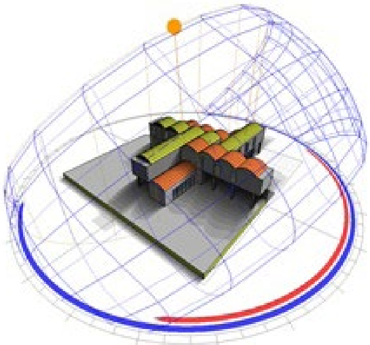


__Fig.25__ - S-W cluster_Shading analysis

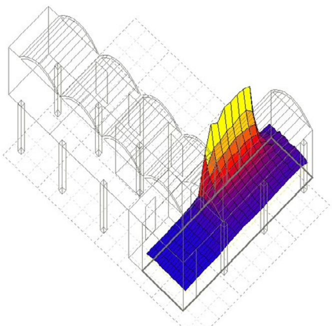


__Fig.27__ - S-W cluster_Ground floor Shading analysis

__Fig.29__ - S-W cluster ground floor (living room)
Interior view _ Radiance. Noon.

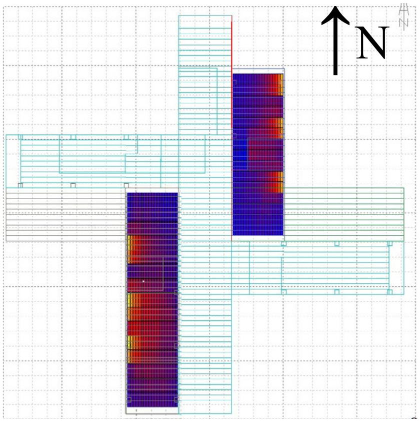


***Fig.30** - First floor_ Light analysis for NE an SW cluster*

The volumes from the first floor receive approximately the same amount of light, having windows oriented towards East and West. Still, the West volume has a better luminance, due to the low evening sun.

Comparing with the volumes on the ground floor, the first floor have better iluminance due to the windows situated on the upper site, in the vaulted roof.

The analysis was made in the afternoon, at 2 PM. Overall, the areas next to the windows receive to much light and the below figures show that the East volume receives diffuse light whereas the West volume receives direct sunlight.

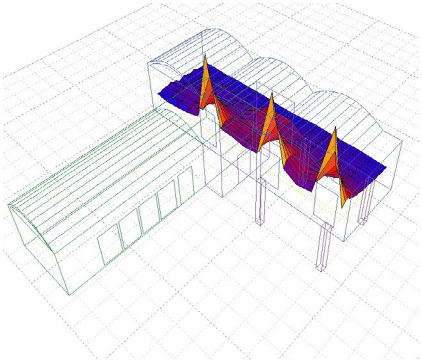


***Fig.31** - N-E cluster_First floor Shading analysis*

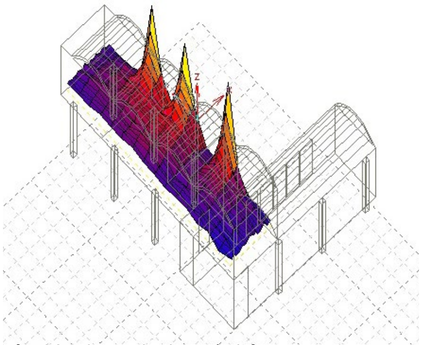


***Fig.32** - S-W cluster_First floor Shading analysis*

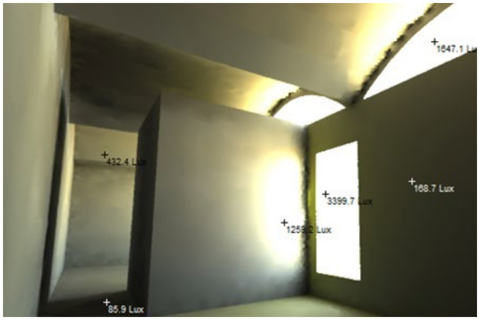


***Fig.33** - N-E cluster first floor (bedroom) Interior view _ Radiance. Noon.*

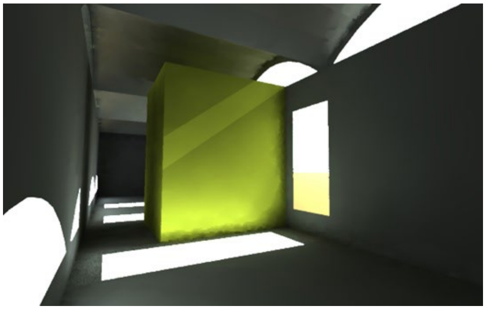


***Fig.34** - S-W cluster first floor (bedroom) Interior view _ Radiance. Noon.*

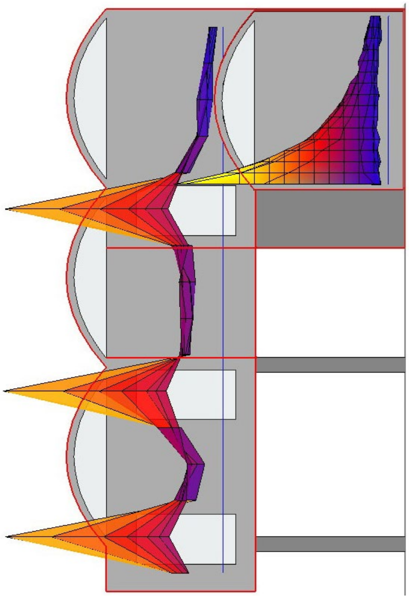
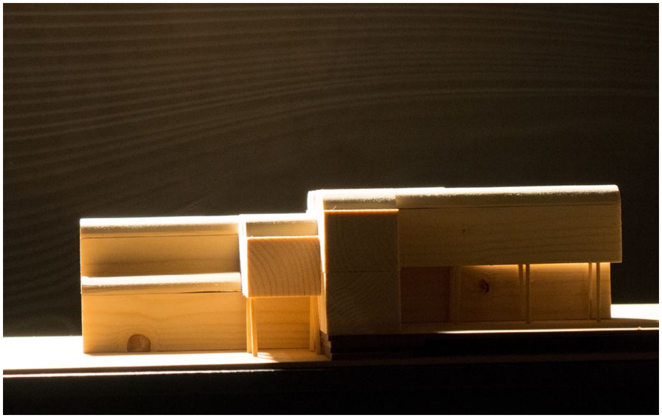


***Fig.35** - Section_Lighting analysis using grid analysis*



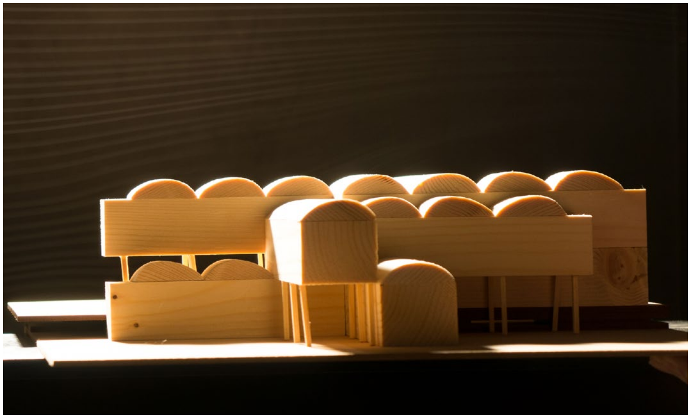


***Fig. 36 -** Wind patterns. East and South direction*

Energy modeling

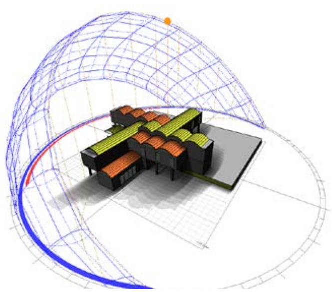
The images from the wind tunnel show a potential for cross ventilation. This was possible if the volumes had windows on both sides and they were arranged with spaces in between.

According to the SIM model input, we can see that the SW cluster is slightly bigger that the NE one, with one module.

The resource consumption graph shows consumptions for cooling from July to September and 3 to 4 times much more heating consumption. Overall, the NW cluster has a bigger consumption that the NE one.

The materials assumptions made for the Ecotect model were as follows:

SIM model input.	Unit	NE /	SW
GEOMETRY resume			
Heated surface	m	88.6	102.33
Conditioned volume	m	193	350
Exposed wall surface	m^2	98.7 33	139. 29
Roof area	m	77	91.22
Windows area	m	19.54	26.47
	South	0	11.54
	North	8.00	0
	East	11.54	0
	West	0	8.00
Glass ratio	%	20	20.8



	Layer Name	Width
1.	Ethyl Vinyl Acetate	0.2
2.	Tin	2.5
3.	Air Gap	35.0
4.	Tin	2.5

	Layer Name	Width
1.	Wood Pine (With Grain)	30.0
2.	Fibreboard, Wet Felted	10.0
3.	Rock Wool	70.0
4.	Plaster Board	10.0

	Layer Name	Width
1.	Concrete	100.0

Fig. 37 - Materials.

Roof_tin roof with air gap

Walls_Timber frame wall

Floor_Suspended concrete floor

Thermal zone settings			Climate data: New Haven
Occupancy	W/m^2	1,5	Climate data: New Haven
Lighting	W/m^2	1,95	Lat: 41.31° N
Tec. equipment	W/m^2	1,8	Lng: 72.9°S
Operation time	h/d/w	16/7/52	
Heating and cooling set point temperature	°C	19-26	

Table 2: SIM model adjustments. Variables assumed during the simulations.

		unit	value
Timber framed walls	U-value	W/m^2K	0.39
Concrete suspended floor	U-value floor roof	W/m^2K	2.98
	U-value roof	W/m^2K	2.77
windows	U-value windows	W/m^2K	5.1
Air tightness	Air tightness	ach	2
Thermal bridges	Thermal bridges	W/m^2K	0.03

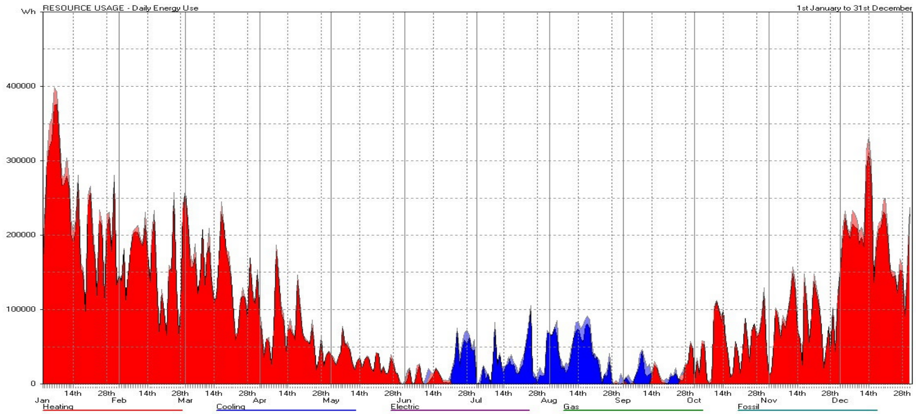


***Fig.38** - Heating and cooling energy demand.*
Bright red and blue - N-E cluster
Light red and blue - S-W cluster

DISCUSSIONS

The Case-Study Oriental Masonic Gardens had four residential units in one cluster, facing the cardinal axis and forming four quadrants in North-East, North-West, South-East and South-West directions. We considered interesting to compare the opposite direction houses i.e., North-East house and South-West house for looking at the behavior towards the climate.

The calculations for the light analysis and energy consumption were conducted. The results show that the North-East house had poor quality of natural sunlight whereas the South-West house was better.

The Resource consumptions were high for heating due to the weak envelope. There are also resources for cooling that we believe it can be avoided by considering a crossover ventilation in the design phase.

ISSUES

Urban: the geometric arrangement of identical units pivoted in pinwheel formation ignores the differences due to orientation.
Technical - solutions that led to leaking problems. Lack of cross ventilation.
Economic: close to the cost of a site built house, due to setbacks a series of setbacks.
Social: the resembling with the trailers made people who inhabited these dwellings to think that they were beneath them.

REFLECTIONS

The most interesting point of the project is that it recalls an important moment when leading American architects turned their attention to the period's housing crisis. he concept of "The brick of the Twentieth century" is provocative on two levels: first, that the building module or "the brick" is something that could be inhabitable and not merely constructive; the architect celebrated the fact that the project contained virtually no technological innovation. Secondly, the suggestion that the architects must scale up building density to meet housing needs.

References:

Barry Bergdoll, Peter Christensen, Ron Broadhurs, *Home Delivery: Fabricating the Modern Dwelling (New York, MOMA, 2008) 154*.

http://prudolph.lib.umassd.edu/node/4492

Weather file from: http://apps1.eere.energy.gov/

Analysis made in Autodesk Ecotect and Radiance.