How architectural design can impact energy efficiency of a residential building.
Case Study: ‘An addition for one-story house, adapting ‘Florida-room’ space.

Enkeleida Prifti

European University of Tirana, Engineering and Architecture Department

Abstract: The purpose of this project and study is to determine and evaluate the sustainability of architectural solutions that will provide energetically efficient buildings. The add to an existing one-story house, by adapting an existing ‘Florida-room’ will expand surface of the conditioned area, and increase the value of the house by modern designed interiors. But the purpose was to reward this investment with an addition that will be sustainable and energy saving. The methods and materials used to complete this project include three stages of work: collection of data’s to compare then the final results for a conclusion, projecting and receiving a permit according to the building code, and construction.

City Hall of Largo, department of 'Permits and Planning' gives information on construction permits and community planning codes for residents of Largo. Department of P&P provided with applications, forms, information about community standards and guidelines from the code council of Florida. With these information started design according to the codes and policies of the state, for an efficient project. This provided as a beginning a successful receiving of the permit and notice of commencement, which allowed us to start construction works. Assessment of major components of project and relations between them showed that: architectural solutions chosen for this project and constructing with new modern materials that meet the standards, affected consummation of energy in lowering consummation per square feet.

Finally two approaches in architectural design were discussed for providing a sustainable design and energy efficiency building.

Key words: Energy Efficiency – architectural design – sustainability - Florida room – residential building quality.

INTRODUCTION

This paper aims to identify and evaluate importance of architectural choices made in project, to contribute positively to the energy balance used in the building through a sustainability design. Shape of a building is one of the important components when architects design it. Concepts have always been discussed by different philosophers, historians, architects, constructors and many others. It has always been issue of aesthetics and construction technology, which are both objective and subjective at the same time. But, after changes that have occurred in society of the 21-st century and electricity required for developing and emerging economies, we still lack access to modern energy services for billions of people. Also the dramatic increase of energy prices and awareness of limited known energy sources shall generate a new way of thinking in architectural design. [1]

"Bring all existing and future elements of the built environment – in their design, production, use and eventual reuse – up to sustainable design standards." - Declaration of Interdependence for a Sustainable Future at the UIA/AIA World Congress of Architects in Chicago, 18 – 21 June 1993. Architects design not only for a concept, for a climate or environment, but also to reduce energy consumption in our bills regardless of market trading prices for energy. [6] Indoor Climate – creates a healthier and more comfortable life for the occupants and has a positive impact on the environment. [4, 5] By the twentieth century the gradual but whole-scale absorption of the responsibility for the environmental performance of buildings by the HVAC engineer appeared complete to the extent that some architecture schools today do not even teach basic building science, concentrating on history, theory, philosophy, graphic design and computer modelling. [4] The power grab of the role of the environmental designer by service engineers from the grip of the architect has been well described by many authors and was outlined in our *ASR* paper on twentieth-century standards for thermal comfort in 2010. [4] The regulatory imperative to replace opening windows with fixed 'glazing' and provide year round ventilation with an HVAC plant was to a large extent driven by the thermal comfort standards that were developed by the air-conditioning industry to enable engineers to determine the best temperatures at which to set building thermostats. That research resulted in regulations based on the idea that 'people' could only be considered comfortable if room temperatures were kept within a narrow thermal band, ranging typically around 20–24°C. [4] The more extreme the climate the greater the HVAC plant needed to achieve these temperatures in buildings that are increasingly 'modern', light weight, over-glazed and energy hungry. [6]

Therefore; having in mind all of these facts, we shall design in order to sustain benefits of the known so far designed methods, providing not only high aesthetic quality but also sustainable and energetically efficient buildings.

MATERIALS AND METHODS

Study area: The one-story house is located in Largo city, state of Florida, USA. Area of construction is the Florida – room of this house. Basic information for the house's plan comes from 'Survey of Existing Key Plan' which is a plan about 'Erosion controls'. Design criteria for all work is in accordance with the Florida Code 2010: Occupancy type R – 3; Construction type V – B; Fire sprinkler No. 3; Flood zone: C; Basic wind speed 150 mph; Risk category: II; Wind exposure: C; Building: Enclosed; Pressure design factor: +/- 0.18 [2]

The existing plan (pic. 3) includes: three bedrooms, two water-closets, living room, family room, laundry, garage; kitchen and Florida-room. Kitchen –is designed according to American philosophy that it should be located at the center of the house, with an open view from the living

room for the guests. Florida – room is located on the northern side of the house. The term "Florida room" refers to an extra living area that features extra glass to bring in light and to enjoy an outside view.
A Florida room has some features in common with a Sun Room, a room that permits abundant daylight and views of the landscape while sheltering from adverse weather. Florida room is a roofed structure with mesh screen for walls and is not air-conditioned. (pic.2)

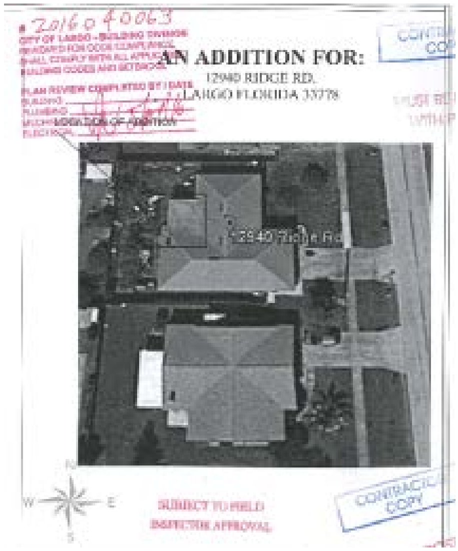
METHOD: Many are the methods and theories designers approach to ensure optimal temperatures for comfort, through year round in all types of climate. [4] [11] [12]. But in the twenty first century architects and engineers have come to conclusions on whether people were comfortable or not, based mainly in two methods. [4] So there are two categories in which project is focused; and buildings can be designed using either method, or both.

- The Heat Balance method: This method discourages natural ventilation and the problem with building models is that they tend to lump the many design factors into one model. [4] In natural ventilation systems, enhanced cooling can be garnered from gusts in airflows and the need for research into optimal gusting frequencies from airflow devices for comfort. It suggests that responsibility for the design of resilient buildings that can keep people thermally safe in a warming world must be taken by the first-stage designers who shape the immutable form of the building and the air pathways through them. [4]
- On the other hand the **Adaptive method** enables natural ventilation and there are International Comfort Standards for

> both. Standard ISO 7730 (BSI 2005) for the Heat Balance model and ASHRAE/ANSI standard 55 (ASHRAE 2010) and CEN Standard 15251 (BSI 2007) both include versions of the *Adaptive approach.* [4]

So far we have seen that a well-designed home can, with a low cost and low impact, provide comfort even at high temperatures, using natural ventilation, energy storage and adaptive opportunities, without compromising indoor air quality. Also highlighted has been that many modern buildings are overheating and will increasingly do so in a warming climate. [4] So the challenge is to reduce overheating in buildings at the design stage. They may include a range of choices from manually to mechanically operated elements such shades, shutters, glazing type and ceiling fans to heating or air-conditioning systems. These secondary systems may all be changed over time but not the fundamental building form itself. [4] Finally, interviews about the development and refinement of house design over time, with the engineers of city-hall Largo; who work with 'HVAC equipment efficiency verification', showed that the occupants of the buildings involved adaptive changes that brought better results in efficiency. So went for the second one, *Adaptive Method*. The following case study demonstrate the importance of climate in design and of architectural shape of the building.

Case Study:



Building Constructed: 1975 (Pic. 1)

Owners: Family with two children

Location: Ridge Rd, Largo, FL; 10 m above sea level

Climate: on average there are 246 sunny days per year; Gets 51 inches of rain on average, per year.

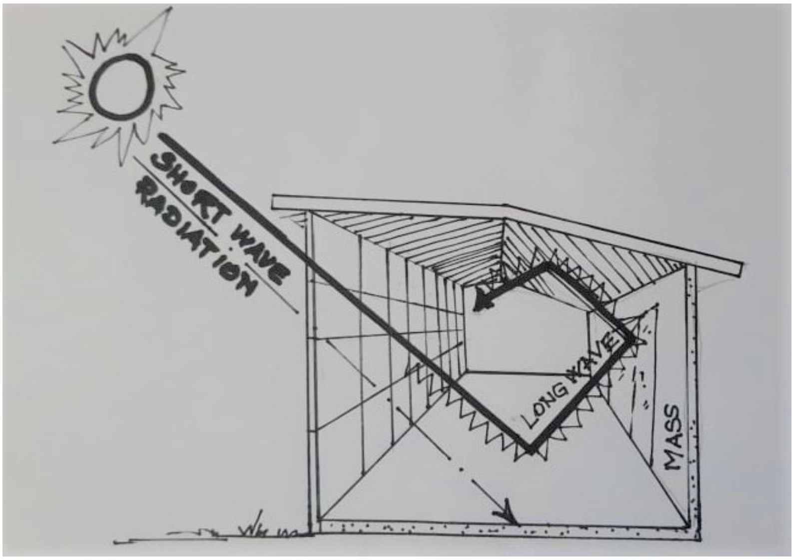
Area: 198 m2

Pic. 1. Permit for an addition for the building

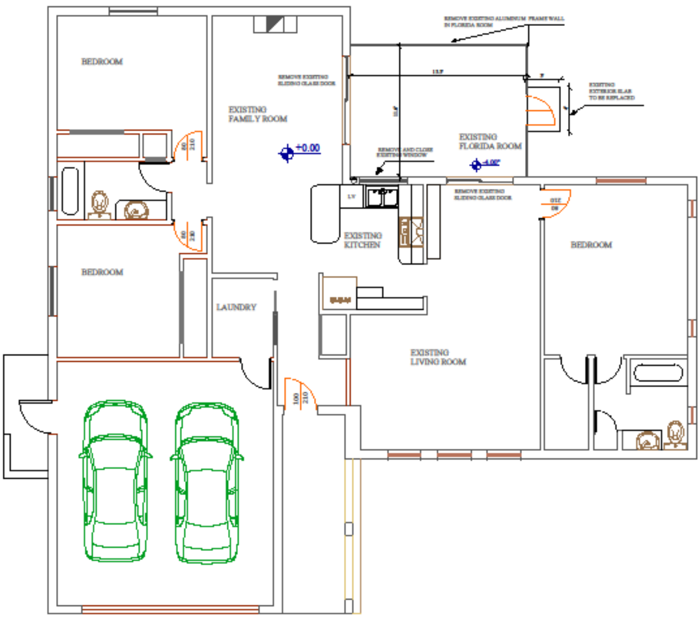
KEY DESIGN OBJECTIVES: 1) Adapting Florida-room into a large kitchen; and giving the existing space of the kitchen to the living-room and to family-room ; 2) Creating a room after the kitchen to isolate direct contact of the kitchen with outside-door in the garden behind; (pic. 3&4); 3) Good new walls and good insulation on walls and roof (pic.11); 4) Use good windows and doors, air tight, no thermal bringing, heat recovery; 5) Renovation of chimney isolation for thermal storage and natural ventilation, 6) building a climate refuge, with mixed mods technology for extreme weather options; 7) improve natural ventilation and adaptive envelope. And of course a well-treaded building is going to be a safe building.

Designing started with verification of all plantings and irrigation / sprinkles systems and risers for spray heads which shall be at least 1 foot from building sidewalls. Soil treatment shall meet the requirements of 2014 FBC R318 Method. Basic information comes from Key Plan and Department of city-planning at City-Hall, which gave the limits of construction field. Existing plan includes a Florida –room which is a space that is not covered by HVAC system. It is roofed with sandwich – aluminum construction and has light walls of aluminum frames. Assessment of major components, and relations between each one of them showed that: we got components that form visual quality of the exterior and interiors where the coverings like tiles, windows, doors, colors of the shingles play an aesthetic positive role to the style of the house [3]; And we deal with components that improve commodity of living such as: better light, ventilation, air-conditioned space, more space for mobility, electric energy saving, hurricane protection, better aromatic inner-climate. So together with all of these above in mind is good that the project achieves some key construction objectives in renovation and construction.

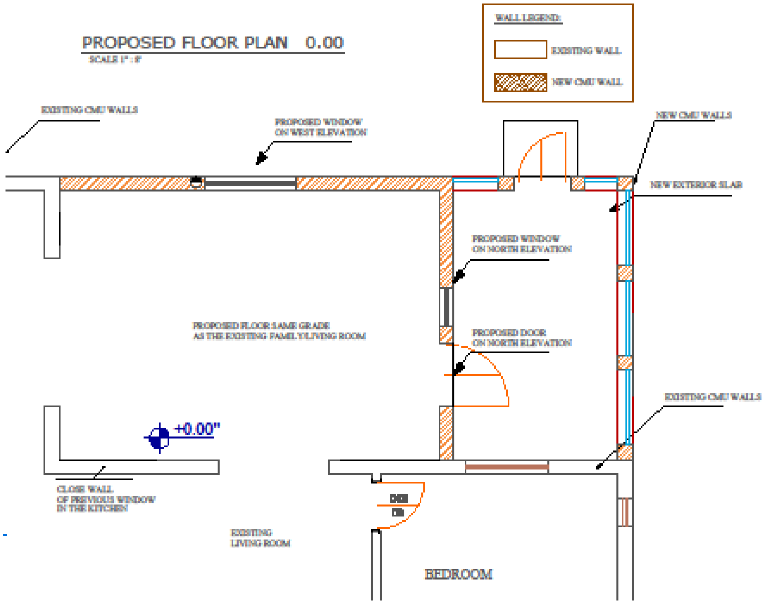
After listing objectives, started with the new planning of the house that includes: 1) replacing existing aluminum frame walls in Florida-room with concrete walls covered with good insulation that will improve energy efficiency of the building. (pic.4 & 13.b); 2) and, replacing old existing sliding glass doors which create vertical thermal bridges. (pic. 3&2)



Pic. 2. Entry of solar radiation in space, transform it into thermal and storage at building blocks.



Pic. 3. Existing floor plan.

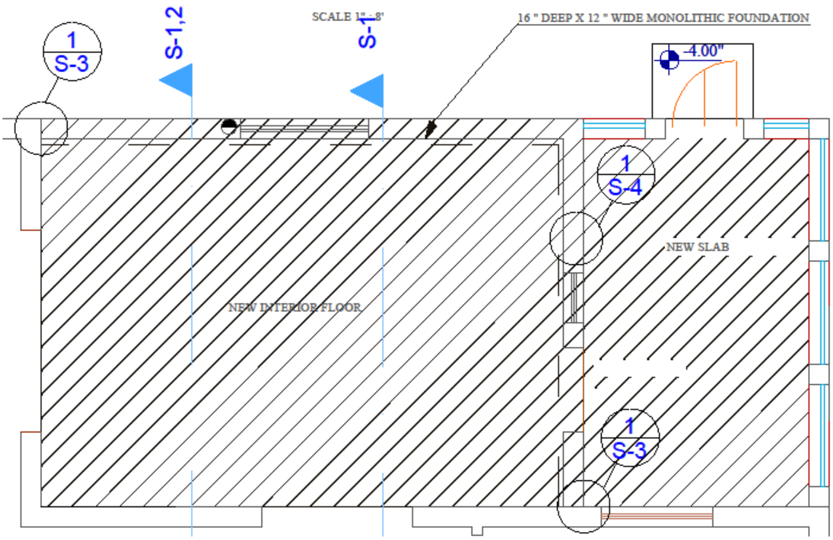


Pic. 4. Final Proposed floor plan.

The second step was to adapt the area of Florida- room into new kitchen. Remove kitchen from the existing place will give more space to living-room and family room for a new design of open-concept, but will also create a wide open kitchen with a space of three times bigger than the old one. (It was 9 m^2 and it became 27 m^2) Putting kitchen further from the living room and bedrooms, improves climate of the house and prevents lingering cooking smells before you even start cooking and even though you use ventilation system from the HVAC. Also positioning kitchen closer to the wall openings and chimney, kitchen gets closer to possibilities of natural ventilation. (pic. 13)

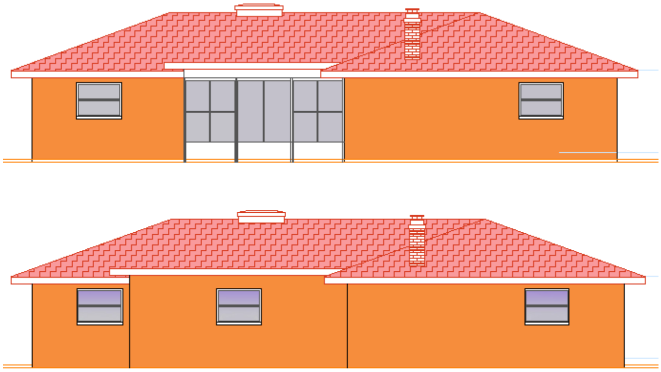
CONSTRUCTION DESIGN OBJECTIVES: Wood grade stakes shall not be used. Protection against decay and termites shall be provided in accordance with 2014 FBC R317, R318. Roof flashing shall be provided in accordance with the requirements of 2014 FBC R703.7.5, R703.8, R903.2 and R905. [2] About soil was noted that: was needed compact back fill 5'-0" from structure. Minimum allowable bearing capacity shall be 2000 PSF. All soil shall be free of debris and organic materials and compacted to 95% of modified proctor (ASTM D1557). Foundations shall be built on undisturbed soil or properly compacted fill material complying with the FBC – R 2014. [2] Stem wall fill shall not exceed 12" lifts, Soil below footings shall be tested and all subsequent fill soil in lift not to exceed 12" intervals. All fill material shall be SP or SM material as defined by the uniform soil classification system. Any questionable soil shall be removed or brought to the attention of the engineer of record for evaluation. Soil bearing capacity in based upon 2,000 PSF. Wood grade stakes are prohibited. [2] During construction works, contractors were to verify manufactured truss plan prior to placement to placement of stem wall or monolithic footing. Plumber is to inform superintendent of any venting which utilizes a masonry wall to resolve any possible structural integrity issues. There were drawings for demolition plan and proposed layout. Modified structural members are in compliance with Florida Building Code 2014. Were designed with dimensions and elevations all architectural drawings.

CAST – IN – PLACE CONCRETE NOTES (Pic. 5)**:** Concrete mixes shall be designed per ACI 30, using Portland cement conforming to AST C – 150, aggregate conforming to ASTM C – 33, and admixtures conforming to ASTM C-494, C-1017, C-618, C-989 and C-260. Concrete shall be ready – mixed in accordance with ASTM C-94. Concrete shall be conform to be following compressive strength, slump and water/ cement ratio requirement: In all salt environments a min. of 5000 PSI concrete shall be used. (Slab shall be exempt.) For other environment use 3000 PSI concrete. All concrete work shall be conform to ASTM A-615, Grade 60. All welded wire fabric (WWF) shall conform to ASTM A- 185 (flat sheets only). All reinforced steel including hooks and bends, shall be detailed in accordance with ACI 315. All reinforcing steel indicated as being continuous (cont.) shall be lapped 40 x bar diameter. Lap continuous bottom bars over supports, lap continuous top bars at mid-span unless otherwise noted. Unless otherwise noted, the following minimum concrete cover shall be provided for reinforcement in accordance W/ ACI 318-08.



Pic. 5. Foundation plan.

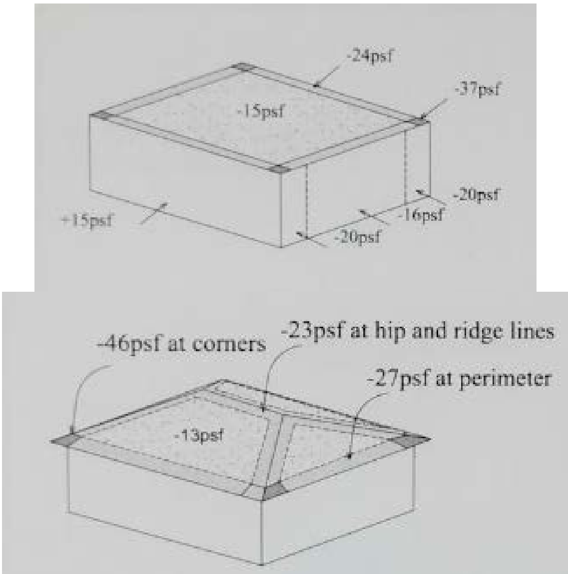
EXTERIOR OPENINGS:



Pic. 6. Existing west elevation (left) & Proposed west elevation (right).

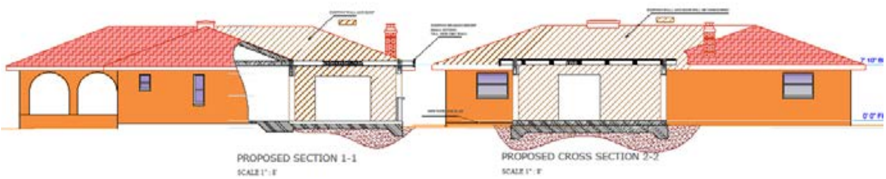
Exterior windows and glass doors (fig. 6) shall be tested by an approved independent testing laboratory and bear an AAMA, WDMA, or other approved label identifying and manufacturer, performance characteristics and approved product ANSI / AAMA / NWWDA. Window and door assemblies shall be attached in strict accordance with the published manufacturer recommendation to achieve resistance to appropriate wind speed with 3 second wind gusts and shall include the specification of buck strip materials and anchoring. Wood cribs above arched windows shall comply with drawing detail contained herein. All shim materials shall be made from materials capable of sustaining applicable loads, and located and applied in a thickness capable of withstanding those loads. Opening perimeters have been designed to transmit the imposed loads to main wind force resisting system. Impact glass or shutters shall be used per FBC 1609.1.2

DESIGN LOADS AND NOTES: LIVE LOADS: Roof -20PSF; DEAD LOADS: Shingle roof - 10PSF; Ceiling -10PSF; DL = 10 PSF in combination with wind loads. Lateral loads in trusses are resisted by roof diaphragm at point of wind load input unless noted otherwise. (Pic. 7)



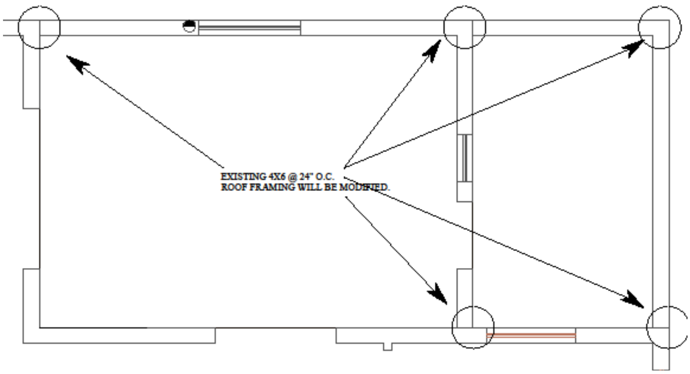
Pic. 7. Scheme of flat gable roof; Hip or gable roof.

FRAMING NOTES: Wood construction, connections and nailing shall conform to the FBC 2014 EDITION. All wood framing materials shall be surface dry and used at 19% maximum moisture content. All load bearing wall framing shall be #2 southern pine. All joist and rafter framing shall be #2 southern pine or hem-fir. All framing exposed to the weather or in contact with masonry or concrete shall be pressure treated. All door headers at bearing walls to be (2) 2x10SYP or better, unless noted otherwise. Prefabricated metal joist hangers, hurricane clips, hold-down anchors and other accessories shall be manufactures by "SIMPSOM STRONG TIE COMPANY OR EQUIVALENT". Install all accessories as per manufacturers' requirements. All steel shall have a minimum thickness of 0.04 inches (ASTM A446 GRADE A) and be galvanized Coating G60). Trusses and beams shall bear directly on GLB or SYP posts U.N.O. where required, shims to be A36 steel U.N.O. GLB or SYP posts U.N.O. shall bear directly on concrete slab or on SYP or PT plate unless noted otherwise. Members designed 'LVL' (E.G., 1¾" x 14" LVL) shall be laminated veneer lumber as manufactured by boise (Versa – Lam) or Engineer approved substitutions. Bolt heads shall be centered & drilled no more than 1/16" larger than bolt diameter. Bolted connections shall be tight but not to the extent of crushing wood under washers. All nail shank sizes to be minimum of 0.131 inches (fig. 8, 9 & 10).



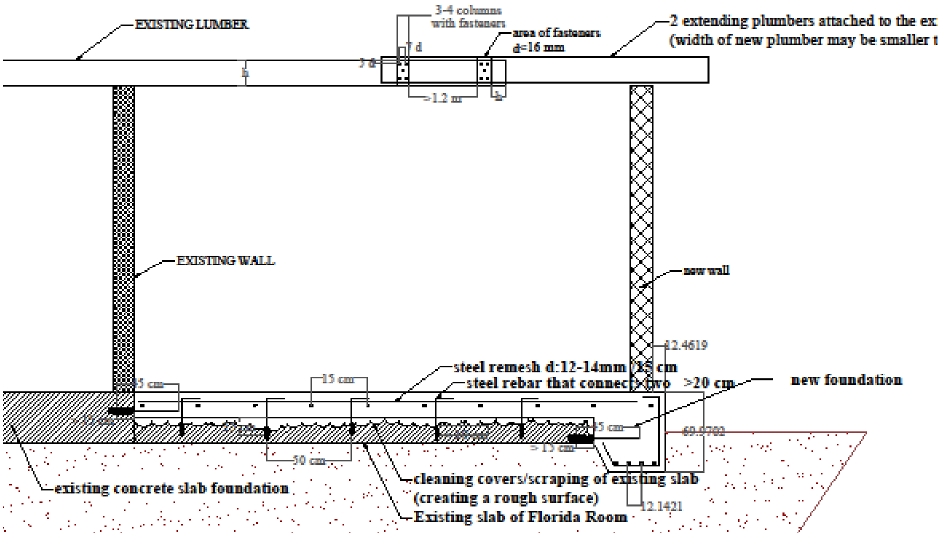
Pic. 8. Proposed cross section 1-1 & 2-2.

ROOF FRAMING NOTES: The design of roof framing shall be based on the requirements of the Florida building CODE, 2014 EDITION. Design wind loads (pic. 7) shall be applied in accordance with ASCE 7 – 10. See wind notes for wind design requirements. Roof truss manufacturer shall submit and provide complete layout and furnish the following information: Roof pitch, lumber size, spacing, species and grading, location and magnitude of uplift loads. Roof sheathing shall be 15/32" CD PLYWOOD or EQ. Trusses must be designed to support walls against out – of – plane loads. This applies to all trusses with a raised heel condition that bear on an exterior wall. Truss manufacturer's truss layout shall show all connections between trusses and other trusses, and between trusses and wood beams. Use Simpson H10 or H10 – 2 at each truss for wood walls and HETA 20 for concrete walls where possible. Where the H-10 cannot be used on wood walls (EG. On 3-ply girders, at corners, etc.) Use Simpson H 2.5 and additional tiedowns to meet uplift requirements. (pic. 9)

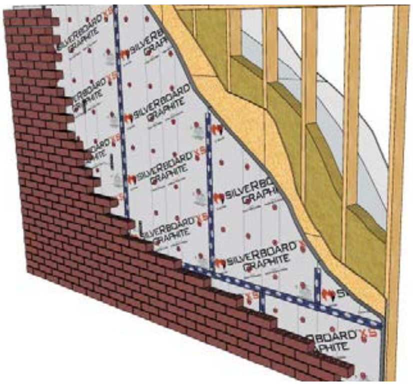


Pic. 9. Roof framing plan – pointing construction and thermal bridges.

NOTES: Extension of beam as is described in the scheme secures us that fasteners will transfer half of the load from the lumber (Pic. 10). This procedure will take place after the wall is built up, so that the beams will be based loosely on the new wall.



Pic. 10. Longitudinal section align the lumber

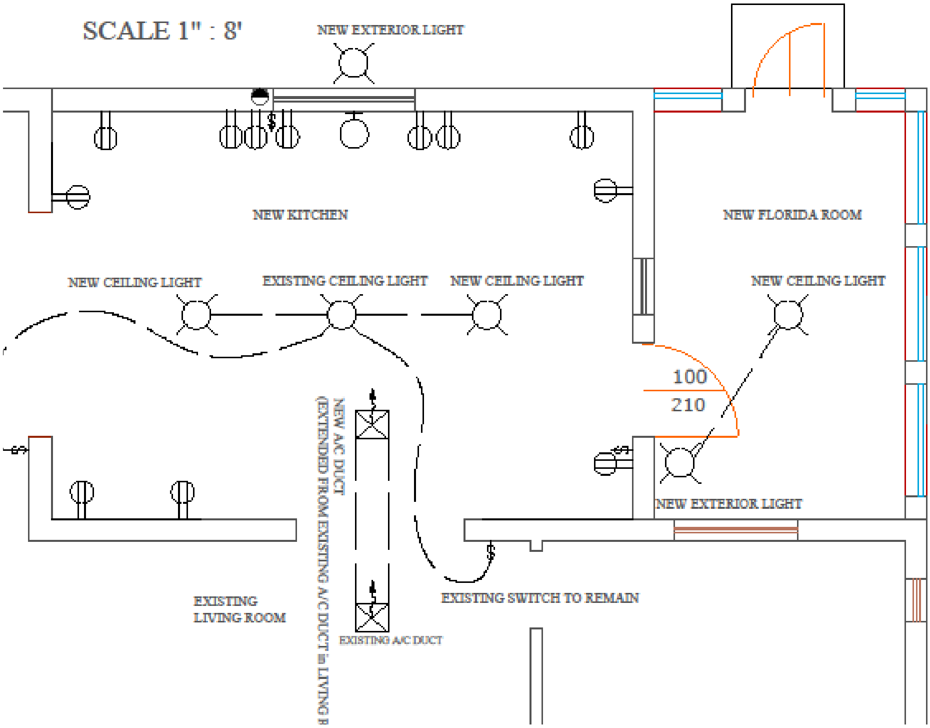


Pic. 11. Insulating sheets used in typical wall (was assembly with SilverRboard Graphite XS as continuous insulation and brick veneer cladding). [18]

PEST / DECAY PROTECTION NOTES:

DESIGN WIND PRESSURES (ASD) FOR COMPONENTS and CLADDING (psf) 150 MPH (ult) CAT B @ 15' HEIGHT					
TRIBUTARY AREA [SF]	**ZONE**				
	ROOF			**WINDOWS & DOORS**	
	1	2	3	4	5
10	+16.0 / -22.2	+16.0 /-38.7	+16.0 / -57.2	+24.3 / -26.3	+24.3/-32.25
20	+16.0 / -21.6	+16.0 /-35.6	+16.0 / -53.5	+23.2 /-25.3	+23.2/-30.3
50	+16.0 / -20.8	+16.0 /-31.5	+16.0 /-48.6	+21.7 /-23.8	+21.7 /-27.4
100	+16.0 / -20.2	+16.0 / -28.4	+16.0 /-44.9	+20.7 /-22.7	+20.7 /-25.3

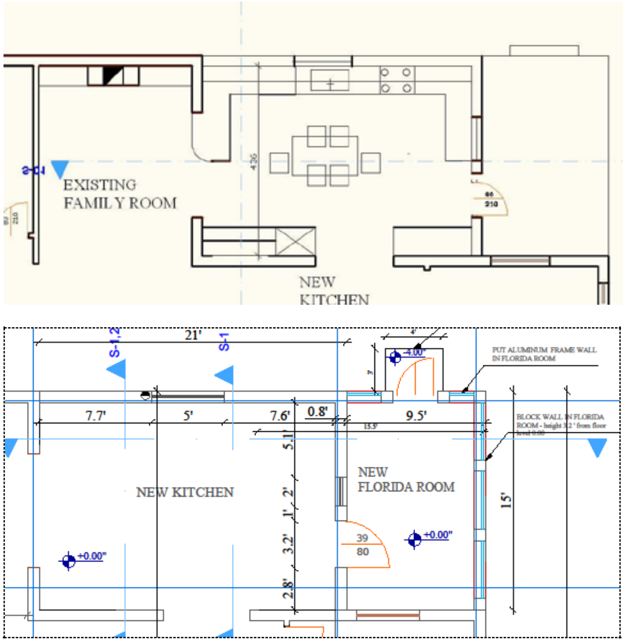
ELECTRICAL NOTES: Electrical work shall include but not be limited to the following: Power for connections to equipment provided and installed by other trades, i.e., HVAC equipment. Notify and install locally certified smoke detectors as required by national electric code (nec) and meeting the requirements of all governing codes. Provide and install ground fault circuit - interrupters (gfi) as required by national electric code (nec) and meeting the requirements of all governing codes. (Pic. 12)



Pic. 12. M.E.P. floor plan.

RESULTS AND DISCUSSION

Once one of the two models designed (pic. 13 a), b) was chosen based on the targets that contractor has set in the beginning, one indicator has been defined and measured. This indicator must be interpreted against a benchmark or a standard to determine whether the observed performance is satisfactory or not. [11]

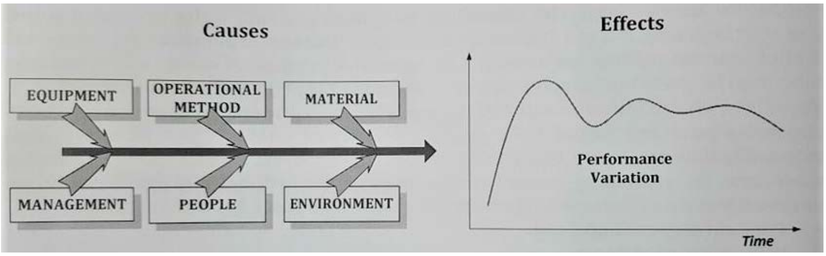


Pic. 13. First proposal plan (a); Second proposal plan (b)

Targets must be set from the position of knowledge on the representative operational circumstances, which may be affected by one or more of the following factors:

1) Current and baseline production volume; 2) Nominal Production capacity (Plant capacity) – production capability over the course of a day, month or a year defined as number of standard shifts per day, hours per shift, multiplied by items or volume produced (pieces, ton, kg..); 3) Capacity utilization – actual production divided by nominal production capacity. ; 4) Product mix.

If any of these factors change significantly over the time, targets may need to be redefined in order to reflect new circumstances. [11] Factors that influence energy and environmental performance are summarized as in pic. 14 [11]



Pic. 14. Symbolic Cause-Effect Relationship of Influencing Factors and Performance Variations.

Although the large part of the project is somewhat technical, there are some sections that help in monitoring and verification of results of the choices made in design and construction. These components are [11]:

- Savings measurement with simple formula: Energy Savings = Base Year Use – Post Retrofit Energy Use ±Adjustments.
- Measurement options: Method of whole building Approach (analyzing utility bills before and after implementation)
- Monitoring and verification plan: calculation and interpreting the intended result at the design stage) (pic. 15)
- Valuation of units of utility resource savings. Energy cost savings may be calculated by applying the price of each energy or demand unit to the determined savings [11]

As a results, after adding air-conditioned surface of 42 m^2 to the existing surface covered by old HVAC equipment (for 1 ton) showed that needs to be replaced to a bigger one (for 2 tons). In the beginning the contractor decided to keep the old one, which failed working after few months the construction works were finished. But this approach in architectural design proved to have positive change for providing an energy efficiency building. Comparing the results with the whole building approach method, this add to the house provided sustainability and energy efficiency for the house. Finally project was rewarded with inspector approval after HVAC Equipment Efficiency Verification.

A series of measures are compared during the years, but comparing one year before add (2016) with two years after the add was constructed, electric energy consumption (with the new HVAC equ.) decreased from 0.5$/m^2 to 0.4 $/m^2. Knowing that: the average residential electricity rate in Largo is 15.32% greater than the Florida average and average (residential) electricity rate in Largo is 10.86% greater than the national average rate, therefor designing an add to the existing building with these results is a practice that will have serious impact for the life of occupants and for sustainability of building and environment as well, making an existing building energetically efficient.

Design Temperature			
	Inside	Outside	Difference
Winter	75	60	15
Summer	79	86	7

HEATING		COMMON DATA SECTION		COOLING	
BTUH LOSS	HEATING FACTOR	SUBJECT	AREA Sq Ft	COOLING FACTOR	BTUH GAIN
		GROSS WALL	1369		
660.05		DOORS & WINDOWS	179		4762
2070.6	1.74	NET WALL	1190	0	0
636.9	0.33	CEILING	1930	1.3	2509
					0.28
7913	4.10	FLOORS	1930	0	0
2288	0.8	INFILTRATION FACTOR BTU Hr		0.4	800.8
13568.55		SUB-TOTAL BTUH LOSS (per 10 deg F)			
X 2		ADJUSTMENT FACTOR			
27137		TOTAL BTUH LOSS			
		PEOPLE(Assume 2 persons per bedroom)		300	1800
		APPLIANCES			1200
		SUB TOTAL BTUH GAIN(Room sensible only)			11072.08
X	1.1	DUCT LOSS / GAIN FACTOR		1.15	X
		SUB TOTAL BTUH (Sensible Gain)			12732.892
		MOISTURE REMOVAL		1.3	X
29850.7		TOTAL BTUH LOSS			16552.76

Pic. 15. Final analyses calculations.

CONCLUSSION AND RECOMMENDATIONS

Twentieth century markets of today can often prove an impediment to the development of truly innovative and ultimately more resilient building solutions. For instance new thinking on natural ventilation proliferates but investment priorities and procurement thinking must change too in response, and be modified to reward more common sense approaches that address the need for better basic climatic design for all new buildings. Where does 'modern architecture' fit into all of this? It should be right at the heart of it, as evidenced by the research papers in this issue and importance of climate in design. No longer should any client accept a building from an architect that does not deal well with the relationship between the indoor and outdoor climate. [6] Nevertheless, there are situations where improper installations, may reflect design faults, so these must be corrected to achieve expected output or efficiency. We shall not assume that the design is correct just because the facility has been operating for a period of time. [11] [10]

As it's said in the Declaration of Interdependence for a Sustainable Future At the UIA/AIA World Congress of Architects in Chicago, 18 – 21 June 1993 : " As members of the world's architectural and building-design professions, individually and through our professional organizations: to place environmental and social sustainability at the core of our practices and professional responsibilities; develop and continually improve practices, procedures, products, curricula, services and standards that will enable the implementation of sustainable design; and educate out fellow professionals. .."
Consequently, design and results of this study provide valuable information for architects, engineer designers and curricula of architecture.

ACKNOWLEDGEMENT

The study forms and 2010 Florida Building Code – Residential that was used for design and construction drawings was launched by City-Hall Largo.

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