Design Report

Affordable Housing for the Future Competition:

Our Response to A Call for Innovative Ideas for the Design of a Model Water and Energy Efficient Low-Income Apartment Building in Abu Alanda, Jordan

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1. Research Methodology

As part of a collaborative team effort, relevant and available resources have been reviewed. This included a comprehensive literature review of architectural journals, Leadership for Energy and Environmental Design (LEED) manuals, relevant design case studies, web resources as well as field research and discussions with experts in the fields of sustainable buildings, architecture and design. We hope that the proposed innovation in our design can also enrich the discourse on possibilities of green design in Jordan, and beyond.

2. Design Concept

It is no longer a luxury to consider environmental sustainability in architecture and design. More so than just a passing trend, "green" or sustainable design has proven itself to be the smart and practical approach to choosing materials and making most of what the natural environment has to offer. Initiatives such as this one answer the cal of the Amman Plan for green and sustainable cities.

The predicament of production housing - often prevalent in low-income housing projects - sets the individual nature of domesticity at odds with standardized building practices. Instead of reducing residents to their perceived least common denominator, we propose a "building set" that composes a diverse platform from which individual lives may be played out. Walking around the development grounds, you are greeted with a refreshing diversity of facades, green plazas and courtyards, instead of a typical cookie cutter style of similar housing projects. Nonetheless, the building set is still a replicable model that could be developed in any other location, striking a balance between diversity and pragmatism.

Within this set, a modern interpretation of the age-old courtyard is reborn. Here, 21 dwellings converge around this common space, engaging ecology and connecting community. Community planting gardens intersperse the building grounds, keeping the connection alive between the inhabitant, the land that is home and neighbors all around.

The apartments themselves are set up in two different topologies: a linear ground-floor plan and an alternative linear/L-shaped layout in subsequent floors. Both set ups allow each apartment to enjoy views to the outer surroundings as well as a view to the courtyard within. However, a sense of privacy is maintained through the adopted window treatment. Each home benefits from passive cooling and heating features, renewable energy sources, massive earthen walls built with local material, efficient insulation, water and energy saving design

3. Design Methodology

As the first cornerstone of the design process, the building orientation was designed such that the building is elongated along the east-west axis, allowing for maximum sun exposure along the southern elevation in winter and minimum exposure to the east/west elevations in summer. In addition, the presence of the courtyard facilitates daylighting and heating through the north facing apartments. Optimal utilization of space and introduction of diversity to the elevations is achieved through the alternating arrangement of the buildings, as illustrated in the site plan.

The building can be accessed through either the upper or lower street levels, where the lower level has been equipped with wheelchair accessible ramps. Following these access points is the courtyard space, which encompasses general allotments which can be utilized by the building's inhabitants for cultivating their own produce and herb gardens. This arrangement offers opportunities for social interaction, economic savings by growing one's own produce and cultivation of the land. In addition, the presence of foliage elevates facilitates natural humidification, thereby having a cooling effect on the western summer breeze.

The courtyard is flanked on either side with a set of stairs, each leading to a reception area for two apartments. This set up offers a sense of ownership of one's entrance, not commonly found in housing projects that opt for a single entrance for multiple homes. The courtyard, as well as the cutouts within the building's elevations, act as conduits for natural air movements and as a means for passive cooling. These cutouts also relieve the elevations from the perception of rigidity and uniformity, enhancing the aesthetic appeal.

A particularly innovative outcome of introducing the courtyard is the increase of the building's footprint without affecting the FAR ratio in order to reduce the amount of excavation / filling required, thereby substantially decreasing the need for high cost bearing walls. This treatment also capitalized on the particularly steep topography of the area, by generating six additional apartments, without compromising the basic need for views and sunlight.

A unique aspect of our design rests in the choice of rammed earth as a building material. Rammed earth is a technique used in the building of walls using the raw materials of earth, chalk, lime and gravel. It is an ancient building method that has seen a revival in recent years as people seek more sustainable building materials and natural building methods. Because of the nature of the materials used it is incombustible, thermally massive and very strong and hardwearing. It also has the added advantage of being a simple way to construct walls.

Stabilised rammed earth is a low-carbon masonry wall material that successfully combines ancient earth-building techniques with modern commercial technologies and building practices. The finished product is a durable material that is costeffective and infinitely recyclable. It is a commonly reported fact that around half of all global CO_2

emissions can be attributed to the construction, and more importantly the operation, of buildings. The reason why rammed earth is an effective low-carbon technology is that it tackles both of these areas. In the construction phase, rammed earth contributes very little embodied energy for two main reasons:

1. approximately 95% of the component materials are unfired

2. the use of locally-available raw materials minimises the level of transportation required.

The elevation walls, as well as the roof top are insulated for maximum thermal efficiency.

Landscaping is used to support in the passive heating and cooling of the building, as demonstrated by the tall deciduous trees planted along the western façade. These serve to shade the building from the strong summer rays, yet still allowing sunlight through in the winter. We recommend using native, water saving plants where possible.

A rainwater harvesting system is incorporated in the building design, based on calculations of the rooftop catchment area, the annual rainfall and runoff properties. Harvested rainwater would then be used to meet the water needs for gardening and landscape irrigation in the courtyard and around each building. A dual stack plumbing system is designed to make use of the resulting greywater from sinks, laundry and showeheads. This water is conveyed to a constructed wetland as a form of biological treatment, where the resulting effluent is used for landscaping of the shared green spaces between the various buildings. The wetland itself is a feature of the landscape, and a symbol of innovative, green design (wetland calculations shown in **Appendix A)**. The dual stack plumping ensures the infrastructure is in place should greywater be treated for use in flushing and irrigation in the future. Water saving sink fixtures and showerheads are recommended.

The buildings are holistically design for energy efficiency. From the material choice of rammed earth with a relatively low u-value and favorable thermal mass qualities, to the use of passive heating and coolilng. Solar water heating is recommended as a minimum solution which should be introduced in all homes, maximizing use of the Jordanian sun for at least 75% of the year. Double glazing is also recommended despite the slightly higher investment rate, which serves to insulate the living enclosures along with roof, basement and external wall insulation. On the long run, efficient insulation and presence of thermal mass would ensure thermal comfort and reduce the need for fuel-consuming heating / cooling interventions.

The table below represents the interlinkages between the proposed green design concepts and their potential to save water , energy and cost, as was to benefit the environment and the community. Many options have more than one positive impact, which synergize towards achieving "Sustainable Homes, for Sustainable Living"

Proposed Green Design Aspect	Water Saving	Energy Saving	Money Saving	Thermal Comfort	Benefit to Community	Benefit to the Environment	Reasonable Payoff Period	
Rainwater harvesting	✓		✓		✓	✓	✓	
Greywater Reuse (constructed wetland)	✓		✓		✓	✓	✓	
Water Saving Fixtures (dual flush toilets, water saving sink fixtures and showerheads)	✓		✓			✓	✓	
Passive Heating / Daylighting		✓	✓	✓	✓	✓	✓	
Double Glazing		✓	✓	✓		✓	✓	
Insulation and Draft Proofing		✓	✓	✓		✓	✓	
Solar Water heaters	✓	✓	✓	✓		✓	✓	
Thermal Mass		✓		✓		✓	✓	
Natural cooling / ventilation		✓	✓	✓		✓	✓	
Choice of Materials: Local / Biodegradable where possible		✓	✓		✓	✓	✓	
Sustainable Landscaping	✓	✓	✓	✓	✓	✓	✓	

4. Cost Estimate

Cost Estimate for 1 building from the Abu Alanda Phase 3 housing project (Total project is for 8 plots and 2700 landscaped area)

Input Data

Estimated Enclosed Area	2887.5	m2
Apartment floor area	525	m2
Appartment area	124	m2
FAR	1.58	

Category No.	Descrption	Unit	Rate (JD)	Quantity	Total Cost(JD)
1	***Substructure***				
	a. Excavation & Filling	m3	5	1706.25	8,531
	b. Concrete Framework and steel reinforcement	m3	57	123	7,011
2	***Superstructure***				
	a. Concrete slabs	m3	50	721.875	36,094
	b. staircases and steps	m3	57	14.1	803.7
	c. columns	m3	70	145	10,150
	d. Rammed Earth Exterior Walls, 0.45 m thickness	m2	74	2182	161,468
	e. Internal Blockworks, 10 cm	m2	9	1575	14,175

	thickness (hollow concrete)				
3	***Finishing Materials***				
	a. Double Glazed PVC windows	m2	60	320	19,200
	b. Internal Plastering	m2	5.5	314.2	1,728
	c. External Plastering	m2	7.5	1250	9,375
	d. floors (terrazzo) and under vinyl	m2	4	2774	11,096
	e. toilet floors (ceramic)	m2	10	113	1130
	f. doors (wood)	m2	95	308.7	29,327
	g. VOC free internal paints	m2	2.5	314.2	785.5
	h. external paints	m2	7	1250	8750
4	***Insulation Material***				
	a.Insulation system with protecion boards to basement walls	m2	5	913	4,565
	b. roof insulation system (2 cm polyurethane with sloped concerete 0.5%)	m2	10	525	5,250
	c. Insulation to façade (extruded polystyrene 0.05 m thickness)	m2	3.5	2182	7637
5	***Landscaping***				
	a.asphalt flooring for	m2	12	330	3960

	parking				
	b. exposed aggregate cement tiles	m2	12	120	1440
	c.curb stone	mr	11	122	1342
	b. gabiaon boundary walls	m2	45	7	315
	e. soil and green cover	m2	15	210	3150
6	***M&E***				
	elevators	each	1	5000	5000
	water pumps (for irrigation)	each	25	2	50
	mechanical (double stack plimping+ water saving shower and sink fixtures)	m2	60	2300	138000
	electrical	m2	45	2300	103500
	Other green design aspects				
	Solar heater	each	350	21	7350
	Additional Pumping for use of Harvested Rainwater in Irrigation	each	30	1	30
	Constructed Wetland Greywater Treatment system	Lum p sump	2000	1	2000
				Total	593,833
	Add 10 % contingency				653,216

Cost / m2	**226**	**J D**

5. Life Cycle Analysis of Water / Energy Investment Benefits

The design applies smart methods of reducing effective power and water requirements at a financially justifiable capital investment cost. Hereunder, the design incorporating these features is referred to as Concept I. Concept 0 assumes an investment and cost scenario where none of these design features were used. Numerical Details are summarized in **Appendix B.**

Investment costs:

By implementing the proposed design features, total initial extra investment costs such as double glazing, water treatment system and solar heaters totaling 58,250 JD is offset by a saving of 194,870 JD in the substructure and superstructure investment costs leading to a total saving of 136,620 JD.

Energy Efficiency Measures:

The solar heaters are expected to eliminate the need for energy expenditure for water heating most of the year, reducing the energy expenditure by approximately 33% (assuming 305 days of no use).The total cost is expected to drop by approximately 42,000 JD/Yr at current diesel prices. Furthermore, Double Glazed Windows are expected to reduce the power consumption for heating purposes by at least 10% with a further annual saving of 4,200 JD/Yr.

Water Efficiency Measures:

The rain water harvesting system is expected to generate 100 m^3 of water per year which, when used for the community garden, this is expected to generate at least 300 Kg of produce at a market value of over 150 JD. The gray water treatment system is expected to generate approximately 8,000 m^3 of gray water for landscaping irrigation per year at a market value of 800 JD.

Financial Analysis:

The total investment costs including replacements are estimated at a net present value of 618,780 JD. The total water and energy savings due to extra design features of insulation, solar heating, gray water treatment, rain water harvesting, water saving fittings and community gardening is estimated at 13,627 JD and 479,347 JD respectively. The NPV of the investments along with the projected savings present a robust positive value for both energy and water, which indicates these are sound investment decisions which will ultimately result in savings for the stakeholders.

Conclusions:

The design has succeeded on two fronts; it reduced the initial investment needed from the base scenario by working with the land and not against it, and reinvested parts of the savings in modern water saving/generating and energy saving systems for further benefits totaling close to 500,000 JD in net present value. Therefore, the extra design features employed are very feasible and of benefit on both the short and long term.

Appendix A: Calculations of Greywater Treatment System (Constructed Wetland)

1- Digging the trench JD 200

2- Gravel (including transportation) 16-32 mm in diameter (2 trucks of 9 cubic meter capacity) JD 250

3- Lining (black plastic mulch of 1 mm thickness) 65 square meter (160 JD)

4- Collection tanks (2 tanks of 2 cubic meter capacity per each) JD 200

5- Submersible pumps : 2 pumps 250 JD

6- Plumping cost : JD 150

7- Pipes : JD 150

8- Bricks : JD 150

9- Labor: JD 350

10- Other : miscellaneous materials like small tanks, adhesive ,valves , etc : JD 200

For a system of 30 square meter capable of treating 3 cubic meter a day , the cost will be in the range of 2000JD

Appendix B: Numerical Representation of Life Cycle Analysis of Water/Energy Investment Benefits

The following table outlines the initial investment costs of each scenario:

Description	Concept I	Concept 0	Cost Difference
Substructure			
a. Excavation & Filling	8,531	90,000	-81,469
b. Concrete Framework and steel reinforcement	7,011	85,500	-78,489
Total Substructure	15,542	175,500	-159,958
Superstructure			
a. Concrete slabs	36,094	36,094	
b. staircases and steps	804	804	
c. columns	10,150	10,150	
d. Rammed Earth Exterior Walls, 0.45 m thickness	161,468	196,380	-34,912
e. Internal Blockworks, 10 cm (hollow concrete)	14,175	14,175	
Total Superstructure	222,691	257,603	-34,912
Finishing Materials			
a. Double Glazed PVC windows	19,200	4,800	14,400
b. Internal Plastering	1,728	1,728	
c. External Plastering	9,375	9,375	
d. floors (terrazzo) and under vinyl	11,096	11,096	
e. toilet floors (ceramic)	1,139	1,139	
f. doors (wood)	29,327	29,327	
g. VOC free internal paints	786	786	
h. external paints	8,750	8,750	
Total Finishing Materials	81,401	67,001	14,400
Insulation Material			
a. basement walls Insulation system/protection	4,565	4,565	
b. roof insulation system (2 cm polyurethane)	5,250	5,250	
c. Insulation to façade (extruded polystyrene)	7,637	7,637	
Total Insulation Material	17,452	17,452	
Landscaping			
a. asphalt flooring for parking	3,960	3,960	
b. exposed aggregate cement tiles	1,440	1,440	
c. curb stone	1,342	1,342	

d. soil and green cover	3,150	3,150	
Total Landscaping	9,892	9,892	
M&E			
a. Elevators	5,000	5,000	
b. water pumps (for irrigation)	50	50	
c. mechanical double stack plumping/ saving fixtures	138,000	103,500	34,500
d. Electrical	103,500	103,500	
Total M&E	246,550	212,050	34,500
Other green design aspects			
a. Solar heater	7,350		7,350
b. Constructed Wetland Greywater Treatment system	2,000		2,000
Total Other Green Design Aspects	9,350		9,350
Grand Total	602,878	739,498	-136,620

Financial Analysis:

	Investment	Savings over 20 yrs	Net Present Value (6% discount)
Total Investment Costs	602,878	-17,850	618,780
Water Saving	36,500	88,831	13,627
Energy Saving	21,750	923,908	479,347

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