# 299: Ilan Ramon-Elementary School, Jerusalem

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The Pilot Project
A new 18 classroom elementary school in South Jerusalem area, 700 m above sea level; stepped two storied terrace, South facing building (mainly classrooms). Total built area 2,251 m2. Designed as a passive solar school, part of a program for school "green design" buildings in Israel. Will serve as a demonstration project.

Finishing date : September 2007.
The Energy Concept
The Energy Vision of the project emphasizes the use of maximum natural resources to create comfort conditions within the classrooms
The southern façade is used for solar air collectors to heat the classrooms.
Night air flushing is used to cool down the building structure, and maximum daylight, using "light shelves" and optimal shading.
Supplementary cooling and heating is supplied by a unitary Air Condition –HP using green refrigerant R-410.

Benefits of the Pilot Project

| | |
|---|---|
| Energy consumption per year of the pilot project is | 107.5 KWH/a |
| Energy Saving per year of pilot project is | 56.0 KWH/a |
| Additional Investment costs in pilot project, | 49,800 € |
| Energy cost saving in pilot project is | 5,740 € per year |
| Cost effectiveness | 8 years, +8 months |

Keywords: sustainable, energy comfort building, green design, natural resources.

## 1. The Location

The school is located on the South East side of the city, approximately 700 meters above sea level. The site for the school is a steep east-facing slope, which poses a challenge for the design of a green school. However, the stepped terrace design takes advantage of the site's extensive open views to the south and to the east. In addition to the elementary school a five classroom kinder garden is located on the site, which is bounded by roads on three.

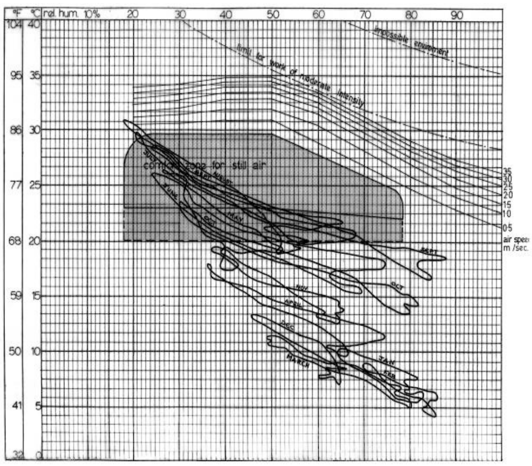

*Fig 1. temperature/ humidity comfort chart, monthly average, Jerusalem*

## 2. The Climate:

### 2.1 The climate is tempered Mediterranean

**The summer is comfortable:**
Average daily 23 c°
Average daily max. 29 c°
Average daily min. 17 c°
Average daily swing 12 c°
The winter is cool:
Average daily 9 c°
Average daily max. 12-13 c°
Average daily min. 4-5 c°
Annual heating degree days- degree 1354 c°

**2.2** The cloudiness varies:
10-15% heavy clouds
60-70% mixed clouds together
with 55-70% of sunshine
20-30% clear sunshine days
**2.3** Relative humidity (midday)
summer average: 40-45%
winter average: 60-65%
**2.4** Heat load is mild
**2.5** Being on the edge of the desert Jerusalem gets "Hamsin" hot (40 cº) and dry (15%), several days per annum.
**2.6** Rainfall: 500-700 mm per annum.
**2.7** Wind – daily mean direction: west.
Mainly noon & afternoon (30-50%)
night mean direction: east (15%)
**2.8** Snow: average annual: 3-4 days, mostly during January – February, (seldom: December / March). 20cm-40cm (extreme 100cm)

## 3. Design Approach

### 3.1 The Building & Site

18 classroom school, with 2 special education classrooms, a library, laboratories, and technical rooms.
The site is a steep East oriented Slope; The difference from top of site to the bottom part is 29.0 m.!
The school is arranged in three stepped down terraced clusters (wings) of classrooms. Each wing has an access to a courtyard, each age group has its own separated courtyard. The area of each classroom is 49 sq.m. and laboratories are 60 sq.m. The entire building is accessible to disables..
The school is designed in four levels, and the total built area is 2251 sq.m

The project was conceived by the city of Jerusalem (the constructing governmental agency) and by IRDEW (a non-for-profit R&D organization) as a prototype for a green school. Its location, in the mountain area near the desert, yet in a prominent location in Israel, promises good results in energy conservation.

### 3.2 Green Design Approach

The green energy saving school design is based on the bioclimatic ecological rationale, adopting the building to its environment, climate, and limited natural existing resources. The design energy saving costs in the building,is aiming at 40% savings. Climate responsive schools will create natural comfort conditions of heating, cooling and lighting, adjusted to the end users.

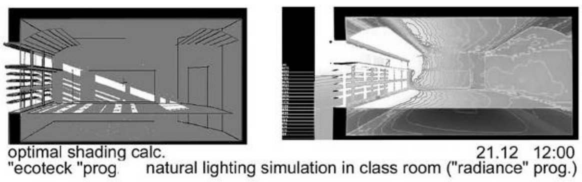


*Fig 3. Optimal shading calc.*

#### 3.2.1 Architecture concept

**1.** The positioning and orientation of the building was checked against the cost of site development, and was set to 16º off south towards the east.

**2.** Direct southern exposure to all classrooms arranged around three courtyards in three terraced wings, following the sites topography, to allow winter sun penetration.

**3.** Non-south orientation of service spaces, i.e. staircases, laboratories corridors, storage spaces etc.

**4.** Minimum openings to east and west.

**5.** Using double facade for different performance layers: collectors+ shading and opening windows.

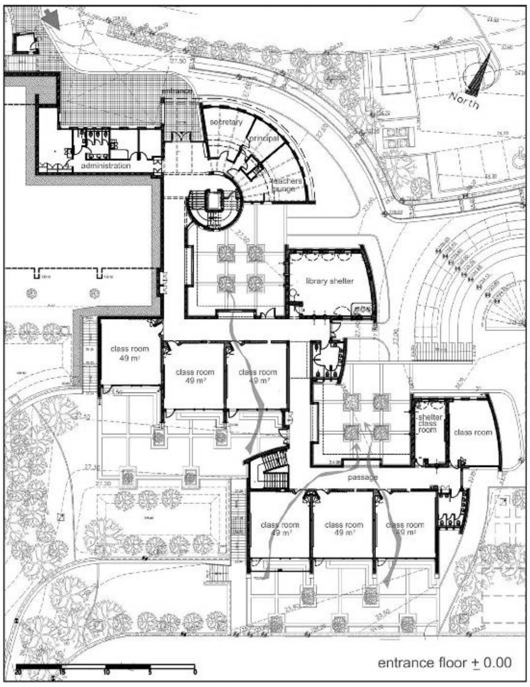


*Fig 2. entrance floor*

#### 3.2.2 Energy conservation

**1.** Improvement of the façade by insulating to save on structural costs and energy losses in winter, and energy gain in summer, making the inner wall into a "climate stabilizer".

**2.** The wall's insulation was checked and calculated against cost benefits, to improve structural performance.

**3.** Light shelves design was calculated and checked using "Radiance" software, and adjusted where needed.

**4.** Design of "light shelves" in the classrooms to increase the level of penetration of daylight to save on artificial lighting costs

**5.** Design of curved suspended ceilings next to the windows to increase depth of daylight penetration

**6.** Use of night air flushing to cool the classrooms through the corridors and northern courtyards.

**7.** Designing shading devices for the southern elevation (doubling as security bars). Calculating optimal shading using "Ecotect" by "Square One" software. Using calculation feedback to improve the design of the shading devices.

**8.** Improving the design with a differential thermostat and calculation of systems ,Improving the design of night air flushing through the courtyards

### 3.2.3 Alternative energy

**1.** Use of southern elevation as air collectors to heat classrooms on two floors, integrated into curtain wall and using "shadow box" technology.
**2.** Using selective painted corrugated steel sheet for the air-collectors
**3.** Using dampers & shutters connected to the air collectors, controlled by differential thermostat

**4.** Checking and calculating the design efficiency of the air collectors design against cost benefit.
**5.** Using automatically opening windows for night air cooling.

## 4. ENERGY CONCEPT

### 4.1 Baseline Situation

The main energy demands in the school build are: Electricity for lighting, computers, office appliances, cooling, and heating

### 4.2 Energy needs

| **Energy Need** | **Peak demand Kw** | **Annual consumption Kwh/year** | **note** |
|---|---|---|---|
| Light | 50 | 40,000 | |
| Computers | 18 | 20,000 | |
| Office appliances | 10 | 14,000 | |
| Cooling | 120 | 50,000 | Unitary DX Air Condition unit Refrigerant -R-410 |
| Heating-Hp | 120 | 65000 | Electrical heating by HP |
| Elevator | 30 | 12500 | |
| Total | 230 | 201,500 | |

### 4.3 conditions

Summer Outdoor design condition -31.5C°.
Summers indoors design condition: -23C°-24.5C°
Building condition area: -1348 m²
Winter Outdoor design condition: -1.0C°.
Summers indoors design condition: -19C° - 21C°.
Light level: -600 Lux.
Domestic hot water for 50 people 4.0 litters/day at 45C°

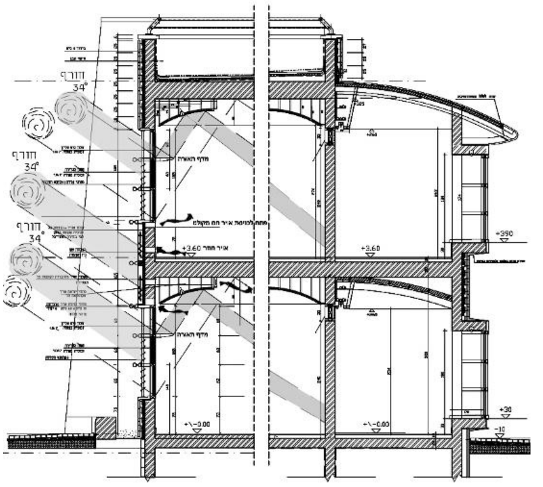

*Fig 4 . Energy concept-south wall section, winter*

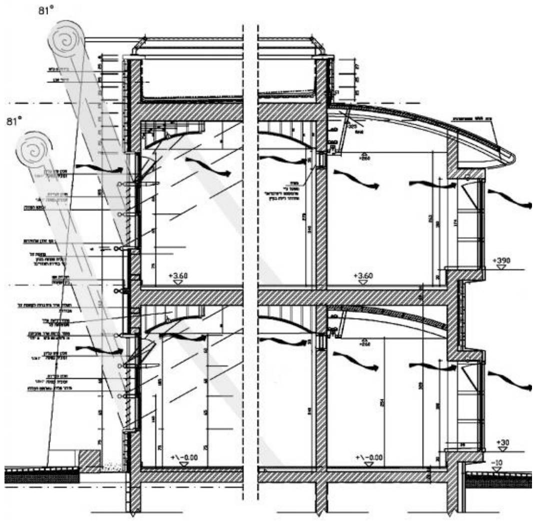

*Fig 5. Energy concept-south wall section, summer*

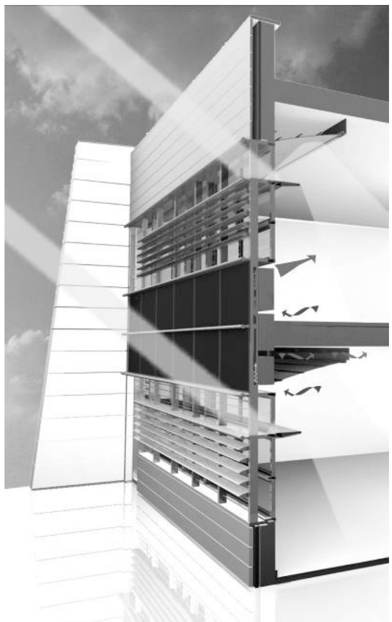

*Fig 6. South facing wall section; shading and ventilation solutions*

## 5. Energy Concept

**5.1** The Energy Vision of the project emphasizes the use of maximum natural resources to create comfort conditions within the classrooms while reducing to minimum the heat gain during summer and the heat loss during winter by optimizing the building's orientation and the buildings envelope's thermal characteristics.

**5.2** The southern façade is used for solar air collectors to heat up the classrooms during winter, using solar passive methods.

**5.3** Because of the high daily temperature swing, night air flushing is used to cool down the building structure and enables it to absorb energy during the day without raising the classrooms air temperature above comfort level.

**5.4** The classrooms are exposed to maximum daylight without creating glare areas within the room by the use of light shelves and optimal shading features.

**5.5** Supplementary cooling and heating is supplied by a unitary Air Condition –HP using green refrigerant R-410.

## 6. measures for energy conservation

**6.1** Insulation, to prevent heat loss: The external Envelope of the building is thermally isolated (double skin stone faced concrete with 50mm insulation) in order to minimize the heat loss from the building year around.
**6.2** Optimal shading, to prevent heat gain.
**6.3** "Light shelves", to improve daylight penetration and reduce the use of artificial lighting, and suspended ceilings next to the windows to increase depth of daylight penetration and reduce the use of artificial lighting
**6.4** Using high efficiency air conditioning unit with reverse cycle heat pump with green refrigerant R-410 for heating, using the outdoor air as a heat source for the unit.

## 7. use of renewable energies

**7.1** Solar radiation for space heating using passive solar air collector system.
**7.1.1** The Heating system is based also on solar thermal collectors which are installed on the south façade of the building.
**7.1.2** The total solar collector will be about: 100m2 (black shadow box, single clear 4mm glazing)
**7.1.3** Automatics dampers system & grilles are installed in the class and supply hot air to the room during the winter season days.
**7.1.4** The effectiveness of the solar air collectors in saving on heating costs in the winter was calculated according the Net heat gain available to the class space through the solar collector and the reduction the envelope heat losses. It was found that per classroom (floor area 49 m2) with an 11.5 m2 solar air collector, and 12.5 m2 glazed window, a saving of 155 Kwh/year is achieved in heating energy.

7. The daily temperature swing (12 c°) is taken advantages of for space cooling utilizing a night air flushing system.

**7.2.1** Night air flushing is implemented through ventilation fans and automatically controlled windows that are operated during the night.
**7.2.2** Utilizing the outdoor lower air temperature compared to the face structure temperature (about Delta T 5-80C). This Method saves about 25% of energy consumption for cooling.

*Fig 7.View from south*

## 8. level of the improvement

**8. Standard Building Solution:**

**(considering a typical school structure in Jerusalem)**

| Building component | Area [m²] | u-value conventional project [W/m²K] |
|---|---|---|
| Façade | 2996 | 1.25 |
| Windows (incl. frames) | 269 | 5.28 |
| Glazing | 242 | 5.28 |
| Roof | 1340 | 1.00 |
| Ceiling | 911 | 1.66 |

### 8.2 Description of level of improvement for the pilot project:

| Building component | Area [m²] | u-value pilot project [W/m²K] |
|---|---|---|
| Façade | 2996 | 0.55 |
| Windows (incl. frames) | 269 | 3.57 |
| Glazing | 242 | 3.57 |
| Roof Alumni cladding | 380 | 0.4 |
| Roof Concrete | 960 | 0.36 |
| Ceiling | 911 | 1.66 |

### 8.3 Percentage of improvement:

## 9. COSTS AND BENEFITS

| Building component | Area [m²] | Improvement of U-value pilot project - % |
|---|---|---|
| Façade | 2996 | 56% |
| Windows (incl. frames) | 269 | 32% |
| Glazing | 242 | 32% |
| Roof Alumni cladding | 380 | - |
| Roof Concrete | 960 | - |
| Ceiling | 911 | - |

### 9.1 Energy savings

Energy consumption of the standard solutionMethod of calculation:

Cooling energy consumption is calculated based on actual operation hours (524 hours) and the full load hour's concept.

| Energy consumption | Energy source | Energy consu.[KWh/a] | Energy consu.[kWh/m²/a] |
|---|---|---|---|
| End energy use for heating | Electricity | 65,000 | 29 |
| End energy for cooling | Electricity | 50,000 | 22 |
| End energy for light | Electricity | 20,000 | 9 |
| Electricityuse for household appliances | Electricity | 26,500 | 12 |
| Domestic hot water | 80% solar | 1400 | 0.62 |
| Domestic hot water | Electricity | 600 | 0.27 |
| Etc. | | 163.5 | |

Heating energy consumption base on degree-hour method in Jerusalem using COP=2.5 for heat pump. Total operation hours 676 (for the school).

### 9.2 Energy consumption of the pilot project

Estimates of the energy consumption including subdivision for energy consumption and energy source:

| Energy consumption | Energy source | Energy consumption [KWh/a] | Energy consumption [kWh/m²/a] |
|---|---|---|---|
| End energy use for heating | Electricity | 39,000 | 17.3 |
| End energy for cooling | Electricity | 30,000 | 13.3 |
| End energy for light | Electricity | 10,000 | 4.5 |
| Electricity use for household appliances | Electricity | 26,500 | 12 |
| Domestic hot water | 80% solar | 1400 | 0.62 |
| Domestic hot water | Electricity | 600 | 0.27 |
| Etc. | | 107.5 | |

### 9.3 Economic analysis

#### 9.3.1 Investment costs

| Building component | Area [m²] | Investment costs pilot project [Euro] | Investment costs standard solution [Euro] | Additional investment costs [Euro] |
|---|---|---|---|---|
| Façade | 2296 | 364,500 | 370,000 | -5,500 |
| Windows inc. glazing | 269 | 99,150 | 90,450 | +8,700 |
| Roof | 1340 | 161,700 | 161,700 | - |
| Ceiling (inc. acoustical panels) | 911 | 102,800 | 99,180 | 3,620 |
| Air collectors | 100 | 34,880 | - | 34,880 |
| Night ventilation | | 8,100 | | 8,100 |
| Total additional investment costs | | 771,130 | 721,330 | 49,800 |

#### 9.3.2. Energy costs

Energy costs standard solution:
Energy costs pilot project

| Energy consumption pilot project | Energy source | Unit price (Euro) /[kWh] | Energy costs [Euro/a] |
|---|---|---|---|
| Costs for heating | Electricity | 0.10 | 3900 |
| End energy for cooling | Electricity | 0.10 | 3000 |
| Domestic hot water | Electricity | 0.10 | 60 |
| Light | Electricity | 0.10 | 1000 |
| TOTAL | | | 7690 |

**9.3.3 Energy cost saving 5740Euro/annual**

**9.3.4 Cost effectiveness 8 years+8 mounths**

## 10. Notes on additional investments costs:

**10.1** Façade: Jerusalem standard façade is a double skin concrete stone faced wall with 30mm polystyre insulation. Implementation of better insulation to the walls, 50mm polystyre, to prevent heat loss.
**10.2** Air collectors façade: replacing part of the concrete faced wall (100m2) with air-collectors, including automatic dampers and grilles.
**10.3** The standard school windows in Jerusalem are aluminium sliding/pivot/fixed panel double glazing windows.
**10.4** "Light Shelves" were implemented to increase penetration of daylight.
**10.5** Ceiling in schools include acoustical panels in passages and parts of the classrooms. Additional cost was added to curved suspended structure to help better penetration of daylight.
**10.6** Night ventilation, using the temperature swing of 12 c° (average in summer) to cool the insulated concrete structure, using differential-thermostat to electrically operate windows and vents.

## 11. Additional Benefits general note on additional benefits

**11.1** The school as a pilot project will demonstrate the technical feasibility and profitability of energy efficiency in school design in Israel.
**11.2** The schools' built area in Israel:
all over: 600 classes = 75,000 m2 per year
Similar climate conditions:
Galil mountains, Jerusalem area, Negev Mountains. 240 classes = 30,000 m2 per year .
Using the pilot project methods in other similar areas will save energy costs of 76,500 €/A
**11.3** Improvements of the school built environment: in Israel are:
**11. 4** natural even day lighting in classes for better concentration of pupils.
**11.5** natural cooling for 4-5 hours for better comfort in classes
**11.6** providing better quality of space heating saving up to 25% of energy cost to school administration budget for better education.
**11.7** Educating the future generation:
adopting sustainable design as a method for living
**11.8** saving on limited resources of fossil energy demonstrating solution for saving on green house gas emission ($CO_2$)

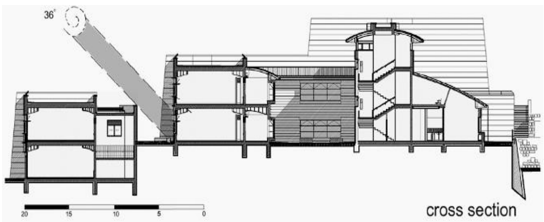


*Fig 8. Section*

## 12.The project team:

architect: Ruth Lahav; R.Lahav-Rigg Architects and Town Planners LTD, Tel Aviv.
Research & development of energy systems: Amos Halfon, AES LTD, Haifa
Structural Engineer, Effi Cohen, Jerusalem
Landscape Design:Tony Rigg& Yoram Shaham
Plumbing:Amnon Yosha
Electricity: Hava Hayat
Optimal Shading Calc.: :Arch.. Eran Kaftan
Project Manager: Udi Golan, NTF, Givataim.
Contractor: Kafrit Construction LTD, Jerusalm.
Documentation and publication: Raphael Yaron, IRDEW, Tel Aviv
Client:: Jerusalem Municipality, Public Building Design Dep. Arale Bin-Nun Head. Arch Oded Lilntal
Financing : Israel Official Lottery.