ENVIRONMENTALLY FRIENDLY CITIES, Proceedings of PLEA'98, Lisbon, Portugal, June 1998
Pages 283-286 © 1998 James & James Science Publishers Ltd

Retrofit of existing housing stock
A feasibility case study

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Abstract

Israel, not unlike other Mediterranean countries, experienced a housing construction boom in the 1950s and 1960s. Many projects from that period are currently undergoing renovation and refurbishment. This study reviewed the thermal characteristics of such projects and evaluated the current refurbishment practices vis-a-vis a combined effort including retrofit. Different solutions for a specific case study were evaluated. The results point toward a vast savings potential in energy consumption on the national level, as well as to marginal savings for individual customers, which such solutions provide at current energy prices in Israel.

INTRODUCTION

The 1950s and 1960s in Israel were marked by massive housing construction, similar to that of the post-war era in other countries around the Mediterranean. High pressure for quick and cheap housing solutions, alongside the development of prefabrication in construction, and the existing paradigms of that period, brought forth the construction of thousands of similar apartment houses, based on minimal requirements in size, as well as in climatic adaptation. Although several research projects were carried out at that time in an attempt to optimize certain features toward the improvement of thermal conditions, most design and construction followed the "guidelines" set by the International Movement around the world.

Forty years after this post-war building boom, the relevance of upgrading the residential building stock dating from that period has become apparent. Following decades of continuous use, with inadequate maintenance, many of these buildings are in urgent need of repair. In addition, initial low insulation values, poor construction practices, low quality of finish materials, faulty fenestration details, and little attention paid to energy considerations, have rendered these buildings uneconomical to run and maintain in their present condition. A need has arisen for renovation and upgrading of facilities and services which, in many cases, are of outdated technology.

This study took into consideration the fact that such renovation of the aging residential building stock is inevitable, and that certain upgrading and renovation will eventually take place in residential blocks of inadequate comfort levels and aging systems. Also taken into consideration was the fact that it has become the interest of governments to encourage energy conserving design and retrofit, as being economically viable and environmentally sustainable.

To illustrate the energy conservation potential of such processes, this research examined a case study of conventional refurbishment in Jerusalem, assessed energy savings and compared them to those simulated for a number of alternative retrofit solutions considered feasible, among them sunspaces and Trombe-Michel type walls. The overall costs were compared and evaluated *vis-a-vis* energy savings for the individual dwelling, as well as on the national level, by taking into account the overall number of similar units. Based on reports of the Israel Ministry of Housing and Construction, the study estimated an existing stock of over 500,000 apartments of similar design, construction and age [1,2].

CONVENTIONAL REFURBISHMENT - A CASE STUDY

One such case study is the Shmuel Ha'Navi neighborhood in Jerusalem, situated close to the pre-1967 Jordanian border. However, its present location is rather central, a fact which makes renovation and upgrading a viable solution, considering current land values.

Geographical location and climate

Jerusalem is located on the Judean Mountains, on the border between the Mediterranean zone and the desert. At an altitude of 850m above sea level, and 31.5° north latitude, the area is characterized by hot dry summers and cold winters. Summer average daily temperatures (August) range between 29°C maximum and 17°C minimum, with relative humidity ranging between 40% (at 14:00) and 80%. Average temperatures in January range between 12°C maximum and 2°C minimum, with an average of 1,354 Heating Degree Days. Temperatures below 0°C and snowfall are not uncommon. Prevailing winds are westerly and north-westerly, with some easterly winds in winter and transition periods [3].

Neighbourhood plan and building characteristics

The Shmuel Ha'Navi neighbourhood was built in the early 1960s to house new immigrants, and consists of 22 apartment blocks, containing a total of 1,150 apartments. The total population of the neighbourhood ranges between 3,650 and 4,560 residents.

Blocks are four stories high and apartments are accessed by a central staircase with two units per landing. Apartments are small ($50m^2$ on average) and consist of two bedrooms, living room, kitchen, bathroom and small balcony. They are rectangular in plan, with long common walls and short facades facing opposing directions (see Figure 1).

The buildings were built of concrete frame and prefabricated concrete wall panels (15cm thick). Between those and an internal concrete block wall (5cm) an air cavity of up to 5cm was created. Floors and roofs were made of concrete slabs. Thermal bridges were common and resulted in condensation on internal surfaces. Common were also leaks through tarred flat roofs.

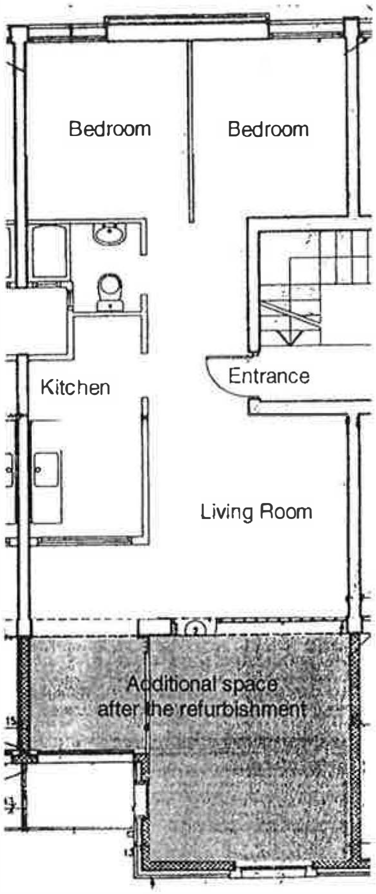


Figure 1. Typical apartment plan with refurbishment addition (shaded).

Refurbishment

Refurbishment briefs prepared in the late 1970s and early 1980s as part of a nation-wide upgrade project, called for the addition of floor area, waterproofing, dampness treatment by insulation, and a general aesthetic "facelift".

The Shmuel Ha'Navi buildings had their whole envelope treated. Roofs were insulated with polystyrene boards and waterproofed. Exterior walls were insulated and stone faced. The specific apartments studied were enlarged by $22m^2$ (appr. 44%) in floor area, through the addition of two spaces. Window area was enlarged from 19% to 23% of the facades.

The retrofit details already included in this refurbishment stemmed from the need to solve condensation problems, and from the existence of the compulsory Israel Standard 1045 for residential building insulation [4]. However, most of the design effort was invested in the aesthetic side of the project rather than the climatic one. The total refurbishment cost was appr. US$ 150 per m^2 [5].

RETROFIT ALTERNATIVE SOLUTIONS

Although already retrofitted to a certain extent, it was assumed that the buildings investigated had a higher savings potential. Several alternative refurbishment solutions were considered, combining different passive or hybrid bioclimatic features, which would not alter drastically the nature of the architectonic intervention. These included additional insulation, double glazing, addition of shading devices (fixed and operable), enhanced ventilation by changing the relative sizes of windows in windward and leeward facades, sunspaces (with single or double glazing), Trombe-Michel type walls, and the conversion of roof areas and staircases into solar collectors and distributors (referred to here as "RCD"). The different solutions were evaluated with the help of QUICK simulations [6]. The additional retrofit costs were compared to the relative energy savings.

These results are presented in Table 1. The figures should be considered under the following conditions: energy for heating was calculated with an 18.3°C internal minimum setting (as defined by Israeli standards), whereas energy consumption for summer cooling assumed an internal maximum temperature of 25.5°C. No internal loads or occupants were taken into account. Infiltration in winter and on summer days was assumed to be 1 Air Change per Hour (ACH), whereas ventilation during summer nights (20:00-07:00) was assumed to be 5 ACH.

It should be noted that in most cases such as the one discussed in this paper (low income housing) air-conditioning is not common. However, the introduction of air-conditioning to residential and commercial buildings is growing rapidly, thus making energy consumption for cooling one of the most problematic sections of the national energy budget. In the period of 1984-94 the consumption of electricity in Israel increased at an average annual rate of 7%. The largest increase was registered in household consumption, primarily due to the increased use of air-conditioners. These trends are expected to continue through

Table 1. Comparison of cost and energy consumption of different solutions.

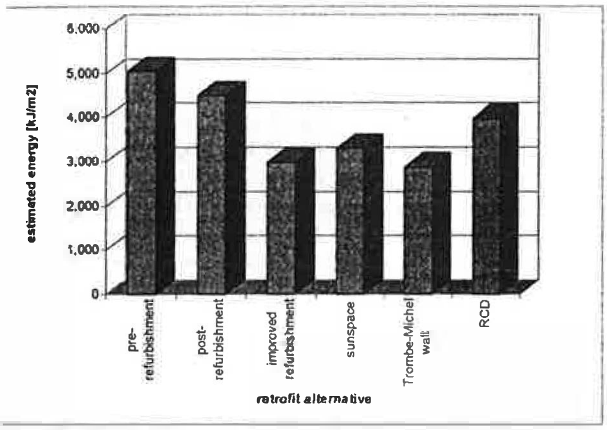
Solution description	Cost per floor area [US$/m2]	Estimated total energy consumptio n - Summer [kJ/m2]	Estimated comparative energy use	min. internal temperature without heating (winter)	Estimated total energy consumption - Winter [kJ/m2]	Estimated comparative energy use
Pre-refurbishment	-	1,138	100.0%	8.6	5,040	100%
Refurbishment	150.33	1,073	94.3%	9.2	4,492	89.1%
Refurbishment + improvements	152.28	910	79.9%	10.2	2,990	59.3%
Refurbishment + sunspace	218.41	1,216	106.8%	11.3	3,293	65.3%
Refurbishment + Trombe-Michel wall	287.85	1,154	101.4%	12.6	2,874	57.0%
Refurbishment + RCD	175.61	1,201	105.6%	11.2	3,973	78.8%

oming years, stemming from a steady population h and a steady increase in the standard of living [7]. facts point toward trends similar to those in other erranean countries, such as Greece, Italy and Spain, : purchases of air conditioners increased by some between 1987-90 [8].

Refurbishment versus retrofit

WINTER

s of simulations were performed for the different ions, with and without auxiliary heating. The bished apartment simulation showed internal eratures in winter higher by 0.5-1°C than those under re-refurbishment conditions, but in both cases these well below thermal comfort. Additional insulation lated for thicknesses of 4, 6 and 8 cm of polystyrene) ed negligible improvement, since the wall section was dy insulated and stone faced. The addition of double ng brought a rise of internal temperatures by 1°C, and red daily energy consumption by over 2.5 kW. The us alternative solutions simulated - RCD, sunspace and be-Michel wall - showed gradual improvement of an ional 1.5°C, reaching appr. 12.5°C for the optimal n simulated without auxiliary heating, and in auxiliary ing simulations lowered energy consumption to 78.8%-% of the pre-refurbishment needs (see Figure 2).



ure 2. Estimated energy consumption for heating.

SUMMER

ferences in summer were far from negligible. With ndows closed and shaded during the day, and efficient ht ventilation, the improved refurbishment option cluding double glazed windows and movable external ding) proved to be the optimal. The use of fixed shading vices helped lower internal maxima in other cases, but ir effect was negligible compared to that of night nvective cooling. However, the solutions most effective in nter (sunspace, Trombe wall and RCD) proved to be a bility in summer, even when theoretically neutralized (see gure 3). All three of them created internal conditions orse than those in the pre-refurbishment case. These sults are logical considering the fact that such solutions clude dark surfaces and glazing that are hard to fully utralize. Experience also shows that in such cases the user ay refrain from treating such systems properly, thus eating internal conditions that may eventually demand xiliary cooling devices.

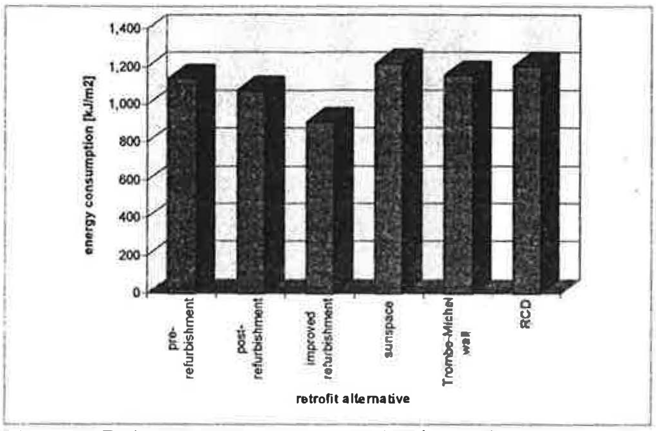


Figure 3. Estimated energy consumption for cooling.

CONCLUSIONS

To illustrate the magnitude of the conservation potential, the following figures are presented: the calculated energy savings for the conventional refurbishment examined (which includes certain retrofit features) for a typical heating day could easily exceed 1,000 MWh per 100,000 apartments, whereas by introducing minor improvements to the refurbishment details (such as double glazing, and enhanced ventilation in the summer) it is possible to increase energy savings by an additional 33.4% at an additional construction cost of less than 1% (under climatic conditions similar to those of Jerusalem). It is possible to reach energy savings of over 50% with more complex solutions, but at a relatively high cost. Although environmentally sound and obviously of great importance on the national level, such complex solutions are hard to promote on the user level, because of the current, partially subsidized energy prices, as well as relative lack of awareness on the public's side. At a current cost of appr. US$ 0.08/kWh, the added cost for a retrofit solution such as the sunspaces simulated in this study, would have a simple payback period of 5-6 years (under Jerusalem conditions - not calculating interest). It should, therefore, be the interest of the state, and especially of the authorities concerned with energy and infrastructure, to promote such solutions, thus lowering energy demand for building conditioning, and limiting the need for the expansion or addition of energy generating and distributing units and infrastructure.

The strange interaction created by the rise of living standards and the lack of appropriate building treatment may be illustrated by the ever-increasing demand for electricity, which in the winter of 1997-8 reached unprecedented peaks [9]. It is obvious then that appropriate retrofit (within the limits of economically viable solutions) could ease the strain on the infrastructure, especially during peak demand on winter nights and summer afternoons.

ACKNOWLEDGEMENTS

This study was partly supported by the Cultural and Scientific Affairs Dept. of the Israel Ministry of Foreign Affairs and the Dept. of Studies of the Greek Ministry of Education.

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   To illustrate this claim, it should be enough to note that on the night of Janua 11, 1998, exceptionally cold onditions (by Israeli standards) caused a peak demand of appr. 6,600 MW, and the projected peak for this winter is 7,200 MW. These data were presented by the Israel Electric Company on the television news on January 12, 1998 (2^{nd} Channel) in an attempt to explain the numerous power failures that occurred the previous day and night, and should be considered vis-a-vis the country's population of appr. 5.5 million.