A Sustainable Development Centre: Xrobb il-Għaġin Nature Park, Malta.

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ABSTRACT: The Sustainable Development Centre is located within the Xrobb il-Għaġin Nature Park at Xrobb il-Għaġin in Malta. The scope of the project is to rehabilitate an existing complex of buildings used for other functions over the years, and to transform the buildings into a Sustainable Development Centre, within the Nature Park to accommodate a new scientific and educational facility. The sustainable rehabilitation of the buildings is based on a comprehensive approach, addressing the architectural value of the buildings, the functional requirements, structural interventions and repair of the structures, the conservation of resources, water conservation, waste water recycling and waste management, services, the inclusion of energy efficiency measures and the use of alternative and renewable energy sources.

1 INTRODUCTION

1.1 *The Xrobb il- Għaġin Site.*

The Xrobb il-Għaġin Nature Park & Sustainable Development Centre, is located on the Xrobb l-Għaġin peninsula, situated to the southeast of the island of Malta. The Park covers an area of 15ha. and is surrounded by agricultural land and the Mediterranean Sea, with the nearest village being Marsaxlokk, circa 2.5km to the west. Between 1974 and 1996, the Site was the location of a Relay Station of Deutsche Welle–Radio (DW-R), which covered the Near Middle East and North African Region for transmissions in different languages. Initially, the station was also used by Radio Canada International, and later by Voice of the Mediterranean. The station consisted of a complex of buildings which housed the main activities of the operation and three small outbuildings. Following the DW-R's departure from Malta, the station buildings and the surrounding grounds were made available for the Fish Farming Industry, and a company used to operate blue-fin tuna farming until 2006. The site was also used for limited agricultural activities, hunting and trapping. The existing buildings were left in a state of disrepair (Gauci, 2008).

1.2 *The Nature Park & Sustainable Development Centre*

The Ministry for Resources and Rural Affairs, with the collaboration of Nature Trust Malta (NTM), is transforming the Site into a Nature Park, through a rehabilitation project involving the afforestation of the part of the peninsula and the protection of an area of high ecological value. The buildings making up the ex-relay station complex are considered to be important examples of 1960 -70s architecture in Malta, and are being restored, to be used as a Sustainable Development Centre. The centre includes offices to be used by NTM who is responsible for the implementation of the afforestation project and the overall management of the Site, and the Department of Electrical Power and Control Engineering, Faculty of Engineering, University of Malta, who will be conducting research on renewable energy technologies. The complex also includes a hostel and will host an education facility in environmental management, including ecological rehabilitation, afforestation, and energy conservation.

2 THE EXISTING BUILDINGS

2.1 *General*

The station complex was designed by Deutsche Welle Architect Willi Schalenbach. It includes features typical of 1960-70s architecture and is considered to be of Architectural value. Furthermore the station buildings represent the regional development in international communications during the second half of the 20th century. The objective of the rehabilitation strategy is to restore the buildings in the complex, provide for flexibility of the spaces and adapt them to a new function through a structured intervention, whilst retaining the architectural integrity.

Figure 1. Representation of The Sustainable Development Centre after Rehabilitation.

2.2 *The Existing Structure*

The buildings consist of load-bearing masonry construction. In general, the buildings rest on reinforced concrete foundations with reinforced concrete ground slabs. Walls consist of globigerina limestone blocks. Various structural roofing systems were identified, and include mainly two typologies; reinforced concrete cast in situ slabs; and composite slabs consisting of precast pre-stressed concrete inverted T beams, with concrete blocks supported between them, and with overlying cast in place structural concrete. Different varieties of roof slabs were identified in the existing structures, namely slabs with a single or with a double beam system. Other reinforced concrete elements include the cantilever slabs and shading devices, the cornice and architectural features including the roof water drain details.

Figure 2. Existing deteriorated structure & reinforced concrete elements on façade prior to repair.

3 REHABILITATION STRATEGY

3.1 *General*

The Sustainable Rehabilitation strategy is based on a comprehensive approach, addressing the architectural integrity of the buildings, new functional requirements, structural interventions & repair, resource conservation, waste management, services, energy efficiency and renewable energy sources. The strategy also required the consideration of planning issues, accessibility and landscaping schemes. The project can be considered to be one of the first conservation interventions on the 20^{th} century architectural heritage in Malta. The rehabilitation of an existing building rather than reconstruction resulted in a larger challenge, in the adaptation of existing spaces for the new uses. In addition the project requires longer timeframes for completion, and particular skills in specific operations including dismantling and repair. The rehabilitation strategy also allowed for conservation of resources and reduction in waste generated. The investigation & design were carried out during 2006 & 2007, and rehabilitation works started in 2008.

3.2 *Structural Assessment Methodology*

The scope of the assessment was to investigate the buildings, and structural elements, and to assess the state of the structure and defects. The investigation was based on a detailed inspection of the buildings and elements, following a structured survey, including detailed visual investigation records; photographic survey records, records and assessment of the structural systems and structural element typologies, and records and assessment of defects. All the data was mapped out on detailed drawings and re-verified. The defects were classified with respect to type, location, extent and materials. A testing plan for materials and structure was prepared on the basis of the investigation carried out. The data of the investigation was used in order to identify and understand the actions on the structures, the failure mechanisms, and causes of deterioration (Borg, 2008).

3.3 *Structural Defects & Material Properties.*

Various defects were recorded in the existing buildings. All the services were non-functional and a new services network was required for the new functional requirements of the buildings. The finishes were in a bad state of repair, and most apertures were missing or damaged.

A number of defects were also noted in the structural elements, with the partial collapse of roof structural elements recorded. The main defects in reinforced concrete elements were cracked concrete, reinforcement corrosion and concrete spalling. In various instances, this resulted in detached concrete and exposed excessively corroded reinforcement and loss of elements and architectural features including the cornice and cantilevers on the façade. Specific roof structures were excessively deflected, in view of past actions on the roofs. Defects in the roof system included longitudinal cracks along the beam elements of the slabs, and defects and cracks in the concrete blockwork supported between beams in the roof slabs. Various defects were also noted in masonry wall structures namely hairline cracks and local defects in stone, due to impact and misuse, and defects as a result of inadequate interventions during past alterations to the buildings. Loss of finish and mortar on exposed surfaces was also recorded.

The investigation carried out included the testing of concrete. Concrete cores were extracted from various parts of the structure & different structural elements including beams and slab elements, following a plan. The concrete core strength, the concrete density, and the depth of carbonation were determined in the experimental investigation. Furthermore the investigation provided information on the roof structure and finishes. The compressive strength of cores extracted from the slab at ground floor varied between $23.5N/mm^2$ and $28.5N/mm^2$. The compressive strength of beam elements at roof level, varied from $20.5N/mm^2$ to $24.5N/mm^2$. However values of $15.5N/mm^2$ (reinforced concrete element), and $10N/mm^2$ (structural cast in place concrete over precast beams slab roof system) were also recorded. The depth of carbonation of the concrete in the cores varied between 25mm and 50mm. The cover to reinforcement was noted to vary, and in some case was less than 25mm.

3.4 *Repair & Rehabilitation*

In the appraisal of the existing structure, various aspects were taken into account including; the age of the structure, exposure of the building to an aggressive environment and proximity to the sea, deficiencies in materials used, defects in detailing, defects associated with workmanship, lack of maintenance of the structure and previous inadequate uses of the building, and actions which were not in line with the intended use. Therefore the scope of rehabilitation was to address the structural performance and structural integrity and also the durability of materials.

In specific cases, the intervention required the re-introduction of elements which were missing due to deterioration or past interventions. In various instances, it was required to replace elements which were excessively damaged and beyond repair particularly where repair was not possible due to the inferior quality of materials, inadequate details, or where repair was not feasible. The latter case refers also to the cantilever elements, various architectural reinforced concrete features on the facades and on the external envelope, and roof structures. Precast Prestressed hollow concrete slabs, together with cast in place reinforced concrete slabs in specific areas, were adopted to replace the deteriorated roof structure. Specific reinforced concrete elements required repair using appropriate materials and techniques, in particular patch repair. The extent of such repair depended on the state of these elements.

In the case of masonry elements, various parts of walls have been reconstructed and/or repaired. Stone masonry blockwork was used in all external areas to ensure the architectural integrity of the buildings. Concrete masonry blockwork was used in specific internal partitions and walls. Adequate pointing and rendering of walls is implemented through the application and use of the adequate materials, taking into consideration also the site exposure.

Various measures were proposed to ensure quality in the rehabilitation of the buildings, during the Design Phase, the Construction Phase, and also the Service Phase. A grade C35/45 concrete was adopted for the reconstructed reinforced concrete elements. An exposure class of XS-1 (EN 206-1, 2000) was considered in structural engineering design, referring to corrosion induced by chlorides from sea water; concrete exposure to airborne salts but not in direct contact with sea water. Particular attention was given to details including adequate concrete cover and waterproofing. A quality assessment plan was implemented and a site management team was responsible for operations, execution of works, and for ensuring good workmanship including adequate compaction of concrete and concrete curing. The buildings shall be used within the limitations set in the design brief, including design loads and other set criteria. A maintenance plan and inspection strategy have been proposed, and will be implemented.

4 WASTE MANAGEMENT & RESOURCE CONSERVATION

4.1 *General*

The repair of the existing buildings through a sustainable rehabilitation strategy, was considered, as against demolition and reconstruction. The objective was to adapt an existing building, to accommodate a new function. Rehabilitation as against reconstruction, addresses both the conservation of resources, and the reduction of Construction & Demolition waste.

4.2 *Construction & Demolition Waste*

The rehabilitation of the buildings required the replacement of various structural elements. However the minimum possible elements from the existing structure where replaced, whilst it was ensured that the repaired and rehabilitated buildings could reach the required functional and performance levels. This approach led to a reduction in the waste generated during rehabilitation. The waste generated during the repair and rehabilitation, was also considered for reuse and recycling. During rehabilitation it was necessary to dismantle the elements and part of the structure to be replaced, rather than demolition, particularly in order to safeguard the existing structure and elements which were retained. This methodology based on a different approach from demolition, supported further the reuse and recycling of waste generated from the rehabilitation of the buildings.

Figure 3. Dismantling and waste classification: RC roof elements and wall masonry elements.

The reuse and recycling required the separation and classification of the waste materials. The waste materials generated were identified and quantified and the methodology adopted followed the Waste Management Plan. The stone masonry blockwork was dismantled and stacked in a storage area on site. They were classified into two main groups; those suitable for reuse in secondary construction, and waste blockwork to be recycled for production of crushed stone for screed and other uses. The reinforced concrete elements were classified on site into two groups; concrete elements and reinforced concrete beams and slabs. These were transported for recycling. The reinforced concrete elements required the separation of the steel from the concrete for recycling, and concrete was crushed for the production of recycled concrete aggregate.

4.3 *Water Management and Waste Water Recycling*

The rain water and surface water runoff in the site will be collected in the existing water culverts and, and stored in the large water reservoir which will be repaired. The water will also be collected from all the roofs of the buildings. The rain water will be used as secondary water in the buildings and for irrigation purposes in the afforestation scheme. The new buildings will incorporate water saving features and accessories in the bathrooms.

The waste water generated in the complex, will be treated in a biological sewage treatment plant, built within the site. The expected daily maximum flow amounts to $10m^3$/day. The sewage treatment plant will be installed below ground, and consists of different zones made up of glass reinforced polyester tanks. The treated effluent will be of the recommended quality for irrigation in the landscaping scheme and afforestation project.

5 ENERGY EFFICIENCY

5.1 *General*

The scope of the energy efficiency measures in the project, is to reduce the energy consumption within the buildings, to minimize internal cooling and heating loads and to maintain thermal comfort. The aim of the rehabilitation strategy is to exploit the features already existing on site and in the buildings, and introduce additional measures for improved energy efficiency. The various measures adopted can lead to satisfactory indoor comfort levels which can be achieved without the use of power consuming equipment.

5.2 *Thermal Efficiency*

The Thermal efficiency of the buildings depends largely on the building envelope i.e. the walls and roof elements. The external walls of the buildings are approximately 510mm thick and consist of two skin masonry construction each having a thickness of 230mm with a 50mm air space. The U-value of the walls is lower than that recommended for Malta.

Insulation will be introduced in roofs to reduce thermal losses; the expanded polystyrene insulation has low heat transfer characteristics and is lightweight. The use of reflective coating on the roof is also considered. A weather resistive barrier will be installed to maintain the R value, and to prevent air and moisture movement into and out of the conditioned space.

5.3 *Shading Devices, Apertures & Natural Lighting.*

The reinforced concrete cantilever structures, particularly along the south east and south west facades of the main building, are an important characteristic of the building. These elements provide effective external shading to windows, eliminating direct solar radiation particularly during the summer season. The building's roof shall also benefit from the shading provided by the photovoltaic and solar water heater roof installations thus reducing the roof's thermal gain.

Windows provide less resistance to heat flow than walls, roofs and floors. Double glazing will be used for all apertures in the buildings, to reduce the transmission of heat. The frame aluminium profile is specified to be sealed and air-tight. In addition, the use of louvers on the external face of the apertures allows for air movement and ventilation. The shutters are also designed to provide visual privacy and security.

Large openings provide for adequate natural day lighting in the main spaces & reduce the need of artificial lighting in buildings. Sun-pipes will be installed in specific spaces, to improve on the natural light from windows, and in the corridors & spaces were no windows are present. Light coloured finishes are to be used on roofs and external walls to reflect radiation. The internal spaces are to be finished in light colours to reflect maximum natural light in interiors.

5.4 *Ventilation, Site Conditions, and Buildings Configuration*

Cooling in summer is to be promoted through adequate cross ventilation within the buildings, achieved through the large openings, and the high level apertures in specific spaces. Sea breezes can be exploited in view of the disposition of the buildings on the promontory and their location. Furthermore the main building is elevated above ground level by c. 850mm. This improves further natural ventilation. Ventilated ground slabs will be installed in specific areas.

The trees and shrubs surrounding the buildings also act as windbreakers. The landform and vegetative cover influence the amount of reflected solar radiation. The discomfort caused by glare is reduced. Soil, trees and shrubs have the lowest reflection values and trees provide shade and shaded ground area around the buildings.

6 INTELLIGENT USE OF ENERGY AND RENEWABLE ENERGY SOURCES (RES)

6.1 *General*

At the design stage of the electrical and energy systems of this project, three types of commercially available RES technologies were considered. These were: photovoltaic (p.v.) electricity generation, wind electricity generation and solar water heating. Furthermore, the electrical system was designed to keep the use of electrical energy at a minimum.

6.2 *PV and Wind Energy*

An electrical set-up was designed to cater for the grid connection of both p.v. and wind energy sources. For the p.v. systems, the dc current produced by the photovoltaic panels shall be transformed via inverters into a single phase a.c. voltage to allow power to flow from the panel's d.c. voltage into the electricity supply. In the case of the micro-wind turbines, wind generator's output initially undergoes rectification and then conversion to a.c. voltage by means of an inverter similar to that used by p.v. systems.

A data-logging system shall be used to monitor and log various related environmental parameters & the performance of the p.v. & wind systems. The p.v. system was designed to have three types of p.v. technologies, mono-crystalline, poly-crystalline and thin-film.

The aim of having three different p.v. technologies installed under identical conditions was to be able to log the 'actual' generation performance of each technology over a number of years. Like this a 'practical' study of which technology is most suited to the Maltese Islands can be done. As concerns the micro-wind turbines, two technologies shall be installed: a vertical axis turbine and a horizontal axis turbine. It is well know that the latter technology is the more efficient, however it was decided to have a mix of turbine designs so as to expose the general public to both types of technologies and their suitability to the natural and the built environment. In this case the wind turbines will be installed in the same area and will be exposed to the same conditions and wind resource. Direct comparison between the performance of each turbine will thus be possible.

The p.v. and wind system of inverters is shown in Figure 4 and was designed to allow electrical energy generation in grid connection mode and in 'controlled' stand-alone mode. In the case of electrical grid failure, this systems makes it possible to power the building to a limited extent as long as the p.v. and wind are still generating electricity. Once installed the stand-alone inverter shall be programmed with a load shedding program so as to provide electricity only to the building's high priority loads (e.g. fridges and selected lighting). The building shall also host a system of solar water heaters (SWH) designed to provide the hot water supply of the showers/toilets with little demand on the electricity supply.

6.3 *Efficient Use of Electrical Energy*

The most responsible attitude towards the usage of energy is to reduce inefficiencies as much as possible and take corrective action in situations where there is energy wastage. Since the project of Xrobb l-Għaġin allowed for the redesign of some of the electrical and mechanical systems, this gave the opportunity to design for the most efficient use of energy. Electrical energy is mainly used for heating/cooling, lighting and power. It is planned that the building shall not make use of electrical air-conditioning but shall rely solely on natural ventilation and proper insulation. Further, energy saving lighting technologies shall be used wherever possible, and motion sensors shall be installed in common areas to turn on the lighting only when necessary.

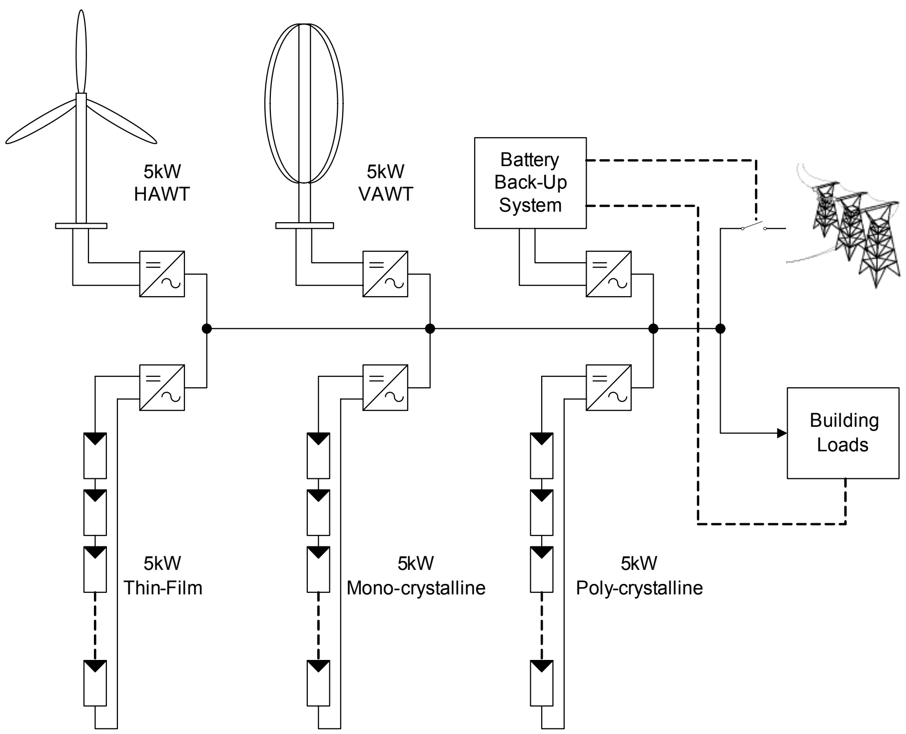

Figure 4. The Connected Grid and Standby RES System.

6.4 *CO_2 Reductions from RES Systems*

The annual energy generation by the photovoltaic (p.v.) sources (SMA) and the wind sources (Gipe, 2004) was estimated. Furthermore the energy saved by using solar water heating rather than electrical heating is shown in Table 1. Apart from reducing the electrical energy consumption, the Renewable Energy Sources shall also contribute to the reduction of CO_2 emissions as indicated in Table 1. (During 2006, it was reported that 0.8782kg of CO_2 were emitted for every kWh generated (Enemalta)).

Table 1. Annual kWh savings and reductions of CO_2 emissions.

RES Technology	Annual Savings	Annual Reduction of CO_2
	kWh	Tonnes
PV System	23500	20.5
Wind System	16000	14.0
SWH System	20075	17.5

7 CONCLUSIONS

The Sustainable Development Centre, within the Xrobb il-Għaġin Nature Park in Malta, is the first centre of its kind in the Maltese Islands, with the scope of addressing environmental management, ecological rehabilitation, afforestation, and energy conservation.

The Sustainable Rehabilitation strategy adopted is based on a comprehensive approach, addressed various fundamental principles, including the architectural heritage, functional requirements, structural interventions and repair of the structures, conservation of resources, water conservation and waste water recycling, waste management, services, energy efficiency in buildings, and alternative and renewable energy sources.

The strategy that is implemented is required to transform the existing buildings, into a functional and energy efficient Sustainable Development Centre, promoting environment and science education.

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