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LESSONS IN BUILDING SUSTAINABLY IN A DEVELOPING COUNTRY: THE HABITAT RESEARCH AND DEVELOPMENT CENTRE, NAMIBIA

The Habitat Research and Development Centre (HRDC) is a government-parastatal partnership to establish a centre for research into sustainable housing in Namibia. The architectural design of the new headquarters building Windhoek, the capital, aimed to initiate and demonstrate the activities and philosophy of the centre in its construction.

The presentation opens with an overview of the Namibian context for an unfamiliar audience and then discusses the three main strategies to achieve this aim:

1. The application of sustainability principles in the building design, particularly referring to energy efficiency.
2. The experimentation with and demonstration of sustainable design principles.
3. The ongoing impacts on the community and possibilities of future developments.

The practical results of the above strategies are reviewed, as construction is nearing completion. The design as a hybrid approach rather than a single statement is assessed. The conclusion evaluates lessons the architect has learned in the process to date which will be of value in the future.

It is the first time in Namibia that such a comprehensive attempt at sustainable building has been made, although smaller projects have contributed to the resource base used in this building.

LESSONS IN BUILDING SUSTAINABLY IN A DEVELOPING COUNTRY: THE HABITAT RESEARCH AND DEVELOPMENT CENTRE, NAMIBIA

Nina Alexandra Maritz

Nina Maritz Architect

1 Introduction

1.1 Geographic and climatic context

Located between 17 and 29 degrees south, Namibia is a vast, arid and sparsely populated country. Windhoek, the capital city and project location, lies 1500 m above sea level (which cools it down in summer), has an average maximum temperature of 32 to 34 ° C in the summer and an average minimum temperature of 4 to 6 ° C in the winter. Humidity averages 10 to 20 % with a 300 to 350 mm median rainfall. The diurnal range is extreme, varying up to 20 ° C and the humidity changes from winter to summer from 0 to 100%, both aspects severely affecting material expansion, contraction and wear.

1.2 Local construction methods

About 50% of the Namibian population live in “traditional” homes, 37 % in conventional brick & mortar dwellings and 14 % in “other” or improvised dwellings[1]. “Traditional” construction consists for mostly of wattle and daub and thatch roofs. As thatch and timber become more difficult to source due to deforestation and as social and cultural mores change, people’s aspirations are moving towards “western” or “modern” houses for status reasons and lower maintenance. Conventional “modern” housing is generally constructed from single skin load-bearing cement brickwork on concrete strip footings with SA pine roof-trusses and metal sheeting roofs. The latter is thermally extremely unpleasant and the manufactured, imported and commercially available materials often too expensive for the poor sections of the community.

1.3 Background to the HRDC

Housing is a pressing need in the country due to rapid urbanisation and the poverty of the majority of the population. The Habitat Research and Development Centre (HRDC) is result of a venture to establish a centre for research into sustainable housing with a focus on environmental appropriateness. The client partners are the Ministry of Local and Regional Government and Housing (MRLGH), the Municipality of Windhoek (CoW) and the National Housing Enterprise (NHE), the latter being the parastatal tasked with addressing the housing problem.

[1] Mendelsohn, J., Jarvis, A., Roberts, C., Robertson, T., *Atlas of Namibia*, www.dea.met.gov.na, David Philip Publishers, 2002

1.3.1 Spatial location

The centre is located in Katutura (the former black township on the outskirts of the city) rather than in the CBD, to make it more accessible to the poorer sectors of the community. It is placed on land donated by Government, next to a major school and is easily accessible by tar road from the rest of the city as well as within walking distance from the extensive informal housing settlements. Surrounded by older established small housing units, it is already a landmark and visible from afar.

1.3.2 Aims and objectives of the HRDC

The building design for the head office aims to initiate and demonstrate the activities of the centre in its construction. In brief, these are:

A:	○ Provide a central information resource centre focusing on sustainable housing
Resource Centre:	○ Promote sustainable housing (i.e. environmentally appropriate and affordable) ○ Liaise between different interest groups in this field, pool resources, create a sustainable housing network
B: Research in three main areas	○ Housing: delivery methods, land provision, plan models, urban design, etc. ○ Sustainable building materials & construction techniques ○ Sustainable and appropriate services (energy, sanitation, etc.)
D: Education & training: Instruction phase	○ Development of skills in sustainable construction methods and service provision. ○ Development of management expertise in the small building sector ○ Education of the public at large on sustainable housing issues.
E: Education & training: Participation & execution phase	○ Development of skills in sustainable construction methods and service provision. ○ Development of management expertise in the small building sector
	○ Educate public at large on sustainable housing issues.

1.3.3 Sustainability in the architectural design of the HRDC

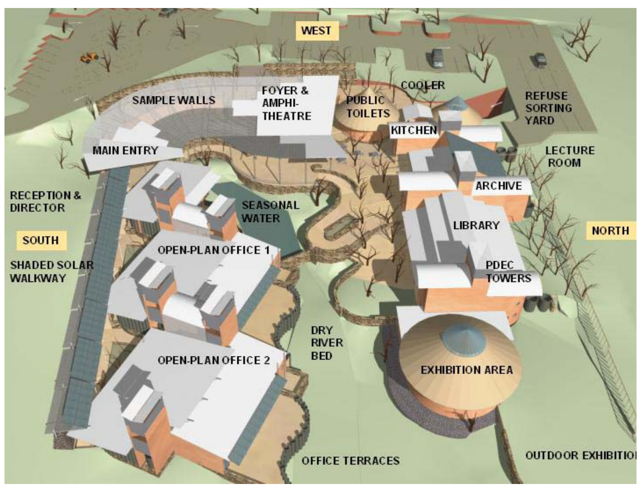
This paper will not discuss the formal design concept, previously dealt with in the original competition entry and other papers[2], but focus on three aspects that emerged as worthy of further scrutiny:

- The application of sustainability principles in the building design with reference to energy efficiency.
- The experimentation with and demonstration of sustainable design principles.
- Ongoing impacts on the community, shortcomings and future developments.

An important consideration in the process was the literal interpretation of "sustainability". Replicability in a self-build housing context was often a factor in the decision to use a certain material or construction method, such the use of corrugated iron.

1.3.4 Components of the building

Phase 1 consists of an administrative wing with reception, director's office, open-plan office module for up to 24 staff and archive storage, with a public wing of open foyer, lecture room, library, exhibition hall and services.



2 The application of sustainability principles

2.1 Passive solar principles

The primary climatic concern in Namibia is heat. Air-conditioning (for cooling) is now the norm in conventional office-buildings[3], but few buildings are heated, as the cold period is short and winter days sunny and warm. The design thus aimed to create a cool building by using passive solar principles, although comfort during the short winter was also a consideration.

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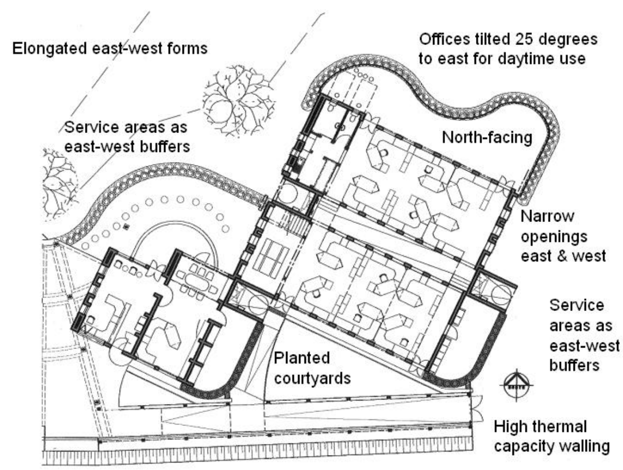
[2] Delivered at the SB'03 conference in Pretoria and the Solar 2004 conference in Portland, Oregon.

[3] The Frans Ndonga Centre in Windhoek being one notable exception with its centralised evaporative cooling system for the entire multi-storey commercial office-block. (Engineer: Henk Spoormaker).

2.1.1 Appropriate orientation

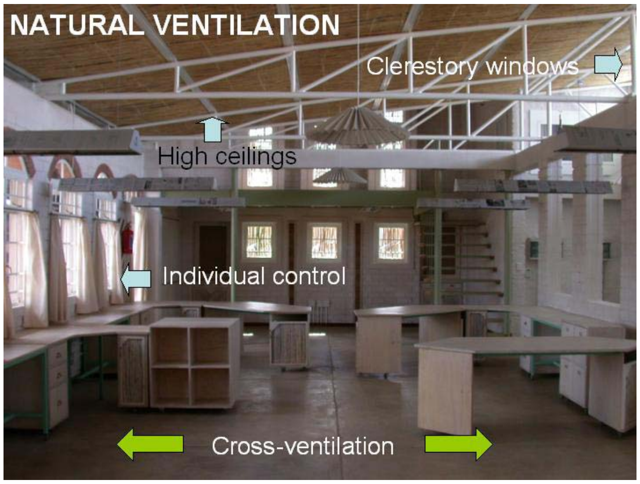
The main forms are elongated along the east-west axis and shortened on the north-south. Buildings and main openings are north- (equator-) facing, with the office wing angled 25 ° east of north to allow early morning winter sun to warm interiors. Openings on the east & west facades are restricted to narrow shaded vertical slits, but these walls are predominantly solid.



PLAN OF OFFICE MODULE

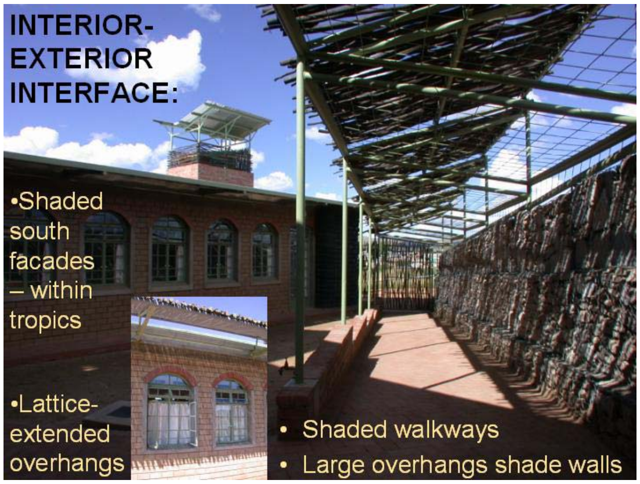
2.1.2 Natural ventilation

Cross-ventilation was provided by placing openings directly across each other. Inland wind speeds are low and obliquely set openings do not work well. Ceilings were fixed above the roof structure to allow a higher internal volume, so that the layers of rising hot air would accumulate above head height. Clerestory windows were installed at the central apex to allow the escape of rising hot air, which is encouraged by the upward slope of the ceilings. Each workstation has individually opening windows to allow personal control over breeze required.



2.1.3 Interior-exterior interface

Walls are shaded by large roof overhangs, angled to allow in winter sun but exclude summer sun. Overhangs include extensions of thin timber laths to provide a latticed shade effect. Walkways to offices are shaded with timber poles. Courtyard spaces are planted and exterior indigenous vegetation retained to create cooling through evapotranspiration, very effective in the dry climate. Windhoek lies within the tropics and it was crucial to shade the southern side, as summer sun moves over to the south from October to March, at solar noon 4 degrees south of the apex.



2.1.4 Thermal capacity

Wall-fabric is solid masonry, punctured with individual windows rather than ribbon fenestration. Walling materials are generally of high thermal capacity, such as compressed soil-cement bricks, stone, etc. Floors are floated, polished concrete surface beds, uncovered to cool occupants through the radiation effect. Service areas form mass thermal buffers to east and west, reducing the need for openings on these sides.

2.2 Energy efficiency, renewables and services

2.2.1 Energy efficiency

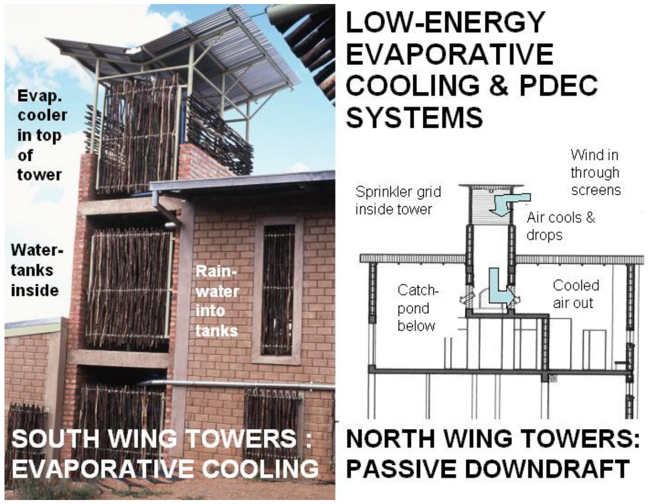
Strong emphasis was placed on energy efficiency, as the generative potential of the Centre is small compared to the potential savings in consumption. Passive methods employed, in addition to those discussed above, were:

2.2.1.1 Lighting

- Window openings maximise day lighting and the side windows and central clerestory distributes daylight equally. Lights only need to be switched on at night or on the about ten overcast days a year.
- Curtains in a translucent white calico limit glare on computers without needing artificial lighting when drawn.
- Arched windows with straight curtain-rod below create a “fake” light-shelf to allow more distribution of light to the interior.
- Artificial lighting is task-orientated and individual switching is provided to reduce consumption after hours when only one or two people are working.
- All light fittings are low-energy fittings (fluorescent or compact fluorescent).

2.2.1.2 Cooling

- A low energy evaporative cooling system is installed for the offices and a passive downdraft evaporative cooling (PDEC) system for the public area.



2.2.1.3 Appliances

Water heating for washing up in the main kitchen is by solar geyser. Boiled water for beverages in the office kitchenette is produced by an in-line boiler with insulated tank (the most efficient small system available). Refrigeration is by highly insulated zero-CFC eco-friendly electrical fridges. The main kitchen will also contain a gas stove, intended to be powered by bottled bio-gas produced by the local agricultural college at Neudamm outside Windhoek. A wide range of solar stoves being tested and promoted by the R3E[4] will also be used by the main kitchen. A large modified traditional farm-cooler was built for storage and cooling of fresh produce and beverages for large events[5].

2.2.2 Water consumption and sanitation

As it has to be pumped from the main storage dam at von Bach, 70 kilometres away to its destination in the higher hilly surrounds of Windhoek, water has a big impact on power consumption. It is of course scarce in a desert country like Namibia and cannot be excluded from any discussion on sustainability[6]. Several strategies were employed to save water:

2.2.2.1 Sewerage

All toilets are dry self-composting units and different patent ones were installed for demonstration and testing. The types of toilets used in the public ablutions to date are the “Enviroloo”, the “Eco-san”, a local builder’s “Cool-drawer” design and another type specially developed for the project.

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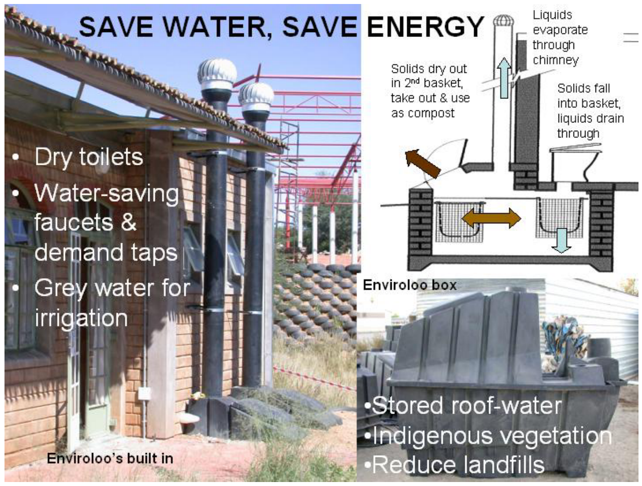
[4] The Renewable Energy and Energy Efficiency Bureau of Namibia, a local NGO renting office space in the HRDC building and participating in many of its projects.

[5] The construction consists of two honeycombed skins of fired clay brick with the cavity in between lined with wire chicken-mesh and filled with invader-bush charcoal. Water drips into the cavity from above to percolate through to a channel below and gathered into a small pond with solar pump which recycles the water to the top. The interior is lime-washed and acts, like the charcoal, as a fungicide. Added features are a clay-brick vaulted roof with charcoal on top and a second roof of micro-concrete clay tiles to shade the entire structure, as well as a palm-leaf screen on the west side to add late afternoon shading.

[6] An unfortunate tendency by mainly European donor agencies is to focus on literal energy efficiency and ignore the issue of water conservation.



2.2.2.2 Water supply and drainage

Though water consumption is far less than in a domestic context, care was taken to demonstrate a wide range of water-saving options. All taps are fitted with water-saving aeration devices which can be fitted to existing fittings and the public ablutions with demand taps. A demonstration shower is located in the public ablutions for use by the maintenance staff and waterless urinals are fitted. Grey water from sinks and basins are drained through home-made filters for irrigation.

2.2.2.3 Rainwater collection

Roof-water is collected and stored in stacked rainwater tanks to serve cooling systems as well as irrigate gardens. As rainfall is restricted to a short season and tanks very expensive, we could not supply capacity for the yearly demand, but compromised with a domestic water connection for back-up. The standard plastic water-tanks are elevated in towers to create pressure and are shaded by timber pole screens to reduce the effect of the strong local sunlight on the material.

2.2.2.4 Landscaping and irrigation

Indigenous vegetation was retained and additional landscaping use locally indigenous plants well adapted to the soil and climate, needing irrigation in the first year of establishment only. The landscaping is irrigated from the Windhoek Municipal semi-purified system as well as the overflow from air-cooling and rainwater collection.

2.2.2.5 Water source

The city relies on underground water for its main supply and landfills are threatening to contaminate the aquifers. By using materials normally dumped in landfills in the construction of the building, for instance for making roof insulation, or as walling material, we hope to reduce this threat by reducing the amount of landfill.

2.2.2.6 Windhoek water initiatives

The City of Windhoek already recycles most of the water used in the city and supplies educational institutions and government facilities with less costly semi-purified water for sports fields and parks. Its project for the replenishment of the natural underground aquifers by clean recycled water is also a world first.

2.2.3 Renewable energy

Renewable energy options were limited due to the high 35% frequency of calms and low average wind speeds of around 10 km/h in inland Namibia. The coast has excellent potential for wind-energy generation, but it was too expensive to install even a small demonstration wind turbine at the HRDC in Windhoek[7].

By contrast, Windhoek's average solar radiation of 6 to 6.2 kWh/m²/day and 8 to 9 average hours of sunshine per day makes it an ideal venue for solar power generation.

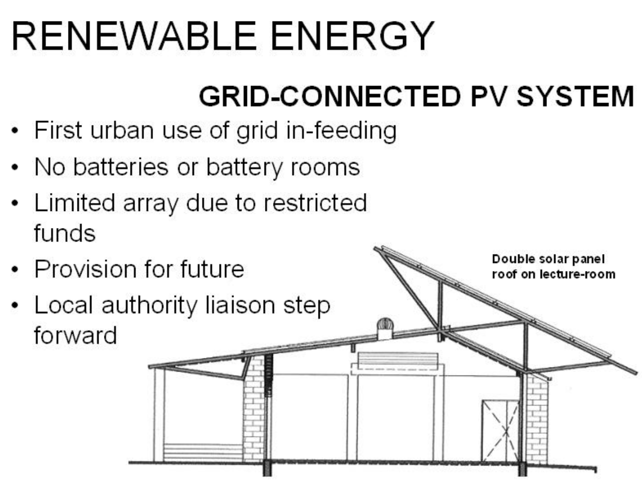
2.2.3.1 Photovoltaics[8]

A grid-connected solar PV system feeding in on one phase will initially be installed in the first urban use in the country, and a solar photovoltaic array of 4.5 kW peak (at a cost of about NAD 250,000[9]) should generate enough power to supply a part of the centre's needs as well as provide excess power over weekends and holidays to feed back into the municipal grid. It was the maximum we could afford at about 2.5% of the project budget, but the design allows for a future total of 6 arrays between 4 and 6 kW peak which will be feeding into all three phases.

The value of the current installation lies in pioneering grid in-feeding. The planning process has already raised awareness at the local authority of the potential for solar power. The solar engineer has had extensive discussions with the utility department in order to overcome natural aversion to the unknown. The main issues that came to the fore were:

- Safety aspects and protection.
- Metering approach (absolute vs. relative metering).
- Quality of supply.
- Tariffs (if any).
- Future regulatory issues.

In order to demonstrate dual function possibilities, the original idea was to install solar panels on all the walkways and north-facing roof overhangs, but this intention had to be curtailed due to the high cost of the cells. Temporary timber laths for shading were installed on the support structures to provide interim shading and complete the construction until funding can be obtained for about NAD 1, 5 million to complete the photovoltaic provision.



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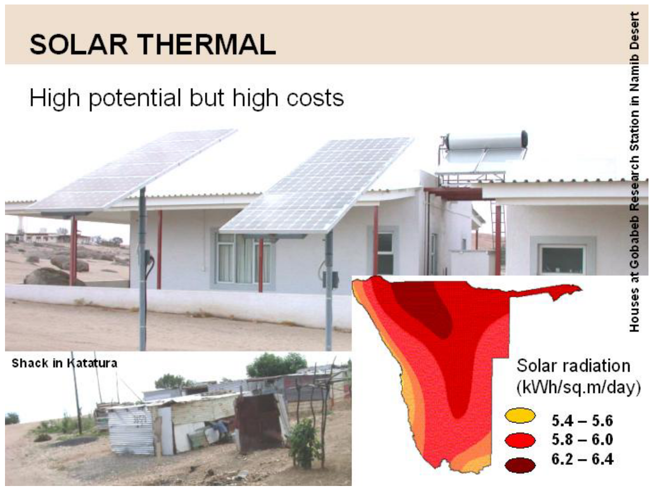
7 However, wind energy potential on the coast, especially at Luderitz, is excellent. Glynn Morris of Agama was involved in the feasibility study for the establishment of a wind farm there.

8 Information supplied by Axel Scholle of Emcon Consulting Engineers, the solar engineer of the project.

9 Namibia is part of the Rand Monetary area and one Namibian Dollar ($NAD) is equivalent to one South-African Rand.

2.2.3.2 *Solar thermal*

Potential for solar thermal is high, with the technology less complex and expensive than photo-voltaics. For the poor, though, even a NAD 1,500 conventional electrical geyser is too expensive to install, and a NAD 12,000 solar geyser is merely a sick joke (the equivalent of a year's wages for many people). The solar geyser installation is thus aimed at a middle- to high-income audience and commercial users, but cheaper low-tech alternatives should be developed.

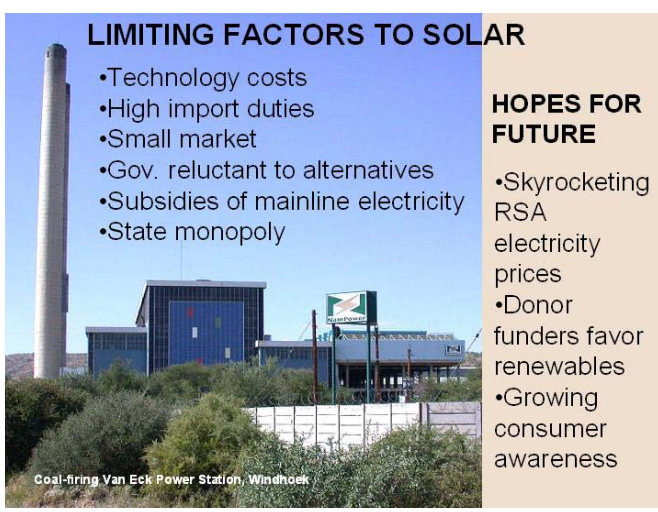


2.2.3.3 *Local development barriers to solar power*

The issues pointed out above underline a problem for the future of solar power in the developing world – the capital costs of high tech solutions prohibit expansion of solar power in these areas so ideally suited for it. Additional factors limiting solar potential are:

- unfair comparisons by the buying public of highly taxed solar components with cheap state-subsidised mainline grid power costs
- state-supported monopolies of grid power supplies
- high import duties on solar technology.

State priorities also lie with electrification rather than the development of alternative sustainable technologies as it appears to be quicker and cheaper. These constraints seem to be insurmountable in the short term and rather than only relying on lobbying the government, ways must be found around the high cost problem by the manufacturers and developers of solar technology.



2.2.4 Embodied energy

Much has been written about the embodied energy of materials in the construction context. The principles of using materials with low embodied energy in all its facets (origin, manufacture, transport, construction, re-use versus demolition, etc.) were all considered integral to the choice of a material or construction method. Though this will not be enlarged on in detail, the basic rule followed was to choose:

- local or Namibian materials as far as possible
- re-cycled or waste materials to be re-used
- unworked or materials close to their natural state
- labour-intensive methods rather than full factory pre-fabrication.

2.3 Appropriate building materials

2.3.1 Walling

Load-bearing structures were mostly used, as frame-and-infill structures rely on expensive timber or steel and thin-skin infill is unsuitable for climatic conditions where thermal mass is desirable. Timber is also a scarce resource with no managed plantations in the country and deforestation becoming a problem. The variety of walling systems used focused on high labour content and local materials rather than fast-track pre-made systems imported from afar.

2.3.1.1 Compressed soil-cement bricks

The Namibian–invented[10] Hydraform system uses an on-site mixer and hydraulic compressor to make cement-stabilised soil bricks. As the available soil had no clay content to act as binder, 6 to 8 % cement was added, producing bricks of about 4 MPa[11]. The bricks are profiled and interlock when dry-stacked without mortar. Soil was sourced from a stockpile at Otjomuise, 4 kilometres away, as the soil on site was contaminated with mica[12], a common problem in the Windhoek area.

[10] By Terrasol , although the patent was sold to a South-African company

[11] Although local building regulations require walling to be made from at least 7 MPa units, the structural engineer (Rolf Trossbach of Buhrmann & Partners), calculated that the loads on the Hydraform were maximum 1 MPa on the foundations, 4 MPa thus being more than adequate to withstand the load.

[12] The mica creates microscopic slip-layers that interfere with the binding of the soil particles.

2.3.1.2 Recycled cement bricks

Cement bricks were reclaimed by hand from building demolition rubble dumped by the Municipality next to the site. They were cleaned using unskilled labour on a cost per unit basis[13]. Though a cost-effective source of bricks, the amount of rubble available in the city is too small for a large building, but it may be feasible for houses and small additions.

2.3.1.3 Sun-dried clay bricks

Sun-dried clay bricks made by the Namibia Clay House Project have been used to build the public ablutions. Although clay has to be brought in, it is valuable to demonstrate the use of these 300 x 300 x 100 mm bricks that have been used to successfully construct over 200 self-help houses in Otjiwarongo.

2.3.1.4 Charcoal-fired clay bricks

Stock brick quality clay bricks are now being produced in new ventures by two Namibian companies[14]. These are an alternative to the ubiquitous cement bricks. The products create employment with labour-intensive production and the charcoal used to fire the bricks in Otavi is made from invader *Acacia mellifera*[15] and *Dichrostachys cinerea*[16] bushes. A scientific assessment of the embodied energy has not been done yet. The structural qualities are excellent[17] and the bricks thus used for the multi-storey sections of the project. The walls are not plastered, giving a warm textured reddish look and demonstrating that plaster is not required in the dry Namibian climate.

2.3.1.5 Rammed earth

Rammed earth using the same constituents as the Hydraform was used for the exhibition hall. Sample walls built on site have shown good results with a 4% cement addition to the soil, whereas pure soil was too friable. Wall sections with 4% cement were built as load bearing, with 2% and 0% mixes alternating as infill panels. The walls were constructed with a re-usable steel shutter and the compaction done by hand-ramming.[18]

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[13] The contractor paid 40 to 60 cents per brick whereas a new cement brick at the time cost NAD 1, 20.

[14] respectively 350 kilometres north and 250 km south of Windhoek at Kombat, Otavi and at Mariental

[15] Locally known as “Swarthaak” or “Black Thorn”

[16] “Sickle Bush”

[17] Averaging 20 to 25 MPa.

[18] Walls are 400 mm wide to allow access for ramming as well as provide the required strength for the 4 m height. Shutters were 600 mm high and filled in six 150 mm loose layers each compacted to 100 mm. The surfaces were trowelled smooth after release of the shutter.

2.3.1.6 Tyres

Tyre walls for archive storerooms were built using “earthship” techniques, filling layers of tyres with compacted soil[19]. Old tyres cannot be recycled in Namibia as the quantities are too small, but create landfill problems. Walls are unplastered to demonstrate the system and interior walls painted white for light reflection. The sheer solidity and thermal mass has been so successful that spin-off construction is already happening. Tyre retaining walls for terracing were also built and the system is soon going to be used in squatter settlements to stabilise eroded embankments.

2.3.1.7 Rubble gabions

Wire basket gabions filled with concrete rubble from demolitions were used for a retaining-shading wall for the offices. Gabion baskets are usually imported from South Africa for civil engineering projects and filled with natural stone, but workers were taught on site to make them from fencing wire with pliers[20]. The building industry

[19] A percentage of cement was added at the foundations to bind the very sandy soil.

[20] The baskets were 1.2 m long (the width of a fencing wire roll), 800 mm wide and 800 mm high. The rubble blocks were packed in-situ into the basket in three layers, each layer being braced across the basket with a wire (“bloudraad”) hook before the next layer is packed. Once the workers got the hang of it (after one day), the construction went very fast. More than 80 cubic metres of rubble was used to create a wall 40 m long by 2.4 m to 5 m high.

generates a lot of concrete rubble dumped in landfills. This wall has proved to be immensely successful with its striking appearance and virtually no cost.

2.3.1.8 Local stone

Mica was obtained from a nearby filling station site for outdoor balustrade walls. The HRDC contractor sourced it soon after the concept of "found" materials was explained and obtained several truckloads for free, as the filling station contractor was relieved to have it removed.

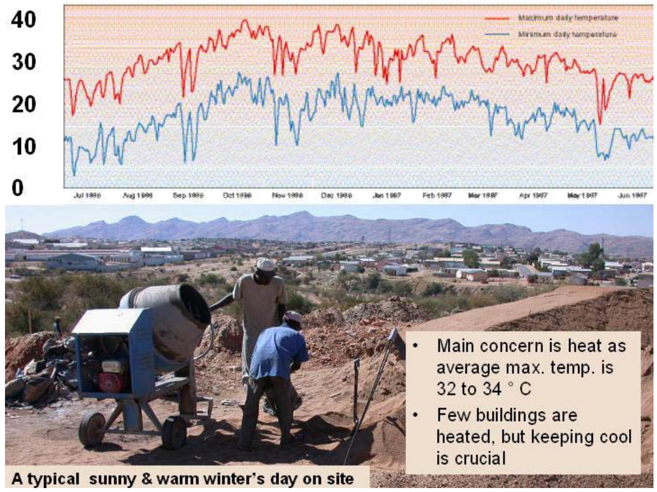
2.3.1.9 Sample walls

Sample walls for basic tests and demonstration are being built in the foyer using sandbags, straw bales, cob, adobe bricks, limestone, glass bottles, mortar & rubble, patent polystyrene blocks and whatever comes to hand. These can be demolished and replaced should they prove to be unsuitable, but if successful, will be used to construct prototype houses in pilot projects.

2.3.1.10 Screens

Various screening methods were developed for solar protection and security.

Poles were cut by unemployed, unskilled workers from *prosopis* (mesquite) trees that invade habitats in the drier areas on a large scale. These were soaked in used motor oil (insecticide and weatherproofer), and used as screens for windows, gates and to shade overhangs and water tanks. The poles were fixed to steel support frames with self-tapping roof screws, and on the shaded walkways, wired to the steel frame, to be removed easily later when replaced by solar panels.



A typical sunny & warm winter's day on site

Recycled metal panels such as oil-drum lids and rods were used in designs by a local artist, Hercules Viljoen, to make security gates & burglar bars for the reception. Used cooldrink tins are wired together to provide a colourful and lightweight infill screen for the main entrance pivot gate, while X-ray plates are linked together to form an air-curtain for the cooler door.

Planting will also be in the form of creepers and trees for solar control, with specific plants, like the Sickle Bush already mentioned, as thorny drought-resistant security hedges.

2.3.2 Roof support structures

The intended second-hand steel pipes were changed to second grade steel, due to a lack of availability on the project scale. The pipes are used in various configurations to demonstrate options from traditional trusses to single short-span purlins directly on walls.

Other materials demonstrated are brickwork vaults, a pin-jointed space-frame and a short-span purlin-only system made from timber poles. South-African wrot pine trusses were avoided, as transportation distances are long (over 2 000 km's), the soft wood deteriorates very quickly in the dry heat and termites are a perennial problem. Most termicides still sold in the country are organo-chlorides banned under the Stockholm convention[21], although more environmentally friendly ones are now available[22].

2.3.3 Roof coverings

Several factors motivated the decision to use corrugated iron sheeting as the dominant roofing material. The long lifespan, lower initial cost and potential re-use make it far more sustainable from an embodied energy viewpoint compared to the other available materials - thatch and clay or concrete tiles:

- Tiles need a stronger and heavier roof structure which is more costly in a housing context.
- The high fire-risk for thatch in an urban area with frequent lightning storms.
- Neither thatch nor tiles are dust-proof, a problem for office spaces in the dry dusty climate.
- All three materials have to be transported to Windhoek from afar, with corrugated iron the least weight and volume for the area covered.

[21] Such as "Chlordane" and "Aldrin".
[22] For instance Bayer Chemicals' "Premise SC".

- Corrugated iron is profiled from flat sheet near Windhoek, providing employment for local people and expanding a limited industrial base.
- Rainwater collection from thatch is not possible, due to dirt and dust build-up, and not as efficient from tiles as from corrugated iron.
- Corrugated iron is the easiest available and cheapest material for low-cost housing roofing and we wanted to find solutions for common problems, such as heat gain.
- Corrugated iron, unlike easily broken roof tiles, can be re-used almost indefinitely and easily. This makes sense in an informal settlement context, where ease of erection and dismantling is crucial to a person without land tenure.

ROOF COVERINGS

Corrugated iron preferred to clay tiles, concrete tiles or thatch

- Longer lifespan
- Lower initial cost
- Potential re-use
- Light structure
- Low fire-risk
- Lower transport costs
- Local employment
- Rainwater collection
- Availability
- Use in shacks

Test spaces roofed with micro-concrete roof-tiles made by a CBO[23] and thatch sourced from the north of the country will be built to assess the above assumptions.

An experimental 6 m diameter roof will be made from sheeting beaten out from cut second-hand paint- or oil-drums, on top of the pin-jointed prosopis space frame, to demonstrate the creative potential of found material in roofing large spaces.

2.3.4 Flooring

2.3.4.1 Internal flooring

Wax-polished concrete surface beds were used for offices where dust control was important and packed clay bricks on a sand bed for the exhibition hall and lecture room. Both finishes have high thermal mass and absorb body heat by radiation while being hardwearing, inexpensive and easy to maintain.

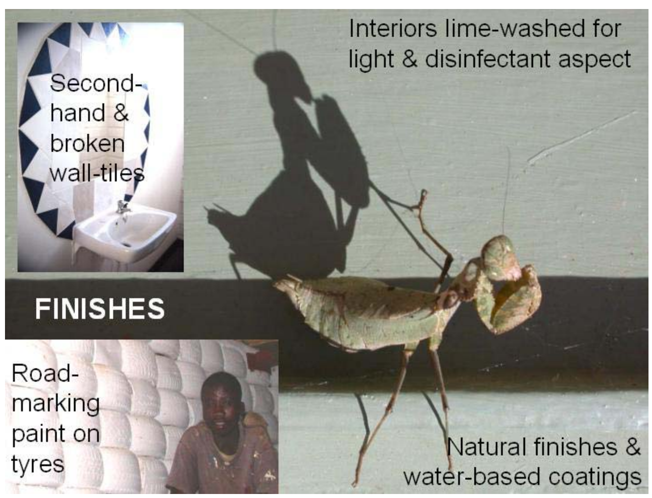
2.3.4.2 Exterior paving

Waste mica stone was used with a clay bedding layer for external paving, interspersed with gravel strips to allow immediate rainwater penetration. Round boulders sourced from debris from recent floods were used for “apron” edges around buildings to reduce water splash. Cubes from concrete testing laboratories make strong surfacing for ramped roadways in the parking area and natural gravel is used to allow in-situ water penetration in the flatter parking areas, yet retain dust. The contractor was instructed not to “skoffel” or clear the soil surface, as weeds, especially thorns, act as pioneers to stabilise soil and allow softer perennial grasses to establish.

[23] Community-based organisation

2.3.5 Finishes

Surfaces were retained in their natural state wherever possible, to demonstrate construction methods and the aesthetic potential. Where needed for weather and corrosion protection, water based paints and sealants were used to reduce pollution and for health reasons. The soil-cement blocks are coated outside with a water-based clear silicate sealant against water penetration. Several types of sealant were tested before this particular one was found to be successful[24]. Two sealants were tested on the rammed earth walls – the same silicate based spray-on sealant as for the Hydraform and seal oil, a by-product of the Namibian seal industry. The latter proved the most successful in terms of its penetrating quality as opposed to the silicate which forms a rigid skin and breaks of when water enters behind. The seal oil, though used traditionally, is not seen as sustainable on a large scale, though, and further experiments with prickly pear juice, etc. are envisaged.



Interior walls are lime-washed white to increase the day-lighting effect. White road-marking paint was used inside on the tyre walls for the same reason. The corrugated iron roof sheeting has an integrated metal "aluzinc" finish on the exterior which is anti-corrosive and highly reflective, reducing heat build-up.

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[24] Siliseal, a silicate-based water-thinned spray-one sealant locally marketed by BCI Namibia.

2.3.6 Ceilings and insulation

Adequate insulation was a priority due to the roof sheet's thermal inefficiency. Several proprietary methods are available in the country, all costly and thus omitted from low-income housing. A material that could support various insulation types as well as provide some insulating value itself was required and reeds were found to be the best option. Also invasive, the reeds occur in seasonal riverbeds and are a flood hazard, thus a free resource for the poor. Between the reeds and roof sheet we tested three main insulating materials:

- Low-grade wool mixed with dried lavender leaves (to act as natural anti-moth agent) was packed into second-hand feedbags.
- Waste polystyrene packaging was used in a similar way at least 100 mm thick.
- Waste brown corrugated cardboard boxes were flattened and layered 60 mm thick.

2.3.7 Fittings

Windows and doors were second-hand from junk yards and demolitions. Curtain rods were from galvanised electrical conduit. Light fitting shades were from the perforated metal tubes and the paper liners of used car filters and also from waste metal printing plates. Furniture was made from second grade steel and shutter board with thin reeds as infill panels. Balustrades were made from steel poles with thick second-hand rope originating from the mining industry as infill. Sanitary fittings like sinks, hand basins and urinals were sourced from auctioneers and junk yards, and from building contractors involved with refurbishment projects.

3 Experiments and demonstrations

Although the construction commenced with a reasonable expectation of the intended building methods, the actual experimentation with assumed sustainable materials and the visible demonstration of the principles of sustainable design still contained a number of lessons.

3.1 The tender, contract and the construction process:

3.1.1 Tender process

A conventional two-stage tender system was utilised, initially with pre-qualification which required information as to the tenderers' construction experience, financial standing, credit ratings, Namibian content, affirmative action, labour relations and a questionnaire investigating their attitude to the principles of sustainability as well as experimentation on site. From eight submissions, only two qualified.

The second stage was a conventional tender submission with a Provisional Bill of Quantities. It was work-shopped with the two tenderers and their Quantity Surveyors to enable understanding of the exact nature of the alternative materials and methods intended, and a longer than normal tendering period was allowed.

The successful tenderer, Groenewald Properties, was incidentally an affirmative action candidate who had previously constructed mainly low-cost housing projects for the NHE.

3.1.2 Contract

The Contract signed was the standard "White Form" [25] and the Contract period was agreed with the Contractor to include an additional period to allow for experimentation and learning curve on site. A "special" contract was not created, as the team were all familiar with the conventional and could more easily work within its parameters than an untested new system.

3.1.3 Construction process

The consultant and contracting team had to adapt to a different process from the normal one of straightforward execution of completed technical drawings. Some construction methods had to be tried out first before final decisions could be taken in

[25] Largely superceded by the JBCC form of contract in South Africa

terms of mix strengths and detailing. This initially led to some tension, fortunately dissipated in a sharp emotional outburst by the contractor. This created a better understanding on the side of the consultants of the stress experienced in such unfamiliar territory by the contractor and a very good relationship reigned henceforth.

One of the most important adaptations the consultants had to make was to discard the conventional role of being the fount of all answers. When problems were encountered on site, we learnt to discuss them first and to ask the foreman's advice before making suggestions.

- The foreman usually had good ideas for solutions based on his extensive experience as well as his rural farming childhood.
- The contracting staff originated in a culture where politeness to superiors and women is deemed more important than finding solutions in a confrontational manner. If we instructed things which they considered wrong, they would not point it out unless we read the subtle signs of discomfort and encouraged them to criticise our efforts.
- When the contractor's ideas were exhausted without a solution to the problem, our ideas were often greeted with relief and eagerness, allowing the contracting team to appreciate the need for consultants in the process.
- The term "we" now includes the contractor and led to the joint decision by the client and consultant team to appoint the same contractor on a negotiated basis for the next phase of the project, due to start in October 2004.

3.2 Some technical lessons learnt

All of the materials and techniques discussed above had been "invented" elsewhere, but the team did not have practical experience of the methods. In that sense the entire project was an experiment, with lessons learnt by trial and error.

3.2.1 Hydraform

Sourcing the soil for a large project can be a problem. Fortunately soil was obtained from a municipal stockpile nearby, but if not available, all the ideas for soil–based walling methods would have had to change, as the site soil was not suitable.

The Hydraform machine's tester provided wildly inaccurate results. Eventually special filler pieces were made to test the bricks in a conventional laboratory, which delayed the project by almost 2 weeks.

The lack of clay in the soil and resultant addition of cement makes it less sustainable. A detailed investigation of potential clays could not be done in time, but the next step would be to compare the cost and energy implications of importing clay to the site.

Though not wet-stacked, the bricks were not completely dry and the resultant shrinking caused marginal opening up of the vertical joints. This was not a visible gap, but the paint-on sealants did not penetrate it and caused water-logging when the rains came before the eaves gutters had been installed. The walls had to dry out thoroughly and a spray-on silicate based penetrating sealant then applied externally.

We have found the Hydraform system, due to its fairly complex interlocking shape, to be most successful on simple orthogonal shapes. It was very labour-intensive in terms of cutting and fitting the individual bricks for complex designs such as our arched piers in the library and fin walls in the multi-purpose room.

The machine was cost-effective on this project, though expensive to buy or to rent, and can thus be recommended for group housing by a developer or contractor with considerable financial capacity. However, it is not financially realistic for small-scale builders or individual low-income owner-builders to buy or rent a machine, unless one is owned by a NGO or subsidized state facility that can rent it out at minimal cost.

Similar systems for simpler forms that are more versatile for complex forms as a result as well as cheaper are now being investigated.

3.2.2 Tyre walls

The tyre walls built at the HRDC were L-shaped on plan with no openings. New structures containing these should be built before the system can be recommended to others.

The contractors struggled with levelling until the tyres were sorted to the same size. They overlapped by half and rods set in the foundation were used as vertical reinforcing, probably unnecessary, but helped to keep the overlapping regular.

Tyres were cut in segments of one sixth with a grinder and tied with strong 3 mm wire between abutting tyres. This segment was also filled with soil to prevent soil from the tyre above leaking out. It also closed the gap between abutting tyres that sometimes opened up due to size irregularity. An additional benefit is the smoother wall surface, easier to plaster.

The main constraints for self-build housing would be the grinder-cutting of the segmented tyres and half-tyres needed at opening edges. This could be solved by a “cutting service” added to a design service to help calculate required quantities.

The fire risk was often queried, but according to the Windhoek Fire Brigade, the tyres will not burn unless a fuel like oil or petrol is added and set alight, and the compacted soil in the tyre should smother any flames originating thus from the exterior.

The tyres were painted internally with white PVA. On some the surface was saturated with oil and black stains kept appearing through the white paint. In these cases, road-marking paint was successfully applied.

3.2.3 Timber poles and reeds

Only young trees or previously chopped (effectively coppiced) trees had straight enough branches for poles. Should the invasive prosopis thus be eradicated or just cut back to sprout again? In view of the invasive nature of the trees and their extreme use of underground water, a more sustainable indigenous version should perhaps be found.

The poles were small, ranging from 30 to 75 mm diameter and were therefore only of limited structural value.

The poles used internally in the archive “brandsolder”[26] ceilings were not treated with oil as no insect attack was anticipated in the contained interiors of these rooms. Little piles of dust below the poles soon showed otherwise and it was discovered that the reeds used for the ceiling harboured a borer insect. The reeds already installed thus had to be fumigated with a pesticide, which, although described harmless by the manufacturer, does not fit in with the ethos of the project. A more stable, less toxic insecticide is now used to fumigate the reeds inside a container before use.

[26] literally “fire attic”, traditionally built in Cape-Dutch thatch houses

The Museum of Namibia's entomologist[27] suggested that a traditional method of charring the green prosopis poles over a slow fire instead of debarking and soaking in old motor oil, will create an effective insecticide as the active ingredients in the bark are driven into the wood a permanent insect deterrent.

3.2.4 Dry stone walling

The undressed stones presented problems for an unskilled workforce and a lot more cement was used in the inside than desired. Stonework is an art and the HRDC will train future workers over a longer period than the contract allowed for.

3.2.5 The "Enviroloo" and other toilet systems

Both the Enviroloo and Ecosan are integrated prefabricated units imported from South-Africa and thus costly. The Enviroloo installed has a persistent urine smell surrounding it. We are currently experimenting with vent inlet and chimney length adaptations. The Cool-drawer has a prefabricated composting tank requiring a forklift to move it and thus not easily installed. Though suitable for institutional and developer-driven projects, these three patents are not ideal for self-help housing and a low-cost in-situ design is being developed.

Provisionally named the HRDC toilet Mark I, it will be tested in the public ablutions and relies on an in-situ brick built composting tank with two wire baskets lined with container bags made from polyethylene feedbags and ventilated by an exterior chimney with rotating self-propelled wind turbine extractor. We are still testing the effectiveness of the sealant used on the inside of the tank, but the potential advantages are: construction by local semi-skilled people using locally available materials, upkeep and servicing by the users, lower costs and scope for improvement.

A constraint is the availability of a suitable toilet pot - the dark grey polypropylene models do not promote easy and regular cleaning, whereas the only white porcelain model available is made on an exclusive licence to Enviroloo.

3.3 Demonstration value

Real-life experience seems to have far more impact on a diverse audience than theoretical writings or multi-media, especially when dealing with construction laymen. The construction site was a valuable tool in explaining methods that will unfortunately disappear at project completion. Despite video documentation of the process, half-built "samples" and partially completed "show-houses" for Phase 2 is thus being considered. Leaving surfaces unplastered, exposing ceiling insulation and providing guided access to most areas (including a viewing platform into the tower for the PDEC system), some of the interest of the construction process may be retained. Samples of bricks and blocks will be piled up in the foyer for visitors to lift up, rotate, touch and stack themselves.

4 Community impact, shortcomings and future developments

4.1 Impact on the community

Reservations about the eccentric design (not 'de rigueur' in architectural circles) was dispelled when group of International School children were taken the completed half of Phase 1. Quickly bored by sustainability talk, one little boy pointed to the area under construction (off-limits to children, saying: "I want to go there, it looks like a castle". As

[27] Eugene Marais

the design is fun and interesting, lay people seem to relate to it and they feel empowered. This might also be due to the fact that they can understand the exposed construction.

The location in Katatura has proven a good choice, as the centre is already a talking point in the area, with people coming round to look at things on their way home. The alternative insulation and walling materials have sparked the most interest to date, perhaps because people's experience of the heat is very real and because walling is popularly (and incorrectly) perceived as representing the bulk of a building's cost.

The target market for the centre's ideas range from specialist consultants to illiterate unskilled workers. Some of the follow-on activities to date are:

4.1.1 Visits during construction

The construction has been visited with keen interest by influential Government and local authority members as well as groups of schoolchildren and students. Several have taken up ideas in their own houses as well as spread them by word of mouth, resulting in enquiries about suitable "green" and cost-effective methods regularly directed to the architects. Several articles have appeared in local newspapers and magazines.

4.1.2 Polytechnic exchange programmes

The Polytechnic of Namibia's Faculty of Engineering runs yearly exchange programs with American engineering students. During 2004, two teams used ideas to kick-start their own projects. The groups visited the project and consulted the architect for advice and comment.

One group did comparative tests of the insulation materials and then refurbished an existing shack to make it thermally efficient. They then took temperature measurements against a control shack. Their study included an assessment of the cost and difficulty of obtaining materials as well as the time, skills and tools required for installation.

A second group developed a public ablution facility for the Municipality of Windhoek to use in its informal settlement upgrading programmes, using the HRDC Mark 1 toilet as a basis for a unit including a shower and washbasin with grey water recycling.

4.1.3 Young Scientists' programme

Participants in the Young Scientists program for secondary schools are testing some ideas: one team built a tyre house in the informal settlement while another studied the waste stream generated by the city for potential recycling projects.

The tyre house highlighted several difficulties when disseminating ideas to a broader community. Working with a skilled experienced builder is completely different from advising unskilled and illiterate self-builders. By trying to avoid having to cut the tyres, the overlaps started leaking soil and the gaps between the tyres had to be plastered to get them closed. By not using the same size tyres, proper levelling was impossible and the structure is very skew, though stable. The community also requested a square house which creates problems with stability at the corners. However, these are valuable lessons to be addressed in the next tyre structure.

4.2 Shortcomings

A current shortcoming is of a lack of empirical data on the materials and techniques used, but the "diving in at the deep end' process has had the benefit of speed and direct impact on local awareness of sustainability issues as well as exposure to choices available. It is now the task of the HRDC staff to further the more scientific research. However, the impreciseness may be essential – the exactness of x°C is not important, just whether it is a lot cooler or a lot warmer.

4.3 Future developments

4.3.1 Phase 2

Future phases will comprise lecture and conferencing rooms, research and training laboratories-cum-workshops, second-hand building material yards and SME[28] units to provide the materials developed for a wider market. Permaculture gardens and an indigenous nature park for the local community will be established during the operation of Phase 2. The SME units will be built first, to produce the alternative materials needed in the construction, then Phase 2, then additional "show-houses" to experiment with and demonstrate other technologies not used to date.

[28] Small & Medium Enterprises

4.3.2 HRDC

The HRDC's brief is to launch and participate in sustainable housing projects in the form of pilot housing, energy efficiency projects, refurbishment of existing shacks and housing, upgrading of squatter settlements and rural outreach programmes. It is already involved in a Danish funded energy efficiency project. It is hoped that through the NHE's regular housing developments, the HRDC can introduce some of the sustainable methods already explored.

4.3.3 Contractor

The HRDC contractor, Groenewald Properties, has adopted a local Aids orphan shelter, intending to build new accommodation using tyres.

4.3.4 Architect

Some ideas have been used in other commissions. A government clinic in the south was built with Mariental clay bricks. A craft centre in Tsumkwe used Kombat bricks. Several buildings have utilised and created a bigger local market for prosopis poles and reeds. A proposal was tabled to install the Enviroloo's in a school dormitory extension in Okahau. Several methods are considered for the Windhoek Waldorf School. A recent commission is a recycling sorting and storage facility for the Windhoek International School.

5 Conclusion

Although smaller projects have contributed to the resource base used in this building[29], most of these projects are private, remote and not accessible to the public. The HRDC is the first comprehensive attempt at sustainability in a public building in Namibia and allows the whole population access to involvement in a sustainable future. It is significant that a government-initiated facility is taking the lead in this field, in developing countries more often the domain of private initiatives. This has lent an air of respectability, making the ideas more acceptable to a mainstream audience.

5.1 Nature of the building and the design process

Unlike most contemporary architecture, the building is a hybrid rather than a single design statement. It evolved from a conviction that an uncompromising stance on purely visual design aesthetics would not be appropriate to the project's intention. The collage character has been flexible and allowed new ideas and techniques to be inserted even during construction. This openness also induced an unusually creative response by the rest of the team, with the engineers and QS proposing radical concepts (such as a steel drum roof, or made from the site signboard) and entering wholeheartedly into the spirit of the project.

"When in doubt, try it out" has become the motto of the team.

5.2 Sources and resources

5.2.1 Where are the ideas from?

- Books - not specific ones, but a wide range of topics on health, materials, communities, building, travel, architecture, etc.
- Talking to people from a wide range of backgrounds, not just those in the construction industry. For example: farmers, squatters, environmentalists,

[29] Such as the facilities at the Desert Research Foundation of Namibia (DRFN) by Erhard Roxin Architects at Gobabeb in the Namib Desert and the buildings at Farm Krumhuk south of Windhoek.

craftsmen, teachers, aid workers, refuse removal company owners, tyre dealers, students, domestic workers, etc. Explain the concept and the ideas will come.
- My father.
- Sustainability is not new. There is a fund of vernacular knowledge – the foreman often said: “yes, this is how we did it in the old days…”
- Conferences & workshops are opportunities for learning, exchange of ideas, and meeting people.

5.2.2 Contextual advantages

There are advantages to working in a developing and economically struggling society:

- The benefit of a naive team, client and audience allows you to try out things that a more sophisticated society would be too nervous of attempting.
- A less regulated society than for instance Europe, with the existence of “double standards” (one set of regulations for the rich and another for the poor) allows more freedom to venture and experiment.
- A lack of experience and a small resource base forces one to make do with what is available and come up with ideas rather than solving problems by throwing money at it.

5.2.3 Replicability

A concern that might be raised is how easily these experiments can be replicated by others:

- We have tried to focus on materials and techniques that are easily accessible to the ordinary person in the country. Some methods need more sophisticated tools, like a grinder, but most need only the normal tools builder use, like spades, wheelbarrows, trowels, etc.
- The consultants have purposefully not given extremely detailed construction specifications to the contractor, with the intention to assess how easy it is to follow the ideas without previous experience. We have found the resultant hands-on learning curve to be very steep, as well as eliciting a problem-solving and pro-active response from the builders.
- The purpose of the centre is to continue both with experimentation as well as training of users in the various building methods. Technology is almost too sophisticated a word for it, as it emphasises down-to-earth resolutions.

5.3 Last words

Some advice to others on the same path of discovery of sustainable building: go out on a limb and risk professionally, being sure that you have the support of the team: the client, contractor, professionals and all. Leave the team sometimes to “sukkel” it out - don’t be a control freak, don’t be precious about the design.

We need is a change of mindset – all projects must become “green” or “sustainable”, not just special ones.