Druk White Lotus School

Shey, India

Architect: Arup Associates / Jonathan Rose
Client: Druk White Lotus School
Built Area: 1,240 m²
Cost: US$ 424,810

The design of this educational community for Ladakhi people uses local materials and traditional techniques (such as a mud roof), combined with appropriate technology. The nursery and infants’ school consists of two parallel buildings framing an open courtyard. Residential accommodation is placed along a separate north-south spine. All the buildings have glazed south-facing facades to gather the sun’s energy. The other sides are enclosed by granite walls that provide thermal mass and protection against wind in the winter. Timber portal frames resist earthquake loading. Solar ventilated latrines and a water-distribution system help to combat drought in this arid region.
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Client
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Design
1994 - 2000

Completed
2003
Druk White Lotus School  
Shey, India

I. Introduction

Druk White Lotus School is located in Ladakh, a sparsely populated region in the Indian Himalayas. Conceived as a model for sustainable development, it aims to provide a high-quality educational environment for children. The initial phases of the project include a nursery and infant school, a junior school, dining hall and residential facilities. The severity of the climate and the scarcity of water have been the essential determinants of the design, directing all decisions towards an energy-efficient architecture, mainly through passive solar systems. Taking advantage of the solar potential in a high-altitude desert climate, all buildings are planned with glazed south-facing facades. The complex consists of typically one-storey buildings organised in parallel pairs, each framing an open, landscaped courtyard. Solar-ventilated latrines accessed from the courtyards create an identifiable sign for the complex, with their slanted walls clad in black metal. All buildings utilise local materials and traditional techniques, enhanced by guided building crafts, appropriate technologies and advanced engineering.

II. Contextual Information

A. Historical background

Set in the Indian Himalayas on the western edge of the Tibetan plateau, the former kingdom of Ladakh is bounded by Pakistan and Tibet and defined by the River Indus, which runs along the Leh Valley at an altitude of 3,700 metres. Rock carvings found in many parts of Ladakh show that the area has been inhabited from Neolithic times. Its earliest documented inhabitants were a mixed Indo-Aryan population, mentioned in the works of Herodotus. Buddhism came to western Ladakh via Kashmir in the second century. In the eighth century, Ladakh frequently changed hands between China and Tibet. In 842 a Tibetan royal representative annexed Ladakh after the break-up of the Tibetan empire and founded a separate Ladakh dynasty, resulting in a predominantly Tibetan population. After the Islamic conquest of the region in the thirteenth century, Ladakh was fractured by invasions from neighbouring Muslim states. In 1470 King Bhagan reunited Ladakh and founded the Namgyal dynasty, which survives to this day. In the late seventeenth century Ladakh was defeated by the Mughals and invaded by Tibet. It was incorporated into Jammu and Kashmir in 1842. Starting from the 1850s, European influence grew, with Leh becoming the headquarters of a mission from the Moravian Church. After the partition of India in 1947, the region passed first to Pakistan and then to India. The Chinese invasion of Tibet in 1950 led to a large influx of Tibetan refugees to the region. The entire state of Jammu and Kashmir continues to be the subject of a territorial dispute between India, Pakistan and China. The region was divided into Kargil and Leh districts in 1979. In 1989, there were outbreaks of violence between Buddhists and Muslims. Following demands for autonomy from the Kashmiri-dominated state government, the Ladakh Autonomous Hill Development Council was created in 1993.
B. Local architectural character

The architecture of Ladakh contains Tibetan influences, especially from the Buddhist monastic tradition. Houses and monasteries (gompa) are built on elevated south-facing sites using a combination of stone, wood and earth (mud brick). The traditional vernacular is characterised by amply glazed windows divided into small panes, and by sophisticated surface decoration. Layered and corbelled wooden decorations typically appear at the lintel level above windows and doors, as well as at the eaves level below the gutter. While Shey is a homogeneous village, the architecture of the town of Leh, some 16 kilometres away, embodies a degree of heterogeneity. Architectural vocabulary varies in religious structures for different communities, but residential architecture remains essentially the same for all groups, regardless of religious or ethnic origin. The modern vernacular roughly sustains the traditional model, albeit with a visible disparity in the quality of design and craftsmanship. New buildings are mostly reinforced concrete structures, as in ubiquitous production elsewhere. Upon this generic frame, the layered and corbelled decorations are applied with generous windows subdivided by timber frames into small panes.

C. Site and surroundings

The school is in the village of Shey, close to the River Indus and its irrigated fields. It is the site of the historic Shey monastery of Ladakh. The school is at the edge of the village, on the main road that leads from the village to other gompa sites. Between the school and the village, a rich cluster of ancient chortens (the local term for stupas) creates a picturesque setting. Next to the site is another school complex of humble quality. The site slopes gently to the south, providing the opportunity for a south-facing settlement. Encircled by peaks rising to over 7,000 metres and overlooked by two important monasteries, the site possesses a unique sense of place.

D. Climatic conditions

Ladakh has an arid ‘high-altitude desert’ climate (3,700 metres) very hot in summer and extremely cold in winter. It is exposed to constant high levels of sunlight, but is cut off by snow for around six months of the year, with winter temperatures dropping as low as -15°C. There is minimal precipitation: the Himalayas create a rain shadow and a barrier to monsoon clouds. The main source of water is the winter snowfall on the mountains. In spring the melt-water swells the River Indus and brings the valleys to life. Summers are short and pleasant, with average temperatures between 10°C and 20°C. The proportion of oxygen is less than in many other places at comparable altitudes because of the lack of vegetation. There is little moisture to temper the effects of rarefied air. Ladakh lies in a very high-risk cyclone zone.

III. Programme

A. History of inception of the project

The project grew out of the vision of His Holiness the Twelfth Gyalwang Drukpa, the spiritual leader of Ladakh, who recognised the need to equip the new generations to face a changing world and sustain a culture that is under threat. For a long time Ladakh was self-sufficient, and
profited from its location close to the Silk Route. With the closing of the borders with Pakistan and Tibet, the region became isolated. At the same time the Ladakhi people were increasingly affected by rapid modernisation. There was a shift from traditional agriculture, with young people drifting towards the towns. Traditional educational models – based on rote learning – do not prepare these young people for the modern world; some 70 per cent of students in Leh fail their school-leaving exams. An over-dependence on government jobs, which have become very scarce, and a weak private economic sector, has resulted in increasing youth unemployment and social problems.

Education in Ladakh was traditionally centred on the monastery. Usually one son from every family was obliged to master Tibetan script in order to read the holy books. Today most schools in this remote region are administered either by the Indian state system or by diverse faith groups. Ladakhi children have to learn several languages, including Bodhi (the Ladakhi language based on Tibetan script), the national language Hindi, the state language Urdu, and English – each of which has a different script. According to the 2001 census, the overall literacy rate in the Leh District is 62 per cent (72 per cent of males and 50 per cent of females). The limited educational facilities and resources are concentrated mostly in the main town of Leh.

Against this background a new educational community was founded in Shey at the request of the local people and with the support of His Holiness the Twelfth Gyalwang Drukpa. The initiative has been advanced by the Druk Pema Karpo Education Society (a non-profit Ladakhi society), supported by Drukpa Trust (a British charity) under the patronage of His Holiness the Fourteenth Dalai Lama. The Drukpa Trust has set up the Druk White Lotus School as an inclusive educational institution, open to all Ladakhi children, with a model curriculum and a fitting architecture.

**B. How were the architects and specialists chosen?**

Drukpa Trust approached Arup Associates in London for the planning and design of the school. The Trust has been collaborating with Arup since 1998, working closely with a team of architects and engineers led by architect Jonathan Rose as the project principal. Arup had several reasons for becoming involved in a community project in such a remote part of the world. Visiting Ladakh at the Trust’s invitation, they were impressed by the ambition of the project and by the visible need for such a school locally. Some of the individuals on that first visit had practical experience in development work in Asia and Africa and they knew that Arup could make a contribution to the project from the earliest stages. As the findings of field research were fed back to the UK and the initial design progressed, it became clear that the school could potentially have a much wider influence, not only in the local region but also in contributing to the development of appropriate building technologies elsewhere in the world.

**C. General programme objectives**

The social objective of this project is to develop a model curriculum for the education of boys and girls from the ages of four to eighteen, integrating modern academic education, traditional values and the practical needs of this developing community. It aims not only to teach children
wisdom but also to equip them for happy and productive lives in a fast-changing world. An important consideration was therefore to balance traditional Tibetan teaching with a modern pedagogy that helps to develop self-confidence and a variety of skills and competencies. A child-centred education is the focus of the curriculum, with an emphasis on continuous staff training to this end.

The architectural objective of the project is to define standards equal to the model curriculum. In an environment that is under enormous pressure to change, it has taken account of both ecological and cultural assets. Local building techniques and materials are combined with cutting-edge environmental design to make them more effective in the extreme climate. The project was based on an integrated approach to the master planning of infrastructure and the design of buildings, planned as a phased programme of construction with a target completion date of 2011. Designed eventually to cater for 750 pupils, the project is conceived as a model for appropriate and sustainable modernisation in Ladakh, providing a high-quality environment for the school community.

The environmental programme objective involved the steady development of the site from an open desert into a human-scaled environment for children and teachers and an important resource for the local community. As the ecological context is fragile, the site strategy aimed to ensure an entirely self-regulating system in terms of energy, water cycle and waste management. The location plan was expected to take account of the extreme climatic conditions. Building design was to be developed according to following criteria:

- appropriate building technologies and sustainable material resources
- maximised solar potential through both passive and active means
- seismic performance of structures
- flexible, high-quality teaching spaces

D. Functional requirements

The client’s brief for the development of a model school was demanding; besides the technical requirements for energy, site infrastructure, buildings and material use, it called for a local project management team, the setting up of a cost database and the optimum use of local resources. The programme for the initial phases included the daytime teaching area (Nursery and Infant and Junior schools) and accommodation area (dining hall with kitchen, and two residences). When the project is complete, the daytime teaching area will have three more teaching units for the junior and senior schools, incorporating computer and science laboratories, a library and community resource facility, art studios, a large multi-purpose hall and an open-air assembly courtyard (now nearly completed). Within the accommodation area, there will be a health clinic, vocational training workshops and additional residences for students and staff.
IV. Description

A. Building data

The site measures 130,000 square metres (13 hectares). The ground floor area of the complex is 1,200 square metres, the total covered floor area being 1,240 square metres. The Nursery and Infant School takes 800 square metres of this total, and the residences take 440 square metres. All buildings are single-storey, except for the Junior School which has a partial second storey.

B. Evolution of design concepts

1. Response to physical constraints

For energy efficiency, the buildings are designed to take maximum advantage of the sun, taking into account the unique solar potential of the high-altitude environment. The buildings in the daytime teaching area are turned 30° from the south towards the east to benefit from the morning sun. All other buildings face south, so as to maximise solar benefit throughout the day and store heat for evening and night-time use.

Water is distributed through a solar-powered system located close to the western perimeter of the site. This infrastructure, referred to as the ‘energy centre’ on the plans, contains the water borehole, water pump and the solar panels and batteries. The design of the toilet facilities also responds to the scarcity of water. Adapting and improving on the traditional dry latrine, these structures are solar-assisted to help natural ventilation and waste recycling.

The complex is isolated from the main road by a surrounding wall and accessed from two locations. The main entrance and bus drop-off to the south give pedestrian access to the daytime teaching areas and the residential spine rising up the slope towards the north. A service road from the west gives direct access to the northern end of the residential area, as well as to the water and energy infrastructure (energy centre).

2. Response to user requirements

Single-storey buildings are arranged like a small village or monastery in contrast to the open desert landscape. The master plan is composed of two main parts: the daytime teaching area, organised on a nine-square grid, and the residential spine, organised along the south-north axis. At its highest point the spine culminates in a temple structure – a building in the local vernacular that is outside Arup’s design brief. At the centre of the nine-square grid, the assembly courtyard is conceived as a place where the whole school community can congregate. These two buildings are still partially under construction, and are not part of this nomination to the Award; however, the latter is included in this report on account of its central location and its unique design features, which complement the scheme.

Daytime teaching area: Within the framework of the master plan, three separate courtyard clusters accommodate the Nursery and Infant School on the west, the Junior School on the east
and the Administration courtyard in between. Each of the schools is planned with two parallel buildings that face each other to define an open, landscaped courtyard. The Nursery and Infant School provides large teaching and play spaces for nursery and kindergarten years, two further classrooms for first year children, and a small suite of rooms for the head of school and administration, all organised on one floor. The Junior School consists of nine classrooms and several staff offices, and has an upper floor used as a classroom and library. In each pair of buildings the northern blocks are enclosed on three sides by a masonry wall that provides protection from northerly winds during the long cold winters. The southeast facades are extensively glazed to provide passive energy for solar heating and good levels of natural light. In addition, the roofs are designed to bring in additional daylight through clerestory windows. For enhanced thermal performance, small windows are set in the north-facing facades to provide daylight. The courtyards are planned as outdoor teaching areas during the summer months and may eventually be covered with awnings made from parachute fabric, which is available locally.

Residential spine with dining hall: A dining hall located between the school and the residences provides a focus for the complex, hosting communal events. It has a central space, defined by heavy timber frames, and two side aisles. One aisle provides a seating area along the double-glazed facade, the other defines the service area along with a linked building that houses the kitchen. Both the kitchen and the dining area have direct access to the outside. To enable children from remote villages to study in Shey, the school provides residential facilities. The accommodation is contained in pairs of parallel buildings that flank the main pedestrian path, stepping down the slightly sloping site. Each of the residence blocks has five rooms, each accommodating eight children, together with staff facilities, a large day living/activity room and a shower room. The rooms are linked by corridors located on the north side of the buildings and lit by small windows set into the stone walls.

Central assembly courtyard: The central square of the nine-square grid is occupied by a circular open courtyard defined by high walls. Its round form draws from the eight-spoked dharma wheel, with alternating solid and void segments. Each of the eight voids is a horizontal picture window with a splendid vista of the mountains and Shey Monastery in the distance. Originally, the solid parts were to contain eight shrine rooms, but this idea was dropped in favour of a less formal assembly space with wide openings to the splendid view and just a few closed rooms to serve as auxiliary spaces during social functions.

Solar-assisted VIP latrines: Toilet facilities are provided in a series of discrete buildings accessed from the courtyards of classes and residences. They are built of granite, with south faces clad in black metal and solar chimneys in angled form. The slanted sculptural form and black colour create an identifiable sign within the complex.

3. Purely formal aspects

The plan for the educational complex is the traditional nine-square mandala figure, surrounded by an outer ring that is concentric with the central circle. The outer ring will be formed by low walls, eight stupas and newly-planted willow trees. The underlying symbolic geometry, which is not apparent on the ground, seems to be used more as an organisational tool than for its
symbolic meanings. When stripped of their local connotations, the eight-spoked dharma wheel (representing Buddhist teachings) and the nine-square mandala (symbolising the inner and outer worlds of the subjective and objective realms) present universally valid configurations for design and planning. In this project, they give formal discipline to the plan and provide an efficient configuration for the distribution of services.

4. Landscaping and water infrastructure

The school courtyards, measuring 36 x 24 metres each, are made up of a series of spaces defined by low walls where children can sit and play. The outdoor areas have been designed to allow each of the classrooms to extend outdoors. A water point is provided for wet-play, and deciduous trees are planted for shade. The planting required a sound water infrastructure. As water is a limited resource, its conservation and distribution constitute a major influence shaping developments in this region. In traditional communities there are distinct riparian rights that limit the amount of water that can be used for irrigation. Networks of channels define landholdings and shape the landscape within the valley. Learning from these landscapes, the master plan included a water distribution and irrigation system. Potable ground-water is drawn from a borehole by a solar-powered pump and delivered by gravity to a site that would otherwise be desert. Wastewater from domestic uses is filtrated via an underground pipe system along tree lines that shade and green the otherwise bleak high mountain desert environment. A solar-powered pump provides additional irrigation water to the whole site and to the vegetable gardens.

C. Structure, materials, technology

The key aspects governing the structural design were earthquake loading, durability and appropriateness. The structure, with its straightforward yet elaborate form, has been designed to be clearly legible to the students as they move through the school.

Walls: The buildings have cavity walls, with granite blocks jointed with mud mortar for the outer leaf and traditional mud brick masonry for the inner leaf. Interior surfaces are finished with clay. This gives increased thermal performance and durability compared to the mud brick walls commonly used in the region.

Roofing: The Ladakhi-style heavy mud roof is supported by a timber structure independent of the walls to provide earthquake stability. Heavy timber portal frames provide the primary structure; massive wooden joists support a traditional clay ceiling insulated with mineral wool. The timber frames project beyond the double-glazed windows, providing supports for sunshades and trellises for future planting.

Variations in structural form of roofs for different functions are as follows:

- In the Nursery and Infant school timber frames help create distinct spaces for the teaching areas. While the side aisle remains at the height of the frame, the middle part is raised higher by means of a V-shaped ceiling. The structural configuration here is an M-shaped frame resting on the primary frame below. The resulting ceiling shape allows for wide
clerestory window on two sides, and is expressed on the outside as a distinctive ‘butterfly roof’.

- In the Junior School classrooms, a ‘knee-brace’ detail has been introduced in the design of the timber frames. This makes it possible to reduce the sizes of timber sections while still maintaining seismic stability. In the two-storey building, a timber-to-timber column splice detail was derived from traditional Japanese construction.

- In the dining hall, the wooden structure has been developed from the one used in the junior school to create taller spaces and longer spans. Here the two side aisles are lower than the middle part, providing clerestory windows on both sides.

- As the residences are made up of a series of enclosed rooms, the structural system has been designed to take advantage of internal walls. These walls were formed from braced timber frames that provide lateral stability and carry vertical loads. Rather than panels, mud brick walls are used in the newer residential building for acoustic reasons. As there are relatively small spans in these buildings, it was possible to use smaller section timbers.

The design aims to use locally available materials and building techniques throughout. It incorporates stone, mud mortar, mud brick, timber and grass, with careful assessment of the sustainability of the supply. Soil – a precious resource in this desert environment – is only used in the internal leaves of cavity walls, in the partition walls in residences, and on the roofs. Modelled on traditional roof construction systems in the region, the roofs are made of round poplar joists topped by willow lath and a layer of grass and mud, with a sacrificial layer of mud forming the surface finish.

As traditional masonry or mud brick walls alone cannot safely resist earthquake loading, timber frames are used for large-span clear spaces. These frames, together with ceiling joists, are used entirely exposed. The large clear spans needed in the classrooms and dining hall, combined with the entirely glazed south-facing facade and the heavy load of the roof structure, required substantial timber cross-sections to ensure safety in the event of an earthquake. The large timber sections are connected by steel plates. These were difficult to procure locally, so the structural framing and connection details for future phases have been altered to reduce the size of timber sections.

The design uses local traditional techniques in combination with appropriate technology. Since ancient times, people have used thick walls of mud brick or stone to trap the sun’s heat during the day and release it slowly and evenly at night. Some of the school buildings incorporate a thermal storage and delivery system called a Trombe wall, named after French inventor Felix Trombe in the late 1950s. The thick masonry that forms the Trombe wall system is coated externally with a dark heat-absorbing material and faced with a double layer of glass creating a small airspace. Heat from sunlight passing through the glass is absorbed by the dark surface, stored in the wall, and conducted slowly inward through the masonry. Adjustable openings on the top and bottom of the thermal storage wall allow heat transfer from the heated air cavity to the room inside. This increases the efficiency of the system and ensures constant comfort levels for the young occupants. In all buildings there are light internal curtains to control glare and heavy curtains to reduce unwanted heat loss from windows at night-time.

Ladakh does not have a waterborne sewage infrastructure, so Arup developed a waterless solar-
assisted latrine. These ‘Ventilation Improved Pit’ (VIP) latrines are designed and tested using computational fluid dynamics. A double chamber system with an integrated solar-driven shaft effectively minimises flies and odours as a result of the induced air current. The system also produces compost and humus that can be used as fertiliser for the home-farm gardens. Another site utility that is crucial in this desert environment is the water distribution and irrigation system. Solar-powered wells pump the snow-melt ground-water from a depth of about 30 metres to reservoirs near the top of the site. One reservoir provides drinking water through a gravity-fed system to the school, while the other reservoir provides irrigation water. Excess energy will in future be stored in solar batteries and used to power the school’s computers. The school’s water pump is powered by solar panels with photovoltaic installation.

D. Origin of technology, materials, labour force, professionals

Technology and materials are mostly from local sources. The granite used for the walls was available on the site; some boulders were gathered from the surrounding field. The mud for mortar, bricks and roofing is excavated nearby. Timber is grown locally wherever possible; the poplar and willow for the rafters came from nearby monastery plantations and from local producers. Ladakh lacks the natural resources required for complex construction, so glass, structural timber, cement and steel had to be bought from outside the local community, mostly from parts of Kashmir or India. Imported products were used sparingly.

The local labour force is supervised by a local project manager who conducts operations in accordance with Arup’s instructions. Local expertise in craftsmanship and detailing is key to achieving the final outcome.

A team of architects and engineers from Arup is responsible for the master plan, concept and detailed designs of each phase of construction. Every year, Arup gives leave-of-absence to an engineer or architect from the design team so they can be resident on site, acting as an ‘ambassador’ for the Trust and assisting the local construction team and client committee.

V. Construction Schedule and Costs

A. History of the project

The project was commissioned in 1992. The design stage spanned between 1994 and 2000; the foundation stone was laid in 1995 and construction began 1998. The first phase of the school opened for teaching in September 2001, after three six-month construction seasons. This phase includes the nursery and infant school courtyard and energy centre. Since then, the junior school has been designed and built: it opened in November 2004. The first group of residences for children from remote areas was completed in 2003, while the first phase of the dining hall was completed in 2005. The final completion date will depend on financial circumstances. The assembly courtyard is planned for 2007, and is nearing completion.

B. Total costs

The total cost of the completed phases is USD 424,810, the cost per square metre being Rupees
33,410 (USD 343). Though the project is a local initiative, it has an international context and is being financed with money raised internationally. Funding comes from charitable donations from the UK, Europe and US, as well as from the local community. The school is managed by the Druk Pema Karpo Educational Society.

Actual Cost per square metre: USD 343
Infrastructure: USD 88,214
Labour: USD 82,163
Materials: USD 152,588
Landscaping: USD 13,332
Professional fees: USD 329,240
Other: USD 59,274
Total actual cost: USD 424,810

(all costs calculated using a conversion rate of Rs.46.58 =USD 1.)

C. Comparative costs

Average building costs in Ladakh are said to be about 15 to 20 per cent lower than the cost of this school. Conversely, the cost of the school is said to be around 15 per cent that of a similar school in the UK.

D. Maintenance costs

Maintenance costs are relatively low, as there are no expenses for heating or air-conditioning. The materials used throughout the buildings are durable, require little maintenance, and are expected to perform well over time. Solar energy systems will require maintenance and upgrading over time to ensure maximum efficiency.

VI. Technical Assessment

A. Functional assessment

The buildings perform well in terms of functionality and ambience. Circulation outdoors, especially the use of outdoor toilets, may be difficult in severe temperatures; yet the locals are accustomed to the conditions. Interiors are successfully handled. Designed for optimum passive heating, natural cross-ventilation, passive shading and glare control, the classrooms provide a comfortable and pleasant teaching environment. As the residential buildings for boarding pupils are mainly inhabited at night, the use of Trombe walls for passive solar heating and ventilation is very efficient.

B. Climatic performance

The environmental strategy seems to have maximised the site’s potential to achieve passive solar heating, natural ventilation and day-lighting. Analysis of Temperature Monitoring, available in graphs showing the temperature curves in the classrooms and residences, proves
the effectiveness of the passive solar energy systems applied in the building. It is observed that
the following measures are working well:

- the 30° rotation of the nine-square grid to exploit the morning sun; also, the consequent
tilting of the back facades to the northwest, in line with the afternoon sun
- the separation of the buildings to avoid shadowing, and full glazing of south-facing
surfaces
- high thermal-inertia stone walls to store the gained heat, as well as the ventilated Trompe
walls in the residences

C. Treatment of water and rainfall

The careful treatment of ground-water seems to have succeeded, as there is almost no
efflorescence throughout the building. The collection of rainwater from the roofs and the
drainage of water from the courtyards are also finely executed. It is unlikely that water and
humidity will penetrate. The rainwater gutters offer easy access for maintenance.

D. Impact of the project on the site

The visual effect of the complex, both from a distance and from within, is poetic. The dominant
horizontality of the settlement is accentuated by strips of dark-coloured glazing on the south
facades. Within this composition of horizontally extended forms, the solar-assisted latrines
stand as emblematic structures, contributing greatly to the settlement’s identity.

E. Choice of materials, level of technology

Design features related to the choice of materials and level of technology in this project
involve, foremost, the intention of fusing local handicraft with advanced engineering. In terms
of technical input, Arup has developed powerful software tools that allow an accurate analysis
of issues such as the ventilated Trombe walls, the feasibility of using wool as an insulating
layer, of double-glazing, daylighting studies and seismic engineering.

F. Response to, and planning for, emergency situations

The client asked the design team to develop a strategy for seismic engineering in the school
buildings. Arup’s Structural Analysis of Timber Frames report shows the behaviour of the
system in resisting seismic loads. Only structures without an accommodation function, for
example the dry latrines and entrance gateways, do not provide structural protection against
seismic collapse. Fire precautions are optimum, given the ease of evacuating one-storey
buildings and their accessibility to the local fire brigade. Aside from the fire blankets provided,
there is an abundance of sand on the site.
G. Ageing and maintenance problems

The building is designed for a long lifespan and easy maintenance. The granite walls and exposed concrete lintels, all accomplished with exquisite craftsmanship, look almost eternal, whereas the timberwork will need upgrading in due course. No laborious efforts are required to clean the large windows, as they are all accessible from the courtyards.

In April 2006 Arup produced detailed ‘Operations and Maintenance’ manuals itemising the necessary inspection procedures for every element in the buildings, ranging from the daily monitoring of the Trompe wall to the inspection of metal sheeting of the roofs every two to three years. This gives the school managers a valuable set of guidelines for the proper upkeep of the complex, provided that maintenance funds are kept at reasonable levels.

H. Durability and long-term viability of the project

Arup has devised methods to ensure the viability of the project. A senior design team member visits the school at the beginning of the building season in April each year, followed by an Arup resident who remains on site for about four months. With the nursery and infant school now operational, feedback is already being generated as to how these first buildings are performing. The design team and the Drukpa Trust both look forward to a process of continuous learning about the school’s practical performance as it grows over the next few years, with the lessons informing the remaining construction work. Besides this, a viable project requires foremost the ability to construct within local cost parameters. From a position of having no reliable cost information at the outset, the design team has established a cost database for budget management throughout the future detailed design phases and construction phases up to the school’s completion. Phase 1 was completed under budget and within acceptable local cost parameters. It is stressed that the team’s aim is to further optimise expenditure, working towards a financially sustainable operating model.

I. Interior design and furnishing

All classrooms are entered from the courtyard via a lobby which provides a thermal buffer and contains shoe lockers. Each classroom has a warm, quiet corner with a small stove on a stone floor. Timber floors and white-painted walls are provided for maximum teaching flexibility in clear, uncluttered spaces. The interior design of the building is a direct expression of its structure. The spaces are embellished with genuine tectonic features of construction, such as the timber frames with black bolts. Basic wood furniture is supplemented with flexible cushions and mats. The minimal furnishing in the dormitories is purely functional and highly aesthetic.

VII. Users

A. Description of those who use or benefit from the project

According to 2001 figures, the Nursery and Infant School accommodated 200 children; the opening of the Junior School brought this up to 304. This figure has risen now to 365, with 97
student boarders and 59 being sponsored. The adult population of the school are as follows:

- 40 permanent staff, including 2 administrators, 18 teachers, 13 support staff (6 at school and 7 residential), 5 construction staff and 2 cleaners
- 15-20 labourers, including carpenters, masons, painters, technicians and labourers. This figure rises to a maximum of 60 at the height of the construction season

B. Response to the project

There is no established architectural professional community in the towns nearby, yet Indian professionals are certainly informed about this project through the web and publications. The project has received a number of awards since the completion of its first phase, including:

- Australian National Association of Women in Construction (2005): Sinclair Knight Merz Award for Achievement in Development

The users of the complex seem very happy with it. The administrators mentioned the keen interest shown by visitors, including teachers from neighbouring schools, solar engineers and students from vocational schools as well as children and parents from Shey, Thikse and Leh. People are aware of the energy considerations in the complex, and are especially interested in the Trompe wall. All parents attend meetings and readily get involved with everything from the planting of gardens to fund-raising.

VIII. Persons Involved

Client:        Druk White Lotus School (His Highness, DPKIS)

Architecture firm:        Arup Associates / Jonathan Rose
Design team:        Jonathan Rose, project principal and lead architect
                     Sean Macintosh and Ian Hazard, architects

Engineering firm:        Ove Arup & Partners
Engineering team:        James Fleming and Martin Self, structural engineers
                     Francesca Galeazzi, environmental engineer
                     Dorothee Richter, public health engineer
                     Khaled Abou-Alfa, electrical engineer
                     Leslie Depp, quantity surveyor
                     Neil Marlow, landscape architect

Local team:        Sonam Wangdus, construction manager (substantial contribution since 2002)
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http://www.drukpa.net/french/education/shey_newsletter.html

Aydan Balamir
May 2007
Nursery and Infant School, plan and section.

Nursery and Infant School butterfly roof and assembly hall on the right.
Nursery school classroom.

Nursery and Infant School, shoe storage at entrance.
Junior School, plan and section.

Pedestrian entry to the complex, administration block on the right.
Junior School with a L-shaped roof, near the assembly hall.

Junior School courtyard.
Northern facade looking at courtyards, school entrances.

Junior classroom.
Dining, plan and section.

Dining room.
Residence, plan and section.

Residence with latrines.
Typical Bedroom

High thermal mass walls composed of 450mm granite, 100mm air gap, 150mm rendered mud brick

Residence, section.

Residential blocks facing south-east to gather the sun energy
View of residential building, southeastern facade.

Student dormitory.
Solar ventilated latrines.
Druk Pema Karpo Institute

Leh
Shey, India

Architects
Arup Associates / Jonathan Rose
London, United Kingdom

Clients
Druk White Lotus School
Bromley, United Kingdom

Commission
1992

Design
1994 - 2000

Construction
1998 - 2003

Occupancy
2003

Site
130'000 m²

Ground Floor
1'200 m²

Total Floor
1'240 m²

Costs
US$ 424'810

Programme
The design of this educational community for Ladakhi people uses local materials and traditional techniques (such as a mud roof), combined with appropriate technology. The nursery and infants’ school consists of two parallel buildings framing an open courtyard. Residential accommodation is placed along a separate north-south spine. All the buildings have glazed south-facing facades to gather the sun’s energy. The other sides are enclosed by granite walls that provide thermal mass and protection against wind in the winter. Timber portal frames resist earthquake loading. Solar ventilated latrines and a water-distribution system help to combat drought in this arid region.

Master Plan
The project has been conceived as a contemporary model for appropriate and sustainable development in harmony with local culture. The Master Plan takes advantage of the site, with a complex of buildings based around courtyards that are planned primarily on one level, orientated along a north-south axis for the residential spine and facing south-east for the Nursery and Infant School.

Nursery and Infant School
The Nursery and Infant School consists of two parallel buildings that frame an open courtyard. Each of these buildings is enclosed on three sides by a stone wall which protects it from northerly winds during the long cold winters and provides thermal mass. In contrast, the south-east façades are extensively glazed to provide direct passive solar energy for heating and natural light.

The building design uses local materials and traditional building techniques such as the mud roof, combined with appropriate technology. A timber portal frame has been designed to resist earthquake loading.

The buildings, appropriately separated to avoid overshadowing, take maximum advantage of the unique solar potential by using glazed south-facing façades to gather the sun’s energy.
**Solar Ventilated Latrines**
A series of discrete latrines are located on the pathway running around the perimeter of the education complex and beside each residential courtyard. Designed and tested using computational fluid dynamics the latrines are built of stone, with a black angled solar chimney that is the fundamental element in the design and an identifiable sign for the project.

**Residences**
The residential buildings are organised around a courtyard with parallel buildings facing south, each with a daytime space for the boarding pupils. The bedrooms and wash room make use of Trombe walls for passive solar heating that ensures that the rooms are constantly kept at comfort conditions for the young occupants. Good daylight and ventilation is also provided to all rooms.
Temperature Monitoring in Typical Classroom

![Temperature Monitoring Graph](image-url)
Typical Bedroom

Trombe wall composed of:
- Mud wall with window and air vents
- Outer glazed screen, openable for maintenance and ventilation

High thermal mass walls composed of:
- 450mm granite, 100mm air gap,
- 150mm rendered mud brick

Corridor
Temperature Monitoring in Dormitory

Outdoor

Hostel room

0°C

30

25

20

15

10

5

0

-5

DAY ONE

AM PM

DAY TWO

AM PM

DAY THREE

AM PM

DAY FOUR

AM PM

DAY FIVE

AM PM

DAY SIX

AM PM

DAY SEVEN

AM PM
Light enters solar flue through fly screen and attracts flies.

Hot air rises in the flue along with flies, smells and moisture.

Dark metal finish heats up and drives solar flue.

Cold air is sucked into the pit along with flies and smells.

Access door to empty pit.

Dry waste composts in twin pits.

Liquids infiltrate into the ground.

Only external light enters cubicle.

Wash trough drains to soakaway.

Drainage to narrow soakaway.
S330249
Druk Pema Karpo Institute
Children in nursery and infant's courtyard

Sohie, Caroline
2001

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S330250
Druk Pema Karpo Institute
Resting and working in residential living room

Sohie, Caroline
2003

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S330251
Druk Pema Karpo Institute
Children at play in classroom

Richters, Christian
2006

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S330252
Druk Pema Karpo Institute
Nursery classroom with rooflight

Richters, Christian
2006

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S330253
Druk Pema Karpo Institute
Nursery and infant’s courtyard with glazed facade

Richters, Christian
2006

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S330254
Druk Pema Karpo Institute
Solar latrine beside nursery building

Richters, Christian
2006

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S330255
Druk Pema Karpo Institute
Residential courtyard from the south
Richters, Christian
2006

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S330256
Druk Pema Karpo Institute
Opening of nursery and infant's courtyard
Reinardy, Roland
2001

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S330257
Druk Pema Karpo Institute
View of Indus Valley with Shey in the distance
Reinardy, Roland
2004

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Druk Pema Karpo Institute

Northern residential block with solar latrine

Richters, Christian
2004
The design of this educational community for Ladakhi people uses local materials and traditional techniques (such as a mud roof), combined with appropriate technology. The nursery and infants’ school consists of two parallel buildings framing an open courtyard. Residential accommodation is placed along a separate north-south spine. All the buildings have glazed south-facing facades to gather the sun’s energy. The other sides are enclosed by granite walls that provide thermal mass and protection against wind in the winter. Timber portal frames resist earthquake loading. Solar ventilated latrines and a water-distribution system help to combat drought in this arid region.