HUYS ADVIES

Design of Primary School Buildings for Remote Mountain Areas

Design for Off-Road Construction in Remote Mountain Areas of the Northern Areas of Pakistan

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August 2000 (Updated 2008)

Abstract

School buildings are viewed by the local population as examples of quality construction designs. Improvement methods for traditional and new houses in remote mountain areas can be stimulated by intelligent school building designs. Techniques that can be replicated locally by craftsmen using readily available building materials are important in remote mountain areas. Area of application of these designs is the Northern Areas of Pakistan, including high altitude regions with long winters.

School building design needs to consider lack of flat land area; requiring schools to be at least two floors high. Schools need to be safe and 50% more earthquake resistant than common housing. After a local disaster, schools need to serve as refugee centres. Lightweight, but strong and ductile, construction methods are recommended using a minimal amount of heavy stone or reinforced concrete. Bringing sand and cement to remote mountain areas is very costly.

Lightweight short span bowstring constructions and long span composite beams from wood and galvanised sheet metal are used, as well as lightweight corrugated floor constructions and staircases. Clean double glass windows facing the rising sun warm the classroom during the morning. The school design includes thermal insulation and leads to substantially increased comfort for the students. Thermal wall and roof insulation uses local techniques and materials. Dry desiccation, double pit composting toilets with urine separation are recommended to minimise water wastage and avoid freezing.

Key Words:
School building. Remote mountain areas. Building construction technology. Earthquake-resistant construction design. Self-help construction. Thermal wall and roof insulation. Double windows. Dry composting toilets. Lightweight floor and roof construction. Composite construction beams. Bowstring beams. Passive solar energy. School furniture. Site planning.

Note:
This document reflects the findings and opinions of the author. It is not an official publication of the Aga Khan Foundation or the Aga Khan Planning and Building Services, Pakistan.

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FOREWORD

The Building and Construction Improvement Programme (BACIP), operating in the Northern Areas of Pakistan, is a project under the Aga Khan Planning and Building Services, Pakistan (AKPBSP). From 1998-2000, the programme was financed by PAKSID, a collaboration between the Canadian International Development Aid (CIDA) and the Aga Khan Development Network. During that time, the BACIP Programme Director was contracted through the Netherlands International Development Co-operation Programme (DGIS). BACIP works in co-operation with other Aga Khan Development Network Institutions (AKDNI) in the Northern Areas and Chitral, Pakistan. During 1999 and 2000, some 40 staff members consisting of architects, engineers and social workers have been involved in the BACIP programme activities. In addition, 200 village-based male and female resource persons assisted on a voluntary basis in the implementation of the programme.

Up to January 2001, the programme concentrated on the development and introduction of house improvements (more than 40 different types) for traditional and new houses in remote villages. In addition, technology and skills development among local entrepreneurs was initiated to enhance the delivery of the house improvements locally. Participatory cluster and village planning was a part of the process, as well and community discussions for determining appropriate housing locations to avoid building in geographically hazardous areas. Parallel to these mainstream activities, attention was given to the design of new schools. As many of the technologies being applied in the new school designs can also be applicable in houses, the demonstration effect would have a high impact on the youth and future house builders.

The present report gives an overview of the first designs for primary schools in three small mountain villages: Hoper-Ratl and Ghulkin villages at an altitude of about 8000 ft. (2400 m) and Gartenz village at 8500 ft. (2800 m). In Gilgit, the Al Azar examination hall was built.

The following people have been intensely involved in the development of the school designs, the testing and realisation of the prototype improvements, and the construction of the first schools:

- Mr. Qayum Ali Shah, Manager Field Operations of BACIP, in the manufacturing and development of the structural elements used in the houses and schools.
- Mr. Sarbas Karim, Site Engineer of AKPBSP (Gilgit), responsible for the realisation of several school buildings in the region and applying the innovative techniques.
- Mr. Jonathan Mitchell, Manager of AKESP (Aga Khan Educational Services, Pakistan), who supported and stimulated the approach followed by BACIP for the new designs.
- Mr. Shah Raees, Social Co-ordinator of AKESP, in communicating with the population.
- Mr. Rehmat Ali, General Manager of AKPBSP (Gilgit), who supplied supporting finance for a number of research activities, particularly related to application in schools, such as the new roofing systems, insulation, reinforcement and school furniture.
- Mr. Noor-ud-Din, Draftsman on loan from AKPBSP, in making the numerous modifications in the drawings during the designing phase.
- Mr. Mubarak Ahmed, Technical Illustrator of BACIP, in illustrating the fabrication process of the various house and school improvements.
- Mr. Assadulla Jan, Architect of AKCSP (Aga Khan Cultural Services, Pakistan), in adopting and adapting the Gartenz design for Ghulkin.
- All other BACIP support staff without whose help the realisation would not have been possible.

In 2005, the AKPBSP was awarded the USD 1 million Alcan Prize for Sustainability presented by the Prince of Wales International Business Leaders Form (IBLF) for BACIP and WASEP[1] efforts to improve Pakistan's built environment and water and sanitation facilities.

The AKPBSP with its BACIP project also received the World Habitat Award in 2006. This award is presented to projects providing practical and innovative solutions to current housing needs and problems.

One of the reasons that lead to the two awards was the extensive and detailed documentation provided by the author and his wife, Doreen.

Since the original school design document was written, new construction materials (such as the PE foam for thermal insulation) are now readily available in the local market. Some designs have been modified to take this into consideration. In this updated version, some pictures are included of the completed schools, among others. The document has been shortened by omitting the more detailed calculations and technical information.

It has been felt that more practical information should be developed on passive solar energy, solar windows and lightweight construction methods to make buildings warmer and safer. In addition educational programmes should be available on how the science and technologies work.

Those interested in the detailed technical information can obtain this directly from the author. It should be emphasized, however, that technical solutions need to be adapted to conform to the local cultural, socio-economic and climate situation of the region of application. In addition, new technical designs should be reviewed with local building authorities. In this respect, the present document provides examples on how practical problems were solved in a given situation.

BACIP STAFF INVOLVED IN THE DEVELOPMENT OF THE PROJECT

[1] Water and Sanitation Extension Programme.

INTRODUCTION

The BACIP house improvements focused on thermal issues and earthquake engineering aspects. The thermal issues included: smoke reduction, improved ventilation and illumination, wall and roof insulation, leakage and dampness control. Earthquake engineering solutions were developed for traditional stone, soil block and cement block constructions. Especially in mountain villages with limited land availability, two-storey houses and building in stages is being encouraged. BACIP realises the training of entrepreneurs and assists them in the distribution of their product.

Similar structural and thermal problems exist in both houses and school buildings. Although some schools are operating in traditional houses, many new schools have been built using cement blocks and reinforced concrete framework, materials relatively new to the area.

The three primary **user criteria** for the new BACIP primary school designs were:
- Increased thermal comfort.
- Maintaining earthquake safety.
- Avoiding incremental cost of the construction.

User Criteria 1: Increased Thermal Comfort
A side effect of the so-called "modern" reinforced concrete constructions and the use of cement blocks was their large heat transmission coefficient and heat (cold) storage capacity. During late autumn, winter and early spring, such buildings become cold and too uncomfortable to sit inside. It was observed that in the winter the existing cement block and concrete school buildings were so cold inside that invariably the children were grouped outside in the sun. In the summer the school classrooms were so hot that the teachers were seeking refuge under the trees. Very low or high internal temperature conditions caused by the construction design make the learning process inside the building highly ineffective. Such ineffectiveness makes the building costly. Building just a storeroom for the school furniture would have been more appropriate.

The new BACIP design therefore focused on increasing the comfort level inside the school building using wall insulation techniques and sun orientation (to capture and benefit from passive solar energy) as major improvements.

SCHOOL CHILDREN SITTING OUTSIDE THE CONCRETE BUILDING IN THE OCTOBER SUN

User Criteria 2: Maintaining Earthquake Safety

Elementary schools built by AKPBSP had the earthquake resistance of the building as a high priority. Low maintenance was an additional design requirement. These two criteria resulted in the use of large amounts of reinforced concrete.

As most of the first schools were built in the larger villages along the main roads or tracks accessible by light trucks, the supply of building materials (sand, cement, aggregate, steel) was not a major problem. Resistance to sizeable earthquakes (grade 7-8 on the Richter scale) was important to allow the buildings to serve as post-disaster shelters and emergency aid. The use of cement blocks and reinforced concrete was therefore chosen, combining durability and ease of transporation. The strength of these buildings could be calculated following standard codes and procedures, and would provide an adequate margin for safety according to the existing building code. The solid reinforced concrete and cement block designs were expected to be rather low in maintenance requirements.

For the new school design, BACIP first looked at reducing the weight or mass of the building; thereby reducing the possible earthquake forces on the construction (the size of the earthquake force is directly related to the mass of the construction).

Secondly, BACIP looked at the possibility of strengthening and bonding the local stone masonry construction with new wire-mesh reinforcement techniques. The BACIP galvanised wire-mesh wall reinforcement techniques are described in detail in other BACIP publications[2]. The wire-mesh reinforcement technique provides increased bondage between the outside and interior faces of stone walls, includes stress reinforcement, and reduces the material and construction cost of the wall.

Thirdly, BACIP looked at creating lightweight floors/roofs and support structures with slow failure characteristics. This means that in the event of a massive earthquake, the construction will not suddenly snap, but will first deform (and with that absorb the earthquake forces) and fail slowly.

TRADITIONAL BUILDING METHODS FALL APART GRADUALLY,
EVEN WITH SMALL EARTHQUAKES

[2] The following publications are available:
- *Galvanised Wire-Mesh Wall Reinforcement Methodology (November 2003).*
- *Galvanised Wire-Mesh Wall Reinforcement Strength (November 2003).*
- *Galvanised Wire-Mesh Wall Reinforcement, Reinforcement Options for Improved Earthquake Resistance of Stone Masonry Constructions (July 2000).*

User Criteria 3: Avoiding Incremental Cost of the Construction

The new school designs must allow for construction in more remote (off road) areas than is presently the case. To meet the demands for higher literacy in the country (especially girls), educational services must be extended to the children living in the remoter villages where there is limited or no direct road access. The current reinforced concrete construction design becomes even more costly for the higher mountain villages as sand and cement (and sometimes even aggregate) has to be brought up from the lower valleys. For remote villages, this often means carrying all the building materials on the backs of mules and/or villagers (both men and women). For a village such as Gartenz, this means climbing for an hour or more with 30 kg sand aggregate on one's back to the school site; that is from the last point a small 4WD truck can reach.

Most schools are built as a community participation project with the collection of locally available materials and unskilled labour (carrying loads) as part of the villagers' contribution. The use of local materials must therefore be considered instead of concrete constructions. Otherwise, higher (remoter) villages would be at a disadvantage compared with those villages situated along the truck roads because sand and aggregate are very difficult to obtain.

The higher the village, the shorter is the building season (see table below), in particular when building with cement mortar is concerned. This is because cement requires a minimum temperature of at least +5° Celsius for continuing the hardening process. As the temperature at high altitudes drops quickly at night, the concrete or cement mortar cannot maintain its heat gain from the day[3].

Once the sun becomes strong enough during the day and the ground thaws, all building activities are stopped by the local villagers in order to attend to the agricultural fields; their livelihood in the remote areas.

The following table is an approximation based on information obtained from local builders. Local contractors will often try to continue for two more weeks into the first night frost period, producing poor cement quality. In the table, a "+" indicates the weeks that cement can be used and a "-" indicates when it is too cold (less than +5° Celsius at night). Overnight evaporation of water will also contribute to the cooling down of fresh masonry. A minimum of four hours of daily sunshine has been considered. Shaded valleys or shaded building sites have one additional winter month.

Village	Altitude	Sept	Oct	Nov	Dec	Jan	Feb	Mar	April - August
	Above		autumn						summer
Gilgit	5000 ft.	++++	++++	++ - -	- - - -	- - - -	- - - -	++++	++++
Hunza	6000 ft.	++++	++++	+ - - -	- - - -	- - - -	- - - -	- +++	++++
Ghulkin	7500 ft.	++++	++++	- - - -	- - - -	- - - -	- - - -	- - ++	++++
Hoper	8000 ft.	++++	+++ -	- - - -	- - - -	- - - -	- - - -	- - -+	++++
Gartenz	8500 ft.	++++	++ - -	- - - -	- - - -	- - - -	- - - -	- - - -	++++

The choice of technical and architectural designs and building materials must therefore try to accommodate the above complexities and not solely the assumed earthquake resistance or maintenance aspect of the building.

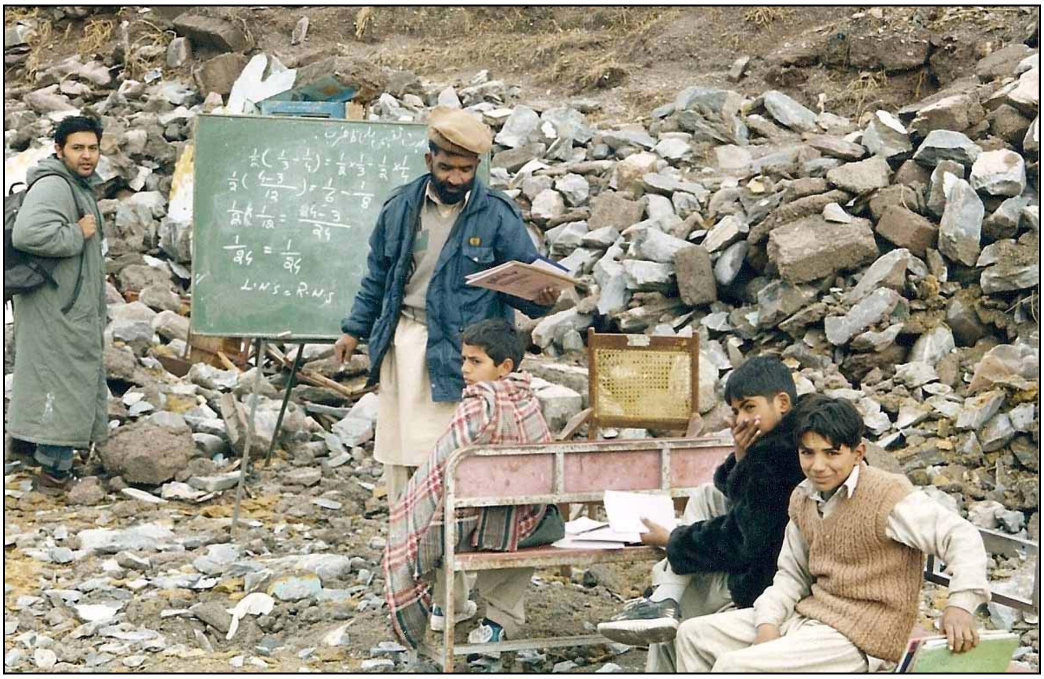
[3] During the building of one school, a plastic greenhouse was constructed over the building; thus raising the inside temperature of the stone mass. Insulation blankets were used at night. Although the masons liked to work inside the really warm greenhouse (and had a job in the winter), the technology was not repeated after the author left.

CHAPTER 1 DESIGN CRITERIA

Research for New Design Options

The new school design needed to incorporate construction methods applicable for high altitude areas, as well as resemble traditional methods as much as possible because these would require minimal external inputs. Yet traditional building methods were not necessarily the best option as most houses are cold in the winter and technically unsafe to resist large earthquakes. The design criteria for the new schools to be built off the main roads had a package of objectives:

- **Earthquake resistant**, including the following:
  - Lighter construction to reduce the weight of the building (potential earthquake forces).
  - Increased coherence between building components to avoid sudden collapse.
  - Increased lateral stability for long wall segments.
  - Functional strength by incorporating storerooms into the structural design.

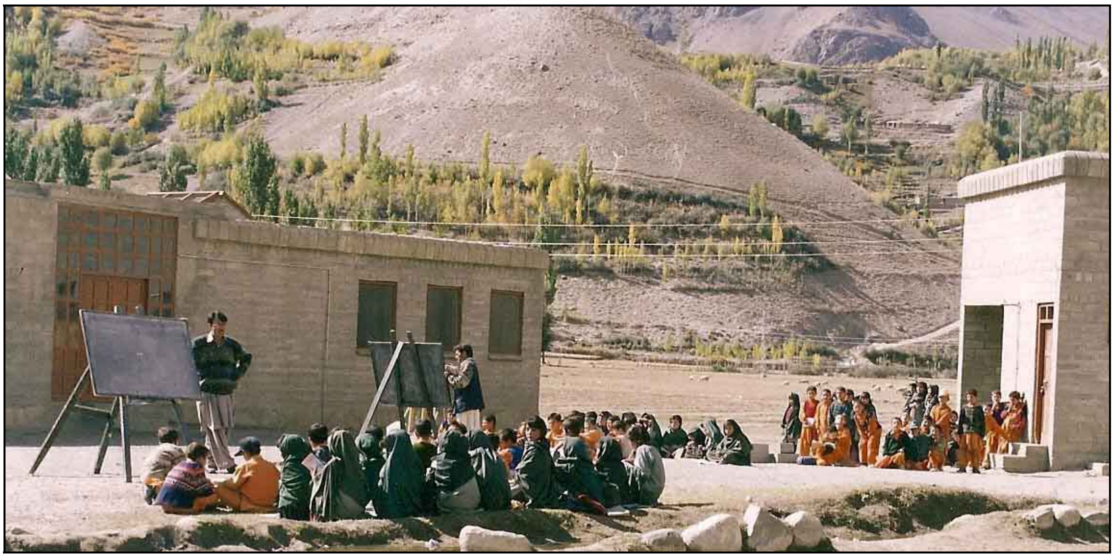


GOVERNMENT SCHOOLS COLLAPSED IN THE 2005 KASHMIR EARTHQUAKE
DUE TO POOR DESIGN AND HEAVY MATERIALS

- **Ability to construct on irregular school sites:**
  - To avoid the need for large and/or flat areas of land by allowing for building on smaller, irregular shapes and sloping terrain.
  - Building one- and two-storey schools to conserve agricultural land.
  - Providing the option for progressive or evolutionary development; building in stages.
  - Within close range of a possible helicopter landing site (agricultural field).

- **Use of local materials as much as possible**, because:
  - Villagers' participation should be as high as possible.
  - Transport from outside the area is difficult due to limited road access.
  - The cost of the construction must be kept low and simple techniques used.
  - Concrete is one of the most costly materials for high altitude construction and must be limited.
  - Replication of the applied techniques must be possible in domestic housing.
  - Future maintenance by users of the school must be possible.

- **Better insulating properties than other existing school buildings**:
  - Insulated walls, windows with double glass, ceiling and roof insulation to avoid heat loss.
  - Use of passive solar energy from the winter eastern morning sun for heating the classrooms.
  - Improved orientation with regard to strong winds (reduce the cooling effect).



IN THE WINTER, CLASSES ARE HELD OUTSIDE BECAUSE IT IS TOO COLD INSIDE THE SCHOOLS.
SCHOOL FURNITURE CANNOT BE CARRIED AROUND.

- **Improved classroom layout and space organisation:**
  - Improved light and illumination conditions.
  - Larger school board covering the entire width of the front of the classroom.
  - Enclosed multi-purpose storage facilities for other school users.
  - Possibility to create smaller spaces for a smaller number of children.
  - Low classroom height to reduce heating requirements.
  - Reduced sound reverberation to improve audibility and understanding of the teacher.
  - Improved furniture to allow flexibility of use and considers the height of the students.
  - Strong furniture (chairs) that would not collapse under a collapsing ceiling.
  - Doors opening to the outside and wide (double) for rapid evacuation of occupants.
  - Indication of safe areas and escape routes.

- **Improved external space organisation:**
  - Creation of external space for outside classrooms.
  - Sanitation that does not freeze during winter nor requires large amounts of water.
  - Sanitation that can be used by a very large number of people after a disaster situation.
  - Partly underground water storage tank for large amounts of clean water (disasters).
  - Protection of underground water storage from flooding or dirt infiltration.
  - Elevated water tank with auto shut-off valve (in case of earthquakes).
  - Free access roads, avoiding landslide areas.

- **Other improved services:**
  - Independently supported communication means through PV power and battery.
  - Possibility to locate kitchen services.
  - Dry storeroom for emergency supplies, including tents, blankets, dry rations (rotating).
  - Health information on post-disaster actions to be taken.

As a result of the above first four design criteria, the BACIP programme needed to analyse two new issues that were of high importance to future primary school building design and different from the house improvement designs, namely:

◊ The creation of larger span constructions or the creation of large open room spaces.
◊ Strong school furniture to allow improved educational use of the classrooms.

Because the current sizes of the groups of students in the remote villages were not very large (10-15 students per study grade; even less in the smaller villages), BACIP realized the large span construction only in a large school in Gilgit (Al Azar examination hall).

Cost of the School Building

When BACIP was requested to make an alternative school design, the underlying idea was to obtain a cheaper building than the current cement block units, meaning lower capital investment. However, the relative cost of a building lies in its usability; a unusable cheap building is very expensive. The actual cost of the construction of a school design depends on several factors, such as:

◊ ***Actual size of the planned construction.*** It is important not to construct more spaces than can possibly be used by the students in the coming five-year period. Constructing classrooms to accommodate 40 students whilst in the coming 10 years no more than 10-15 students can be expected is uneconomical. In such a case, large rooms need a different classroom organisation. Use of sound and space separators in the classroom should be considered. Large span design is unnecessary in this case and columns can be used. For the Hoper-Ratl school, it was decided to build one standard classroom and one smaller in size.

◊ ***Limited outside walls.*** As the winters are cold and long, the surface area of the exterior walls needs to be kept to a minimum. Communal walls separating the classrooms are recommended. The possibility of attaching new classrooms to the existing classroom(s) in the future should be kept in mind.

◊ ***Roofs should function as future floors.*** As there is a great shortage of land, two-storey and even three-storey building constructions must be considered. As multi-storey buildings are uncommon in the area, it is suggested to have only two storeys (ground plus one). This means that the roof of the classrooms must be designed as future floors and allow for the bearing of the planned load.

◊ ***Materials used and the local availability of these materials.*** The reduction of the thickness and mass of the walls is important for both saving on building materials and reducing the weight, the latter beneficial in earthquake terms. Inside insulation can be made from local materials, such as plastered wattle panels. Abundant willow trees are available in the area.

◊ ***Participation of the local population in the construction by supplying local materials and unskilled labour.*** Local builders must become familiar with the new building methods introduced by BACIP. The training of the craftsmen is organised by BACIP.

◊ ***Minimal land requirements.*** The school design needs to be flexible to allow for construction on a variety of sites. In choosing a school site, the risk of natural hazards (such as rock falls) must be analysed to ensure that no dangers exist.

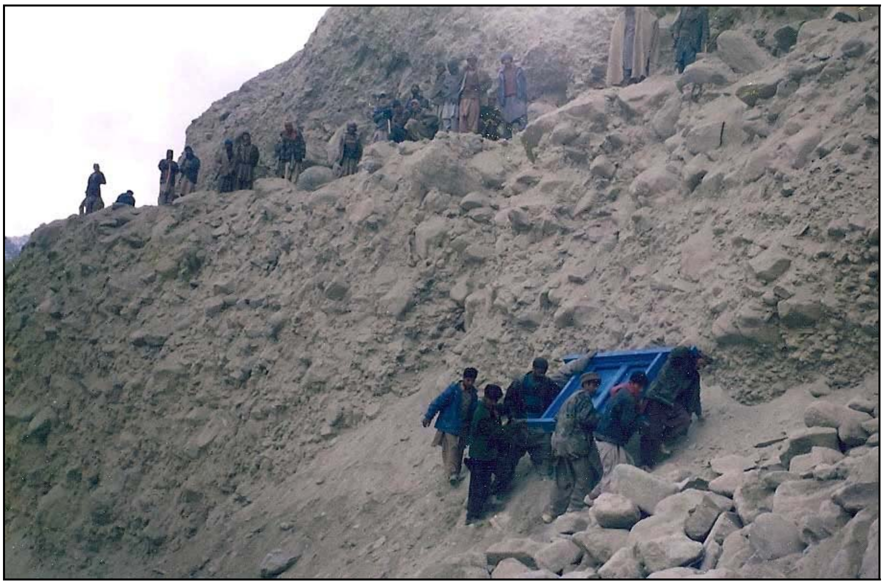
Prefabrication

It will not always be possible to build the school on site using exclusively local materials and skills. The supply of prefabricated schools and local assembly of the components will often be the preferred method by local government or external agents, especially when speed is the issue.

In the colder upper mountain areas, some construction is undertaken during the winter period when there is no snow cover. During the warmer months, the demands of agricultural activities keep villagers extremely busy with little spare time; while in the winter they do have available time.

Manufacturing of prefabricated components should be undertaken in the main towns and transported to the village well before the building period. In Gartenz (8500 ft.) a storeroom was built at the end of the road (7500 ft.), allowing the villagers to gradually bring the items uphill. The construction of soil stabilisation and retaining walls are activities which can be realised during the winter period.

For mule and human transport, building components should not be longer than 10-12 ft. or wider than 3-4 ft. with a maximum weight of 50 kg. When prefabricated lightweight galvanised steel frames are used, the sections need to be assembled on the building site. To reduce the overall transport weight and size, large elements can be made in sections. The connections between timber frame sections can be made with bolts on site. Vehicle transport can combine heavy pieces with voluminous thermal insulation material. Pre-cut glass sheets should be packed together for transport and fitted locally into the window frames.



TRANSPORT OF A LARGE BUILDING COMPONENT ACROSS A LANDSLIDE

It pays to make intelligent lightweight designs, allowing for strong and thermally well insulated buildings, rather than trying to minimise costs. The cost reduction is realised in easy transport and quick assembly. The same design components should be applicable for two-storey house constructions. Once the villagers have constructed the school, they can replicate the same technology for their houses.

CHAPTER 2 SITE SELECTION

A. Site Selection of Hoper-Ratl School

The first school site study was for an additional school in Hoper-Ratl (Shiqamating), a village well off the road at an altitude of over 8000 ft. (2400 m).

BACIP held discussions with the villagers regarding the site selection and planning for the proposed school. Several sites were viewed and the advantages and disadvantages discussed. The following points were considered in the site planning:

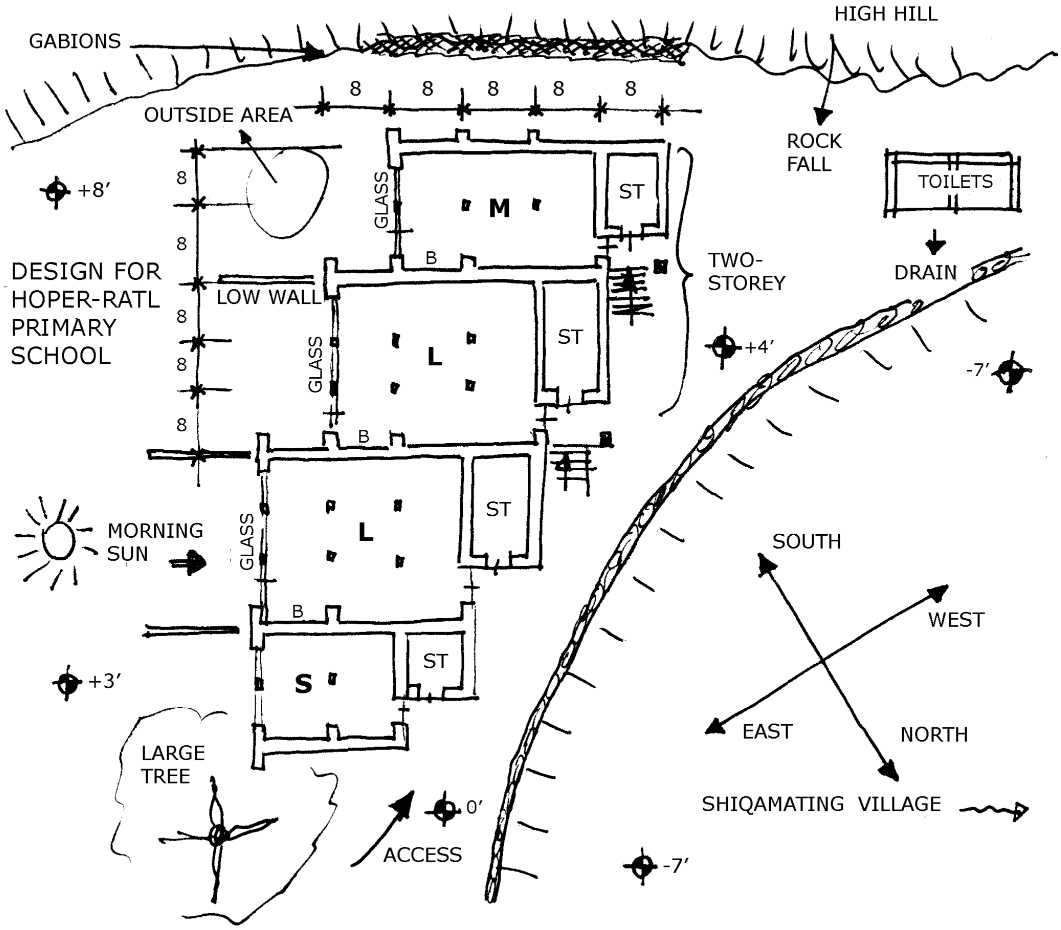
IN SEARCH OF A SUITABLE SCHOOL SITE WITH A GROUP OF VILLAGERS

- The site should be as close as possible to the target village of Shiqamating to avoid long walking distances for the girls to/from the school.
- With the village situated on a peninsula hilltop, future expansion of the village was limited. Building the school at the extreme outer limit of the hill would be disadvantageous for future students because of walking distance. Preferably, the school should be situated somewhere between the village and the nearest truck road.
- The site should not be next to the village pond as boys often swim (half naked) there in the summer and this would be a distraction (inappropriate) for the female students.
- The site should not be within 100 m of the border of the glacier deposits as the glacier erodes 5-10 meters of land yearly. This would mean that in 10-20 years the school would fall into the glacier.
- The site should preferably not be in the winter shade projection of the mountain as that would eliminate the possible use of solar heating of the classrooms.
- The site should not be on land currently under legal discussion between owners or related to heritage problems. These types of problems often last for many years and never get resolved.
- The site must be donated by a villager or bought from a villager without reservations.
- The site should not be in an area subjected to geological hazards, such as on or under potential landslide areas, or in the course of possible future mud slides or rock falls. In many cases the historical information from the villagers may provide an indication as to where the hazards have been during the last century.
- It must be possible to bring local materials to the site, such as rock (from higher terrain to lower) or sand and gravel (from the river upwards).

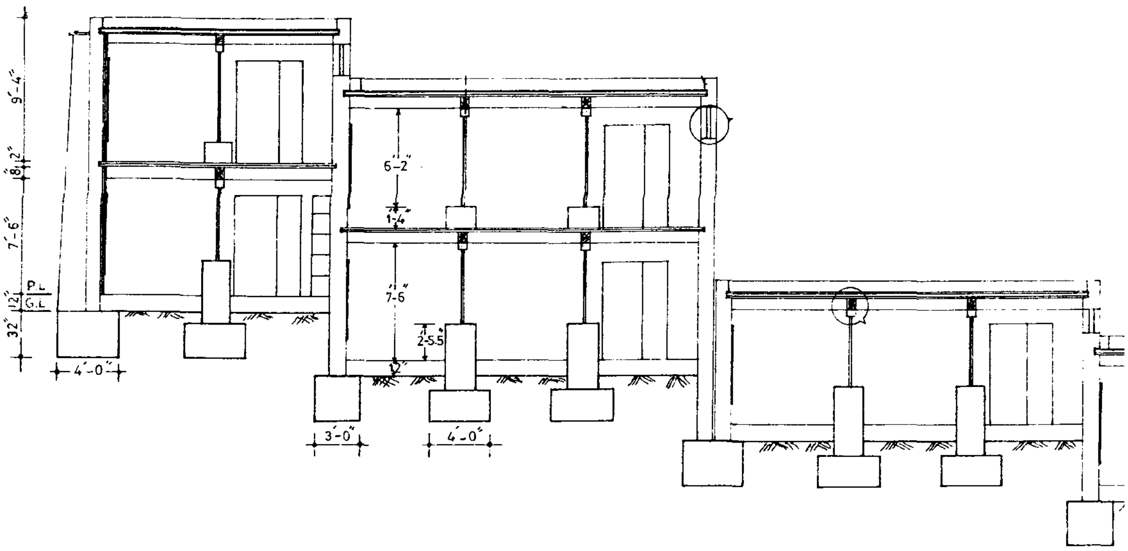
♦ It would be advantageous if the site would have some tree shading during the summer period.
♦ The site must be large enough to build two double-storey classroom blocks and a sanitation unit.

After visiting and assessing the available sites, a selection was made. The possibility to have the site between two neighbouring villages was highly valued as future students from the neighbouring village would be able to contribute to the financing of the school's operational costs. In this case the economics of the school operation was an important long-term objective.

The possible layout of the buildings with the orientation to the morning sun was an important factor. The classroom units were all oriented towards the low, eastern 09:00 hr. sun, but staggered in position. This allowed the creation of outside sitting areas. In addition to the shifting of the horizontal position of the classrooms, they were also staggered vertically to match the gradual slope of the terrain.



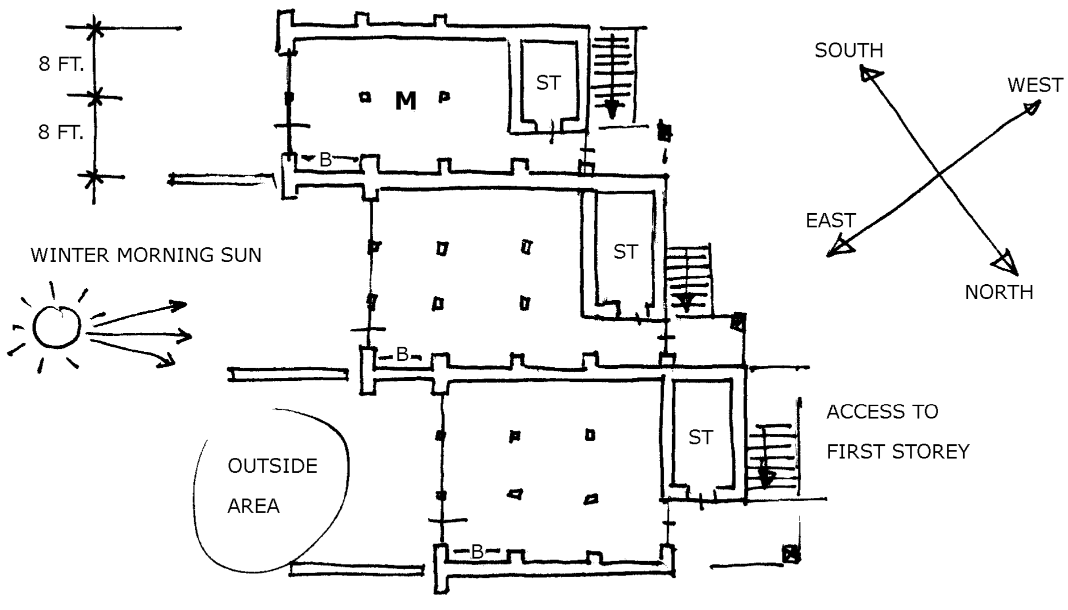
FIRST SITE LAYOUT FOR THE HOPER-RATL SCHOOL



HOPER-RATL, CROSS-SECTION OF THE SCHOOL AS SEEN FROM THE SOUTHEAST

The proposed school layout design was reviewed with the responsible persons and an actual layout was pegged out on the proposed school site for consideration by the village people.

The following figure provides an example of an alternative layout of the classrooms, still with the sun orientation to the southeast for capturing the morning sun.

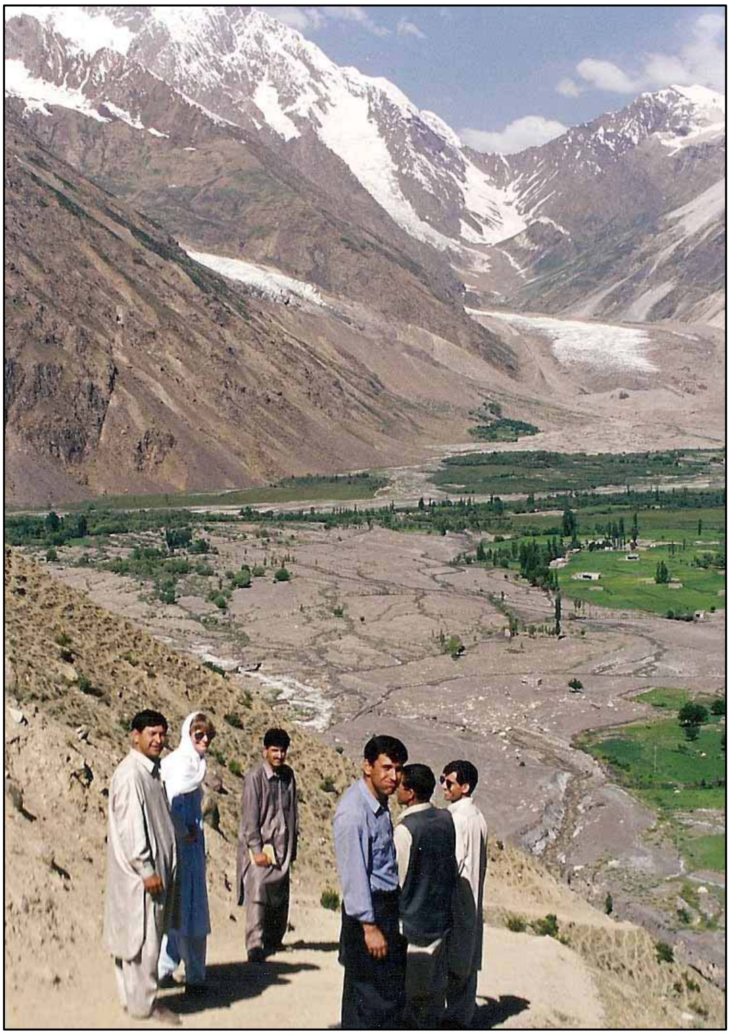


ALTERNATIVE SITE LAYOUT FOR THE HOPER-RATL SCHOOL

B. Site Selection of Gartenz School

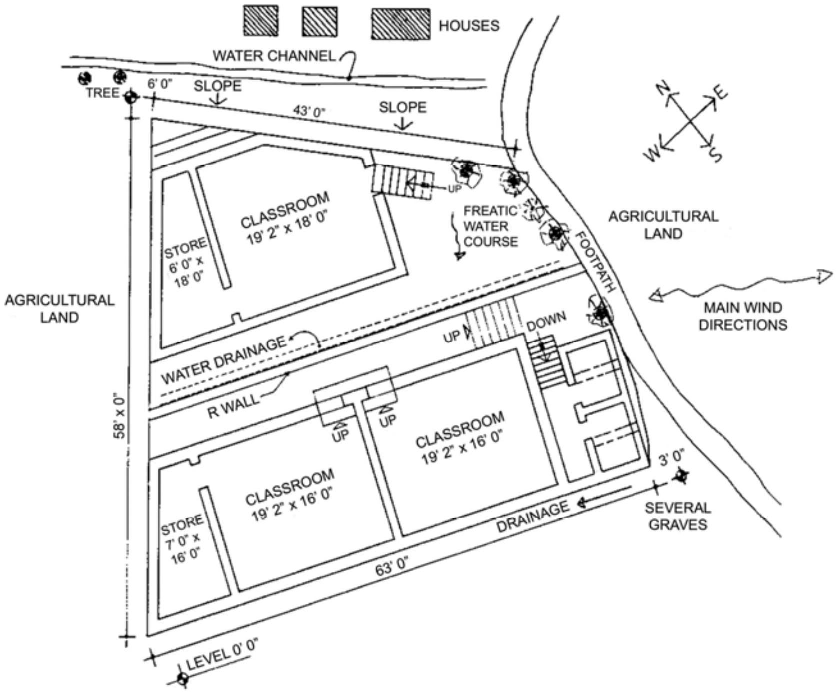
The village of Gartenz in upper Yasin has no truck road access at all. Situated at an altitude of about 8500 ft. (2800 m), Gartenz has a long winter and only a one-crop season. All materials supplied from outside the village are first deposited at the foot of the mountain (8000 ft.) and then gradually hand carried up the steep mountain track, taking minimum a half hour for a conditioned villager or an hour for any of the project staff (without a load).

TRACKING UP TO GARTENZ VILLAGE FOR THE SURVEY OF THE SCHOOL SITE



The school site in the village had already been chosen by the population (donated by a villager) and the community had already collected locally available materials on the site. From discussions it appeared that very little land was available for optional locations. Thus, it was the task of BACIP to determine the best school design to fit the given area. The following points were considered:

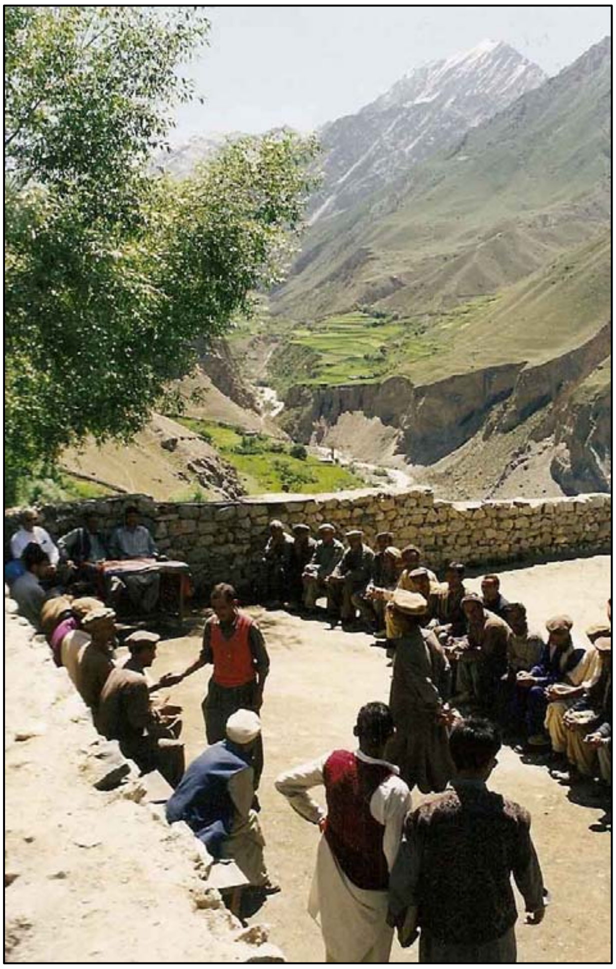
- ♦ The site did not have any particular geological hazards.
- ♦ All materials, cement and sand aggregate had to be hand carried up into the village on the backs of men, women and mules. A lightweight construction design and material use were essential.
- ♦ A supply of good quality granite stone for construction was already available on the site.
- ♦ The manufacturing of various components in the lower valley (village at the base of the mountain) was a possible option. The completed article could then be carried uphill.
- ♦ Possibility to construct or rent a building in the lower valley village for the storage of building materials and tools or to use as a workshop for manufacturing (windows).
- ♦ Road access to the store in the lower valley village is limited to the summer and autumn.
- ♦ Sloping terrain from the southwest up to the northeast.
- ♦ Underground water flows down from the slope in the summer, passing through the terrain and flowing over a steep footpath running alongside the terrain.
- ♦ Some old gravesites were located on the lower side of the adjacent land.
- ♦ Cold winter winds along the southeast to northwest axis in two directions.
- ♦ The planning of a two-storey construction in a future stage was necessary.
- ♦ Frost-free sanitation system, possibly with composting.
- ♦ Main construction work to be realised in the winter or non-farming period.



SCHOOL SITE OF GARTENZ, CLASSROOMS FACING SOUTH

Following an assessment of the terrain, possible layout and sun orientation, the location of the first two classrooms was oriented lengthwise on the lower border of the site with the stabilisation of the building by the storeroom and sanitation unit. These two units would also provide shelter against the cold winds. The following points were included in the planning:

◊ The front side of the building needed to be flat to avoid wind chill.
◊ This flat side had full view over the valley and received the morning and midday winter sun.
◊ The storeroom has a trapezium shape to conform to the given shape of the terrain and block cold wind from the west.
◊ A two-storey unit was planned on the higher part of the terrain overlooking the lower building and having a magnificent view over the valley and the opposing mountain range. The headmaster's room would be located on the second floor of this unit.



FOR EVERY SCHOOL DEVELOPMENT, EXTENSIVE MEETINGS TOOK PLACE WITH THE VILLAGE ELDERS AND COMMUNITY LEADERS

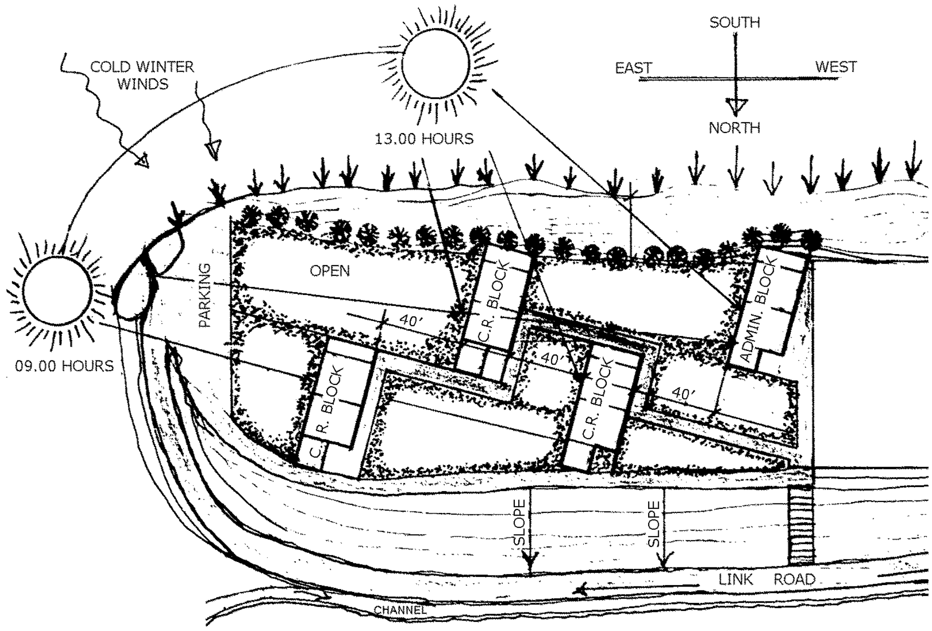
FRONT BUILDING OF GARTENZ SCHOOL IN PROGRESS OF CONSTRUCTION
LARGE WINDOWS ON THE SUN SIDE, STOREROOM ON LEFT END FACING COLD VALLEY WIND,
AND TOILET BLOCK ON RIGHT END

C. Site Selection of Ghulkin School

The Ghulkin community solicited BACIP's advice for a flexible school design as they had only one location available on the top of a (windy) hill. Eventually the community wanted to develop a complete six classroom school there, but currently only had finances for building part of this planned school. Given the site and possibilities for construction, the following points were considered:

- The peninsular-shaped site did not have any particular geological hazards.
- A steep downwards slope existed on all sides of the terrain. A truck access road will eventually be developed along the peninsular hill on the north-western side.
- A number of large boulders existed on the site that could be used for shielding the buildings against the strong winter wind coming out of the southeast.
- The buildings to be constructed on the side (above the slope) should have wind deflectors made of gabion walls.
- The fractionated site with boulders and a narrow shape, combined with the planned sun intake from the southeast, would require individual building blocks of two to three classrooms.
- The building blocks can have a toilet or storeroom on each end to enhance stability.
- The toilets need to be frost resistant.
- The south-eastern façades should have flat surfaces to minimise wind chill and double glass windows for light and heat intake.
- The building blocks as a whole should be staggered on the site to allow winter sun intake in all the ground floors. One building should not block the sun intake from another.
- No water supply is available on the site, but could possibly be brought from a higher hill.
- The possibility of making a playground at the entrance of the plot should be considered. To allow sufficient area for the playground, the school buildings should be made two storeys high.

Given these conditions, the design of the Gartenz school was slightly altered and fitted on the Ghulkin site, placing four sets of double storey classroom blocks.



NARROW HILLTOP SITE FOR THE GHULKIN SCHOOL ~ SCHOOL TO BE BUILT IN STAGES

Ghulkin Primary School

The first building block of the two-storey primary school in Ghulkin was constructed in 2001 and two other classroom blocks the years thereafter.

In the first school building, all the east facing windows are double glass with the centre window being openable to both sides. All the inside glass windows could be opened to the inside to enable cleaning. However, the openable inside windows were not kept clean. In addition, lack of hold-fasts on the centre outside windows and strong gusts of wind caused many glass panes to break. When these blocks were converted into dormitories, neither the inside nor the outside glass panes were cleaned, and broken glass panes in the central windows were not replaced. The effect was that little solar heat was gained and cold wind from outside entered freely.

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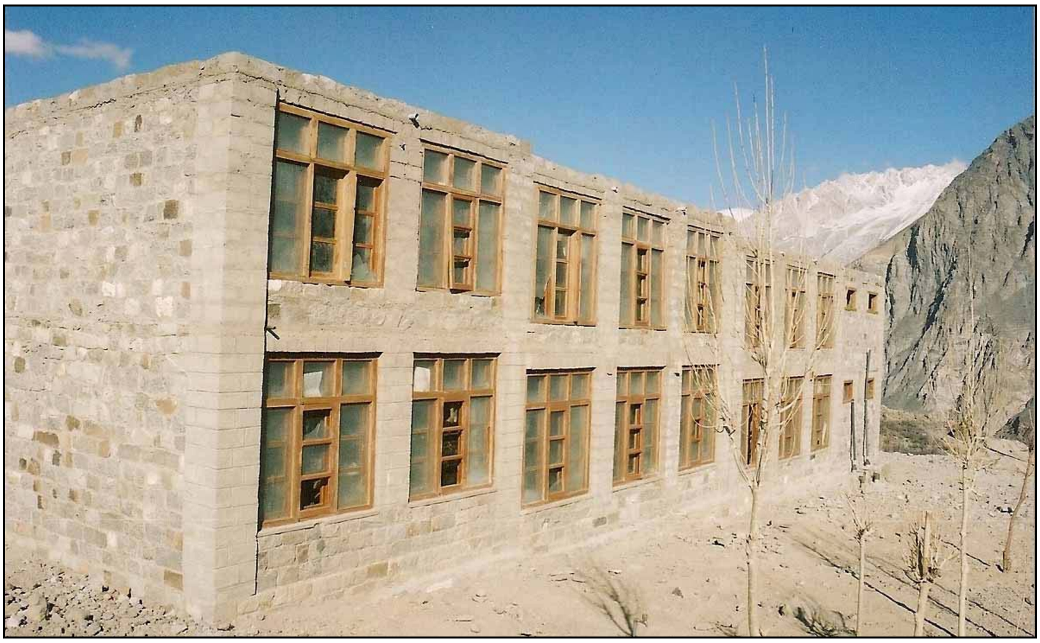


GHULKIN SCHOOL OLD FAÇADE ~ FACING EAST TO CATCH THE MORNING SUN

Based on observations of the first block, some design features were modified in the second block. Each window is divided into three sections with only the centre section having a ventilation window. The first modification was to replace the openable inside windows on either side of the ventilation window with fixed glass panes. However, now the in between glass surfaces cannot be cleaned unless one takes the glass sheet out of its frame.
The second modification was to fix the movable ventilation window <u>in between</u> the posts of the main window frame, instead of <u>on top of</u> the window frame, hence reducing sun intake.
The third modification was placing an awning above the window. This would in one way reduce sun intake after 10:30 hr. (shadowing the top window), but on the other hand, it better protects the windows against weather influence.

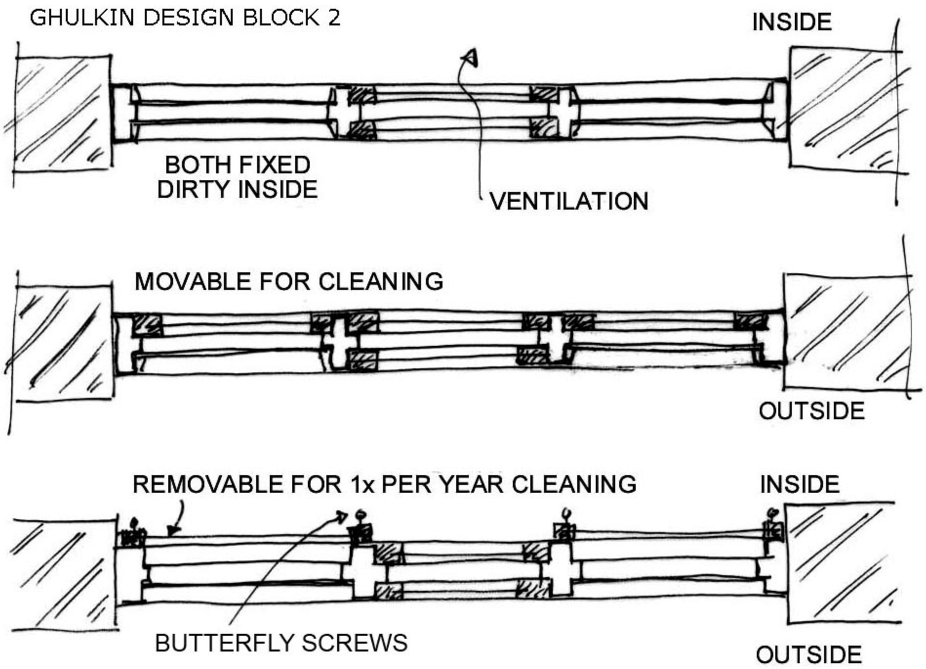
The disadvantage of the new fixed window design is that dust enters in between the two glass sheets and reduces the heat intake from the sun. In addition, as was observed during the day of the site visit, the two <u>external</u> glass surfaces were not clean, further reducing the solar heat intake. Yet the classroom was warmer than any other school and the students felt comfortable. From discussions with the students, they understood the effect of the double glass.

GHULKIN SCHOOL NEW FAÇADE WITH MODIFIED WINDOW FRAMES

Based on the students' comments, it appears they are very happy with the improved solar window design because no additional heating was required for the classrooms by means of a firewood or kerosene stove. This also has an important influence on the health and study capacity of the students as a fire draws oxygen out of the classroom making everyone sleepy.

A lesson learned from this experience is that the science of solar windows needs to be explained in detail and a formal "window cleaner" (or rather "energy manager") should be appointed to take care of keeping the solar windows clean and, when applicable, opening and closing shutters to regulate the inside temperature.

- In cold zones, the science of "solar windows" and their potential of being a heat source need to be incorporated into the classroom curriculum. In this way the design and operation technique will be used for housing as well.
- The architectural design should be accompanied with user instructions.
- Thermometers should be fixed in the classrooms to enhance information.
- Management of sun reflecting fly screens during the summer needs to be incorporated into the management.



The top window drawing above illustrates the double fixed glass pane in the side windows of the new Ghulkin construction. The middle drawing presents the original design of the first building block by which the inside window could be opened for cleaning purposes. The heat gain with the double window was substantial and therefore cleaning the glass was not considered an important issue. Measurements on clean and dirty glass panes, however, indicate that each slightly dirty glass surface has a reduction effect of between 5% and 10% of the heat intake. Four dirty glass surfaces will easily reduce heat intake by 30%. This results in a temperature loss of several degrees Celsius in a classroom and can be the difference between comfort and discomfort.

With good thermal insulation of the building, solar heat stored during sun hours will keep the room warm overnight, having a cumulative comfort effect.

CHILDREN IN THE NEW BUILDING BLOCK
ALL COMMENTED THAT THIS CLASSROOM WAS THE WARMEST PLACE IN THE VILLAGE

CHAPTER 3 SPACE DESIGN

Size of the Classrooms

To define the classroom size for new school buildings, the number of students per classroom and the furniture use and sizes need to be determined. For all three schools, the number of students per classroom was given at 40, being the maximum number for which the room size should accommodate.

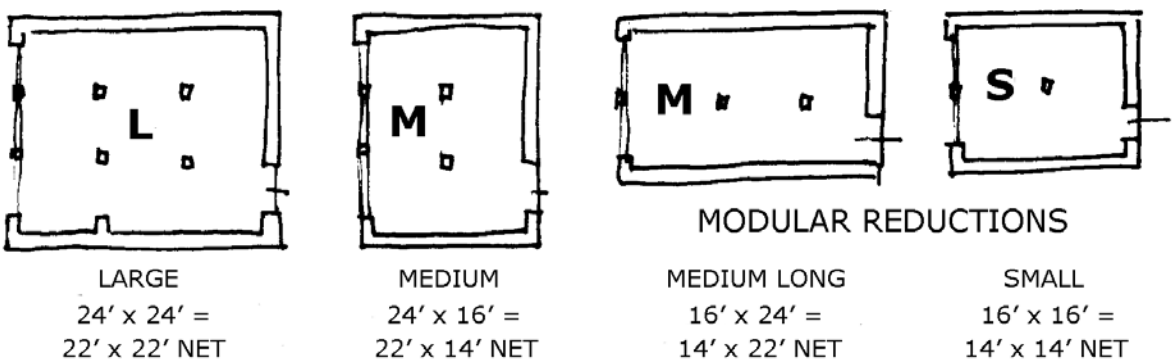
On the basis of 40 students and the surface requirements for the furniture, the minimum classroom size has been determined as follows:

- For 14 years and older: 1.1 m² per student or 44 m².
- For students younger than 14 years (tables 100 cm x 50 cm): 0.87 m² per person or 35 m².

The large classrooms can be occupied by two groups of students, separated by cabinets. If it is evident that for the time being the population growth does not merit larger classrooms, then one or two smaller classrooms can be designed. The size can be 24 m² to 18 m² respectively.

Number of Students and Age	Table Sizes	In Square Meters	In Square Feet	Net Room Sizes
40 students older than 14 years	120 cm x 60 cm for two students	1.1/student = 44	484	20 ft. x 24 ft. or 22 ft. x 22 ft.
40 students younger than 14 years	100 cm x 50 cm for two students	0.87/student = 35	385	20 ft. x 19 ft. or 16 ft. x 24 ft. or 22 ft. x 17 ft.
20 students older than 14 years	120 cm x 60 cm for two students	1.2/student = 24	264	20 ft. x 13 ft. or 16 ft. x 16 ft. or 22 ft. x 12 ft.
20 students younger than 14 years	100 cm x 50 cm for two students	0.9/student = 18	198	13 ft. x 16 ft.

On the basis of the above measurements, the maximum classroom size of 22 ft. x 22 ft. was chosen (including the width for the supporting walls 24 ft. x 24 ft.). This area was subdivided lengthwise into three to allow for a roof supporting structure of 7-8 ft. supported by either strong beams crossing the room or slender (steel) columns. The 8-ft. span corresponded with the possibility to realise the light and strong metal/concrete floor in a modular system.



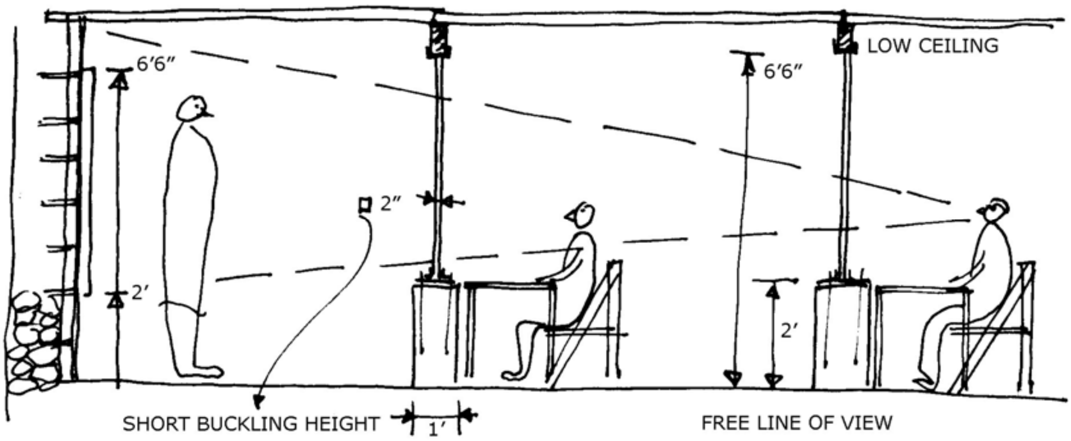
SELECTED CLASSROOM SIZES (GROSS AND NET SIZES)

Height of the Classroom

The height of the classroom has been kept at only 6 ft. 8 in. under the long beams. Reducing the physical and visual classroom height is important for several reasons:

- To limit the heating requirement in the winter.
- To keep the weight of the walls low and with that reduce earthquake forces.
- To keep the height of the walls low to reduce material use and labour.
- To create a psychologically more confined area; being more appealing to small children.

In order to comply with ventilation requirements, sufficient windows and ventilators must be available for fresh air. While it is important that the classrooms have adequate ventilation during any time of the year, it is especially essential during the winter when the room is heated with a wood stove because the stove will consume a large amount of oxygen. Also, for this reason, the wall and ceiling insulation of the classrooms must be of good quality. Due to the better insulation of the classroom, heating requirements will be less, drawing less oxygen out of the room for the burning of fuel.



PRINCIPLE OF THE DESIGN OF THE SLENDER COLUMNS
OPTION SHOULD BE COMBINED WITH A SCHOOL BOARD OVER THE FULL WIDTH OF THE FRONT WALL

Sanitation System

The design of the sanitary facilities has been based on a double vault dry composting latrine. The BACIP model is an improvement on traditional design toilets and has better hygienic properties[4]. The urine and wash water is separated into a drain/soak-away, which keeps the faeces dryer as compared to local systems. When dry clay is added after defecation, the system will be largely free of odour. Being resistant to freezing, it can operate year round, a very important factor in the high altitude school areas[5]. When one vault is filled with solids, it is closed with a ceramic plug. The alternate vault is then emptied and put back in use. The size of the vaults allows an annual changeover. The one-year-old compost can be safely handled and used for agriculture fertilization. The system can be easily reproduced by the villagers. Since 2005, low-cost lightweight (fibreglass- reinforced polyester) Ecosan toilets have become available on the market[6].

[4] Villagers complained that wet composting toilets had excessive stink and liquids leaked through the walls.

[5] It was observed in many schools in the higher altitudes that flush toilets were invariably non-functional due to cracks caused by frost. The toilets in the schools cannot be kept frost-free.

[6] See: www.ecosan.nl; www.ecosanres.org; www.gtz.de/en/themen/umwelt-infrastruktur/wasser/9399.htm; www.gtz.de/en/dokumente/en-ecosan-pds-005-china-guanxi-2005.pdf

Sanitation Block

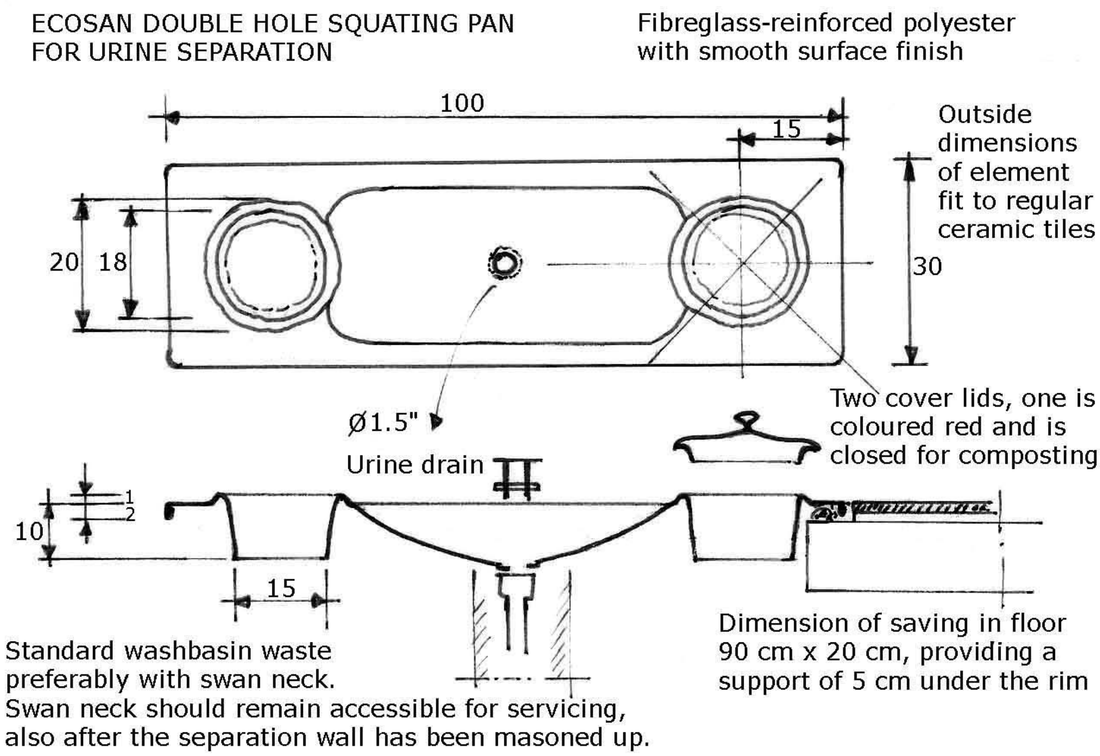
The position of the toilet or sanitation block depends on the soil conditions, wind direction and stability requirements of the classroom block. Ideally the unit should be placed at the lee wind side to avoid unpleasant odours from the vent pipe. The squatting floor is placed about 5-6 ft. above the ground to allow a large enough vault under the toilet. The urine and water drainage from the pan goes directly outside the unit through an insulated pipe. The drainage ends in an underground soak-away, the size of which depends on the type of soil and amount of liquids expected.

Dry Composting Toilet (Ecosan)

Water infiltration into the hillside from wastewater and toilet soak-aways could cause landslides. It is technically wrong to place a soak-away in the upper hillside slope above a house (or school) because infiltration of wastewater will then flow under the foundation and adversely affect the stability of the house (or school). This is especially the case when the soil has substantial clay content.

Not only is there limited water supply in many mountain areas, but the poor quality agricultural soil requires fertilizers. The urine separating (desiccation) and dry composting toilet requires a minimum amount of water for anal cleansing and far less water than a pour-flush toilet. The dry composting toilet (Ecosan) produces high quality fertilizer annually. The dry composting toilet resolves both the water and fertilizer issues at the same time. Therefore it is recommended for many remote mountain areas.

The BACIP design of the dry composting toilet has urine separation, is clean, odourless and gives excellent compost quality. A number of villagers have upgraded their previously installed WASEP soil floor toilet with the more sanitary BACIP dry composting unit.



TWO-HOLE UNIT IS PLACED OVER A DOUBLE VAULT, ONE SIDE COMPOSTING

Issues to be Considered

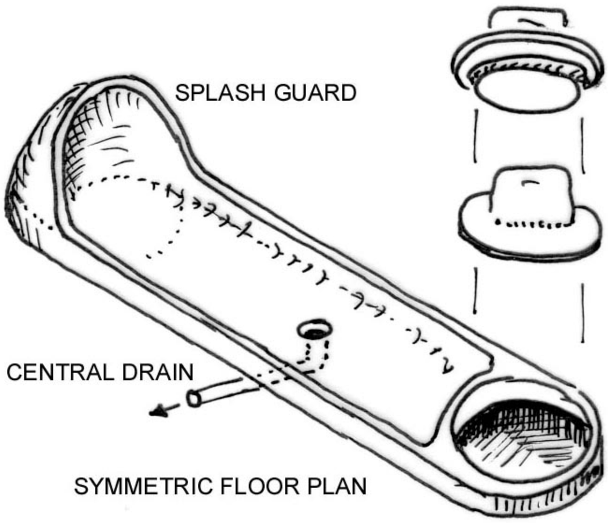
The following issues need to be considered:

- There needs to be a proper understanding of the better technology of the urine separating dry composting (desiccation) toilet principles with the local engineers and administrators.
- The design has a central fibreglass-reinforced polyester receptacle for the urine, eventually complemented with tiled footsteps. This receptacle should be adequately deep and long. Examples are now available from several sources.
- There needs to be collaboration between the building and sanitation programmes on promotion of the various technologies, providing villagers with information on the systems so they can make an informed choice.
- Introducing new designs among youngsters is easier than convincing older people. Schools can play an important role in introducing new, environmentally beneficial methods of sanitation. This is especially the case in saving water and improving the compost quality. In post-disaster situations, water will be a scarce commodity.

Different designs of fibreglass-reinforced polyester receptacles are being manufactured for the Ecosan toilet.

One design has two closable holes (see sketch page 21). One squatting hole remains closed with a lid for one year (recommended), while the other is in use After defecation, the user simply shuffles forwards, closes the hole with the cover and applies anal washing over the central basin.

Another design (sketch right) has a unit that can be turned after one year (when the lower collection chamber is full), changing the position of the squatting hole. These fibreglass-reinforced polyester squatting and anal wash units are lightweight and do not break during transport. All designs require the collection chamber to be ventilated.



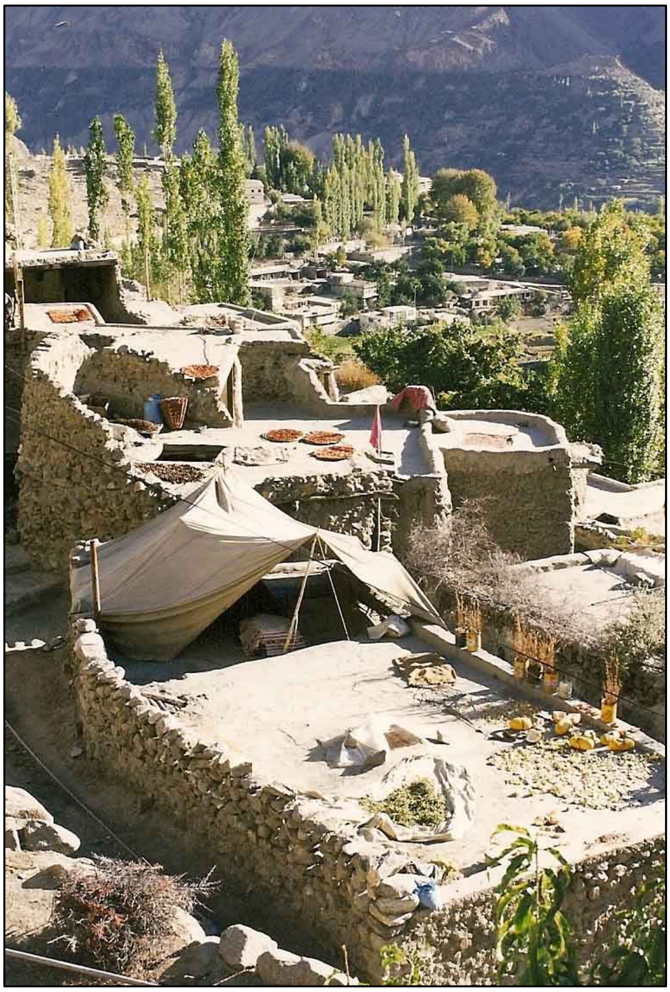
CHAPTER 4 LIGHTWEIGHT CONSTRUCTIONS

Earthquake Forces

Earthquake forces are directly related to the weight (mass) of the building components. In particular, falling heavy stone walls and mud roofs of traditional houses have caused many deaths, broken limbs and substantial destruction. To reduce the forces, building constructions must be as light as possible. The composite roof beam and light floor constructions are two BACIP products which can be further promoted for building earthquake-resistant structures.

The traditional flat heavy roof is a particular problem. In addition, it is not good in heavy snowfall areas when it absorbs large quantities of water. A simple solution is a pitched roof made of corrugated galvanised iron (GI) or zinc aluminium roofing sheets on a timber frame. Such a roof needs to be thermally insulated, especially in the higher mountain regions (above 1500 m).

A big disadvantage of a pitched roof for mountain people is that it eliminates the flat roof area which is commonly used for storage, drying and relaxation. With about the same amount of timber and corrugated GI roofing sheet materials required for a pitched roof, a lightweight flat roof can be made that doubles the available floor space of the house.



THE ROOFS OF HOUSES IN MOUNTAIN AREAS ARE IMPORTANT EXTENSIONS OF THE HOUSE

Wall Constructions

Making traditional dressed stone walls more earthquake resistant is extensively dealt with in other BACIP documents. Because villagers mainly use the 18" dressed stone wall system or “modern” cement blocks, structural cavity walls are not covered in this document.

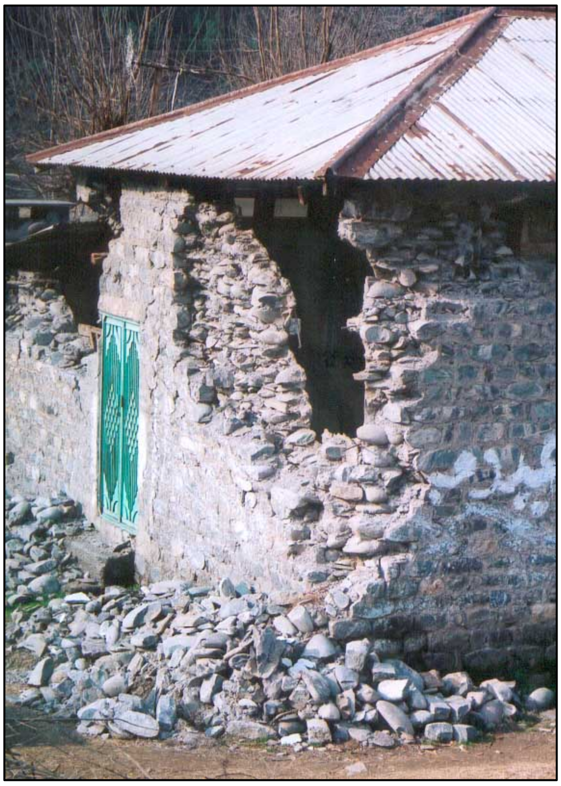
In order to make really lightweight constructions, lightweight building materials, such as cement plastered high density Expanded Polystyrene (EPS), should be introduced. However, such a lightweight and voluminous building material needs to be imported from towns being two to three days drive away. In addition, these systems require major finances as compared to the use of traditional materials.

One of the main issues in earthquake-resistant designs is to keep the weight of the floors low because during an earthquake these cause a massive horizontal force to the top of the walls and columns.

The Kashmir earthquake of 23 October 2005 painfully demonstrated that traditional stone constructions are very vulnerable for earthquake damage. In addition, more than 90% of the reinforced concrete buildings which collapsed were non-engineered and realised in a very deficient manner, including faulty reinforcement design.

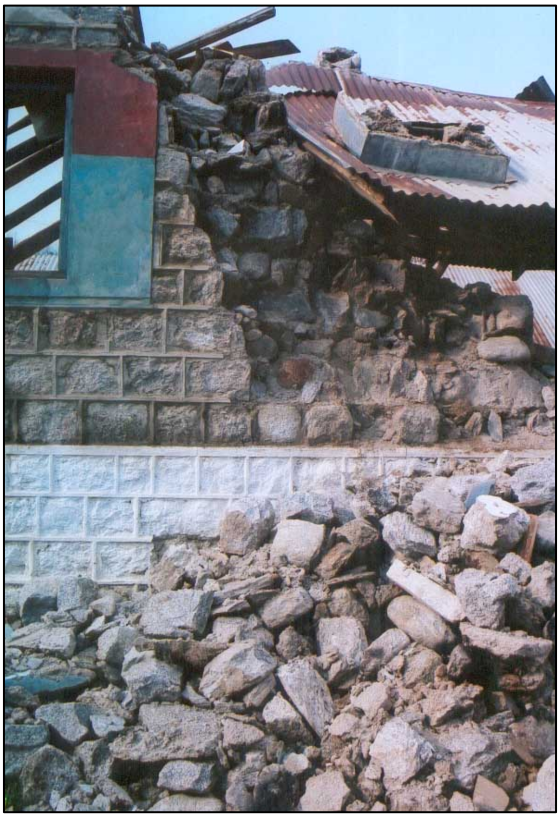
Dressed Stone

Semi-dressed stones are slightly tailored to fit the wall width, but have no binding between the inner and outer faces of the wall. Many through-stones are needed in these walls, as well as horizontal stress reinforcement. The house in the photo right did not totally collapse because of its very light GI roof construction.



Cut-face stones are used in government buildings (police posts and schools). With cut-face stone the outside face looks straight; their appearance is nice appearance, but they have no internal bonding and fall apart in an earthquake. **Galvanised Wire-mesh Reinforcement** provides essential reinforcement, connecting the inner face with the outer face of stone walls and providing lengthwise reinforcement.

Heavy stone walls should be internally reinforced and framed with reinforced concrete columns, foundation, window sill, lintel and roof plate beams, all linked together.



Reinforced Concrete

The picture below illustrates some of the typical problems in non-engineered reinforced concrete construction: the connection between the column and floor construction fails.

The following issues can be mentioned:

- The concrete floor constructions were heavy and very stiff.
- Large and stiff floor beams makes the top and bottom of the columns the weakest areas in the construction. With the failure of the column, the building collapses.
- Insufficient stirrups exist in the column footing and top areas where maximum moments develop. These areas are the first to fail and without adequate caging of the broken concrete with sufficient stirrups, the column falls over when not supported by shear walls.

By reducing the weight (mass) of the walls, the building and earthquake loads need to be carried by the columns. The manner in which the internal cage reinforcement in the extremes of the columns is realised will determine whether the structure stands or fails. Caging and slow failure may provide valuable time for occupants to vacate the building.

The building on the right is a good example of a reinforced concrete construction with sill and lintel tie beams. When the walls in a construction are not load bearing, these can be made of lightweight material such as Expanded Polystyrene (EPS) and plastered with cement mortar, or from fibre-cement panels with insulation. The plaster is fixed to the wall by means of a wire mesh, inside and outside.

With insulated fibre-cement panels or EPS walls, the overall construction will be much lighter and have a very high thermal insulation. When buildings are entirely built by institutions and all materials are brought into the region, plastered EPS or fibre-cement infill walls are less expensive than stone masonry.

HEAVY CONCRETE FLOORS AND FAULTY DESIGN OF TOP AND BOTTOM
COLUMN REINFORCEMENT CAUSE COLLAPSE

Lightweight Construction of Floors and Roofs

The forces of an earthquake are directly related to the weight of the construction. Some schools had reinforced concrete floors and beams spanning 16 ft. (5 m) between two classrooms measuring 16 ft. x 20 ft.). The beams were 3 ft. high and more than 1 ft. wide. The weight of such a beam by itself is 1000 kg/m or nearly 5000 kg. The classroom roof of the two classrooms was more than 6" thick, including the finishing. With a surface of 16 ft. x 40 ft., the total weight of the roof would be 24,000 kg. These values do not yet consider the live load.

The BACIP-designed central roof beams can span 5 meters and have an own weigh of only 50 kg/m. Four of such beams are necessary to carry the BACIP floor. With a floor construction of only 4 cm thick concrete-cement, the own weight of the 16 ft. x 40 ft. floor is 5300 kg. Together with the four beams, this is less than 6000 kg or ¼ of the concrete roof mentioned above.

Several observations can be made here that influence the choice of design and materials.

- Earthquake forces are considerably larger with heavy reinforced concrete, thus requiring more reinforcement and again adding more weight.
- Without adequate quality control of reinforcement positioning, amount of cement, aggregate and water, and proper curing, the reinforced concrete constructions will become very dangerous death-traps once copied by the villagers. This is the main reason why so many reinforced concrete buildings fail in an earthquake.
- Reinforced concrete constructions have high thermal conductivity and for high altitude schools cause cold rooms in the winter and misery for the students.
- When massive earthquakes occur, it is always the reinforced concrete buildings that cause the greatest damage and highest death tolls. These buildings are also very difficult to repair.
- For high mountain villages where the season for working with cement and concrete is very short, it is time-wise not a good material.
- In mountain locations having no road access or easy access to sand and aggregate, concrete becomes very expensive in terms of transport costs.

For the above reasons, the traditional reinforced concrete construction designs are uneconomical for high altitudes. For lower altitudes with road access, close supervision must be guaranteed to make safe reinforced concrete constructions.

SLENDER COLUMNS WITH LARGE SPAN COMPOSITE BEAMS
THESE 3.5” x 3.5” COLUMS CAUSE MINIMAL VISUAL OBSTRUCTION
THE TABLE-HEIGHT CONCRETE COLUMN REDUCES THE BUCKLE LENGTH

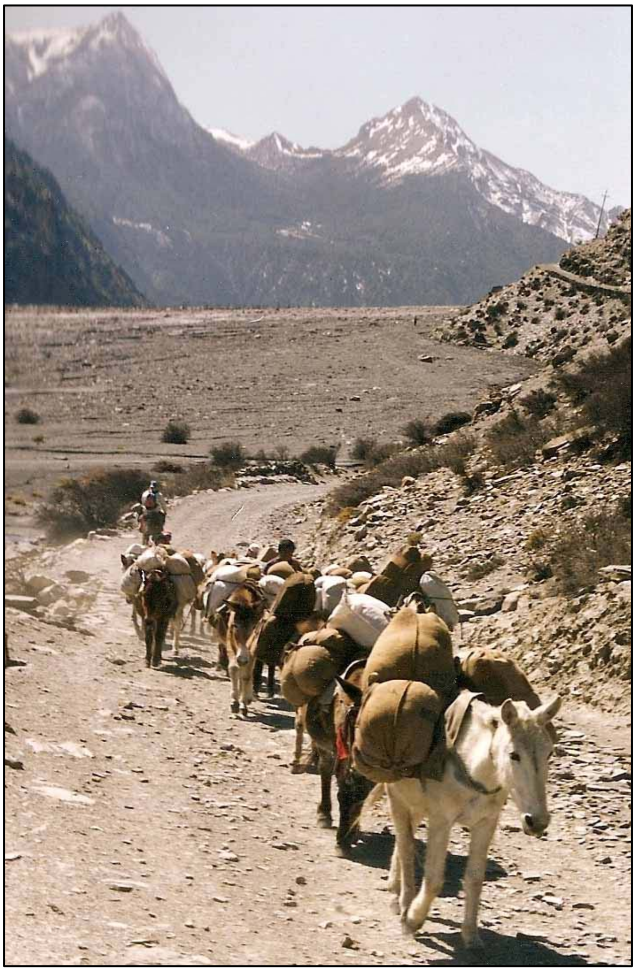
Construction can be kept light by reducing the free span of the floor or roof construction. Although the desire exists to have large open spaces for classrooms, there is no need for such large spaces. The issue in the classrooms is that the students have a free line of vision to a central point (when the teacher stands in front of the classroom). This can be perfectly achieved in a **short span construction** and **slender columns** that do not obstruct the view. A wide school board is important.

Slender Columns

The organisation of the classroom was designed with a **short span construction** to reduce the high cost of long spans needed to carry large loads. The intermediate columns should not obstruct the view for the students. This was achieved by having columns with very slender (but strong) midsections at eye level of the students. The intermediate columns have a reinforced concrete base column up to table height. The middle section of the columns is made from a heavy gauge 2" water pipe (carrying capacity 1 ton) or welded 2" x 2" steel angle irons, thus providing only minimum visual obstruction.

Mule Transport

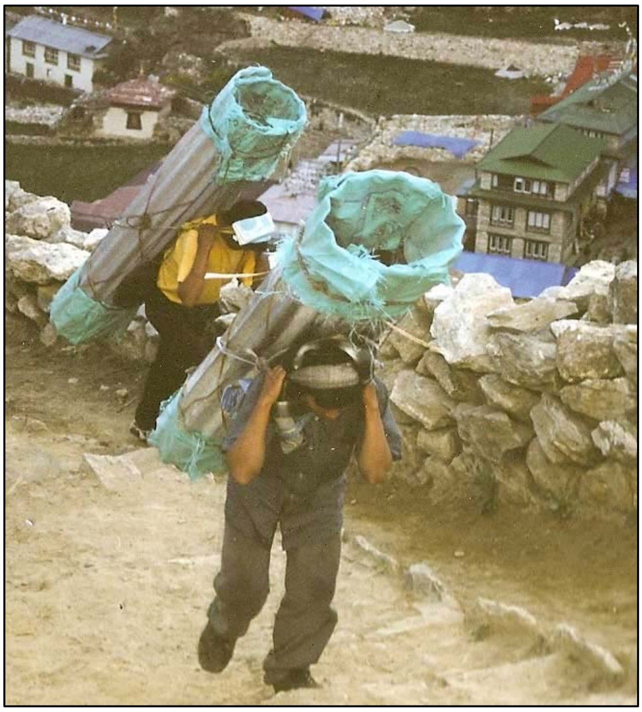
Although it may be possible to manufacture a large support beam to span the entire width of a hall (see photo page 27), for remote areas this will be impossible to transport. Hence the intermediate column is an economic solution.



In remote mountain areas, mules carry roughly 50 kg each and elements no larger than 10 ft. or wider than 3-4 ft. Prefabricated building elements should therefore be within these dimensions. Heavy elements can be combined with lightweight thermal insulation material (EPS or PE foam).

GI Roof Sheet Construction

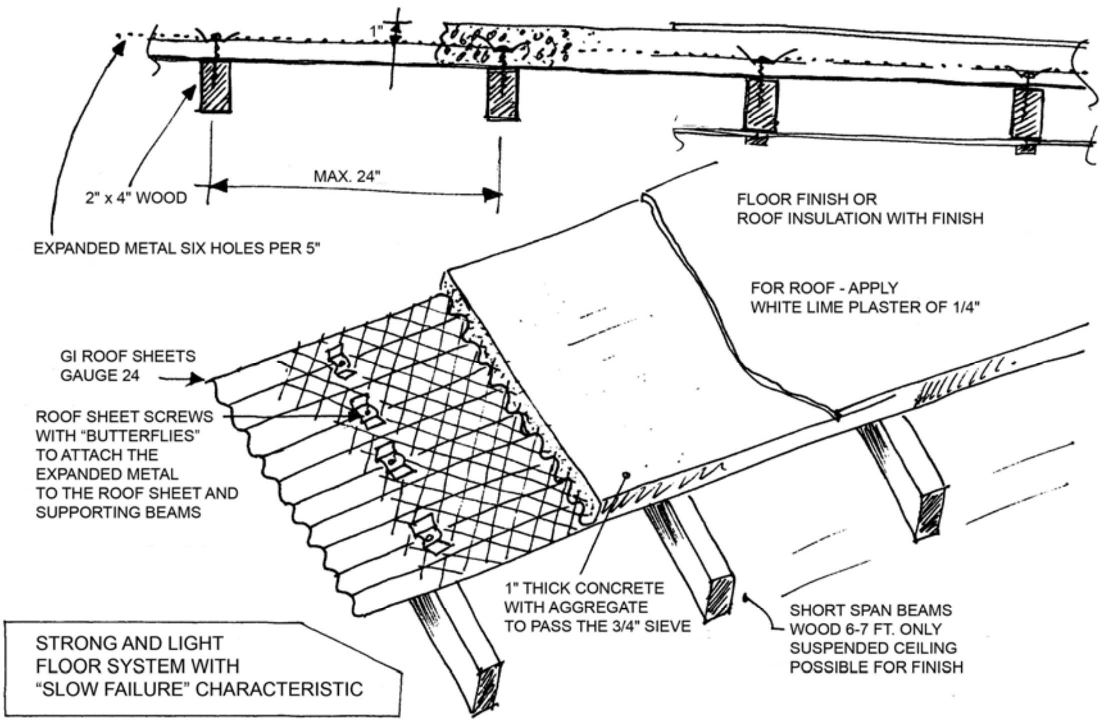
Two intermediate columns divide the span into three causing only **one-ninth** of the moment for the dead and live load, thus allowing a lighter beam. The lightweight floor construction is **one-third** the weight of a 5" concrete floor. The combined effect of span and weight is that the construction requires less than **one-fifteenth** of the strength of a full span traditional concrete floor; also reducing considerably materials and labour, and increasing safety.



Intermediate columns exist in the traditional house design, dividing the 24-ft. span of the main living area into nine sections of 8 ft. square. This 8 ft. corresponds to the length of sheet metal and plywood.

House construction in the Northern Areas does not always have a regular plan. The floor/roof spans are of a variety of dimensions that sometimes changes during the construction period. The floor system in two of the remote mountain schools is made of 0.7 mm GI sheet (gauge 24). This can be rolled up for manual transport (photo).

The GI roof sheet is fitted with an expanded wire-mesh having butterfly-shaped washers and nailed into all the support beams to enhance the bonding between the concrete and the GI sheet. The light wooden support beams are placed centre-to-centre of 2 ft. with a section of 2" x 4" and a span over the 8 ft. length. The larger wooden support beams that carry the entire roof load are placed over the intermediate steel columns. The GI sheet will less easily corrode with condensation.



The GI sheets can be cut to size at the building site with a pair of large sheet scissors and no formwork is required for casting the concrete. A suspended ceiling can be attached onto the wooden supports. This flooring system can be made as a floor diaphragm to hold the wall construction together. It also has a "slow failure characteristic".

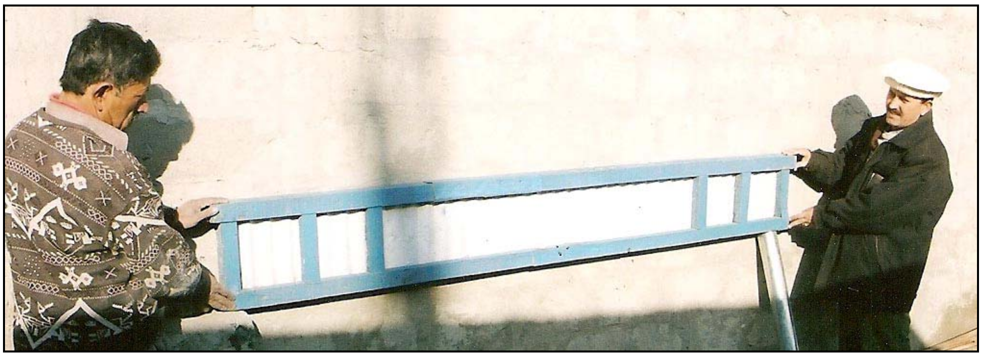
TESTING OF A THIN, LIGHTWEIGHT STRONG FLOOR FOR SHORT SPAN CONSTRUCTIONS

Composite Floor and Roof Beams

Three types of composite floor beams have been designed for the above schools; two for the lightweight roof construction and one special design for the 9 ft. + 28 ft. + 9 ft. span of the Al Azar examination hall[7]. The 1.2 mm GI sheet timber connectors have been made with sufficient galvanised nails to transmit the maximum stress the wood section can support from one plank to the next in the stress zones. Standard designs can be made for short beams having a construction length of 12 times their height.

ESPECIALLY DESIGNED LONG SPAN COMPOSITE BEAMS FOR THE AL AZAR EXAMINATION HALL

If adequate quality control cannot be realised, the builder should use pre-manufactured galvanised steel frames that are assembled at the building site from short components.

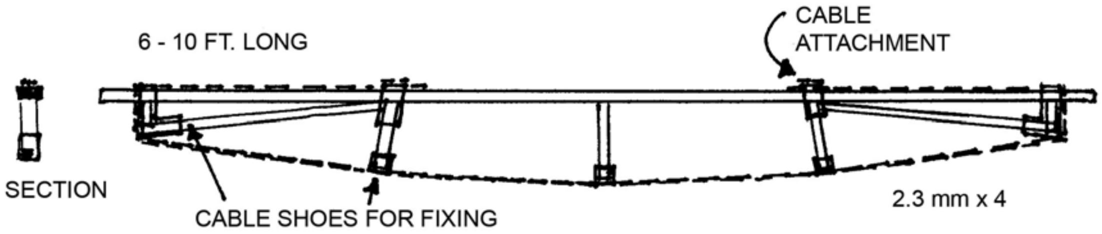


PRE-FABRICATED COMPOSITE BEAM

[7] Spans larger than 16 ft. (4.80 m) should be calculated and designed per case. Pre-manufactured beams should have a maximum load indication.

Bowstring Beams

In order to reduce as much as possible the use of timber in the roof construction, the 8-ft. bowstring beam has been developed having a carrying strength of 1000 kgf. Comparing this with a solid wooden beam, less than one-fifth of the amount of wood is necessary to obtain the same bearing strength. Four times 2.3 mm galvanised wire cables take the stress force and are securely anchored with nailed GI sheets on the upper side. The lower side of the bowstring beam can be used to fit a suspended ceiling under the cables, thus creating an air cushion of thermal insulation under the roof. The height to length ratio of this beam is 1:10.



THE BOWSTRING BEAM FOLLOWS THE DESIGN OF BRIDGES IN THE NORTHERN AREAS

BOWSTRING BRIDGE

COMPOSITE SUPPORT BEAMS WITH BOWSTRING BEAM
REALISATION OF INSULATION AND SUSPENDED CEILING UNDER GI ROOF

CHAPTER 5 THERMAL INSULATION

Wall Insulation

All inside faces of the exterior walls of the BACIP-designed school buildings have improved thermal insulation properties as compared to old buildings. BACIP has designed several wall insulation construction methods for (stable) existing and new walls. Wall and roof insulation should increase in correlation with the altitude of the building location. The following thermal insulation thicknesses are recommended minimums for Himalayan areas:

Minimum Winter Temperature	Approximate Altitude	Recommended Thickness of Insulation Layer	Heat Resistance of the Insulation R_c in m^2K/W
0 degrees C.	4000 ft. (1200 m)	2” (5 cm)	$R_c = 1.3$
-5 degrees C.	5000 ft. (1500 m)	3” (7.5 cm)	$R_c = 2.0$
-10 degrees C.	6000 ft. (1800 m)	4” (10 cm)	$R_c = 2.6$
-15 degrees C.	7000 ft. (2100 m)	5” (12.5 cm)	$R_c = 3.3$
Colder than -15 degrees C.	8000 ft. (2400 m)	6” (15 cm)	$R_c = 3.9$

When buildings are exposed to strong winds and have little sun exposure (in the shade of mountains), additional insulation is needed. Temperature buffer zones, such as storerooms, closed corridors and vestibules, will also provide additional insulation.

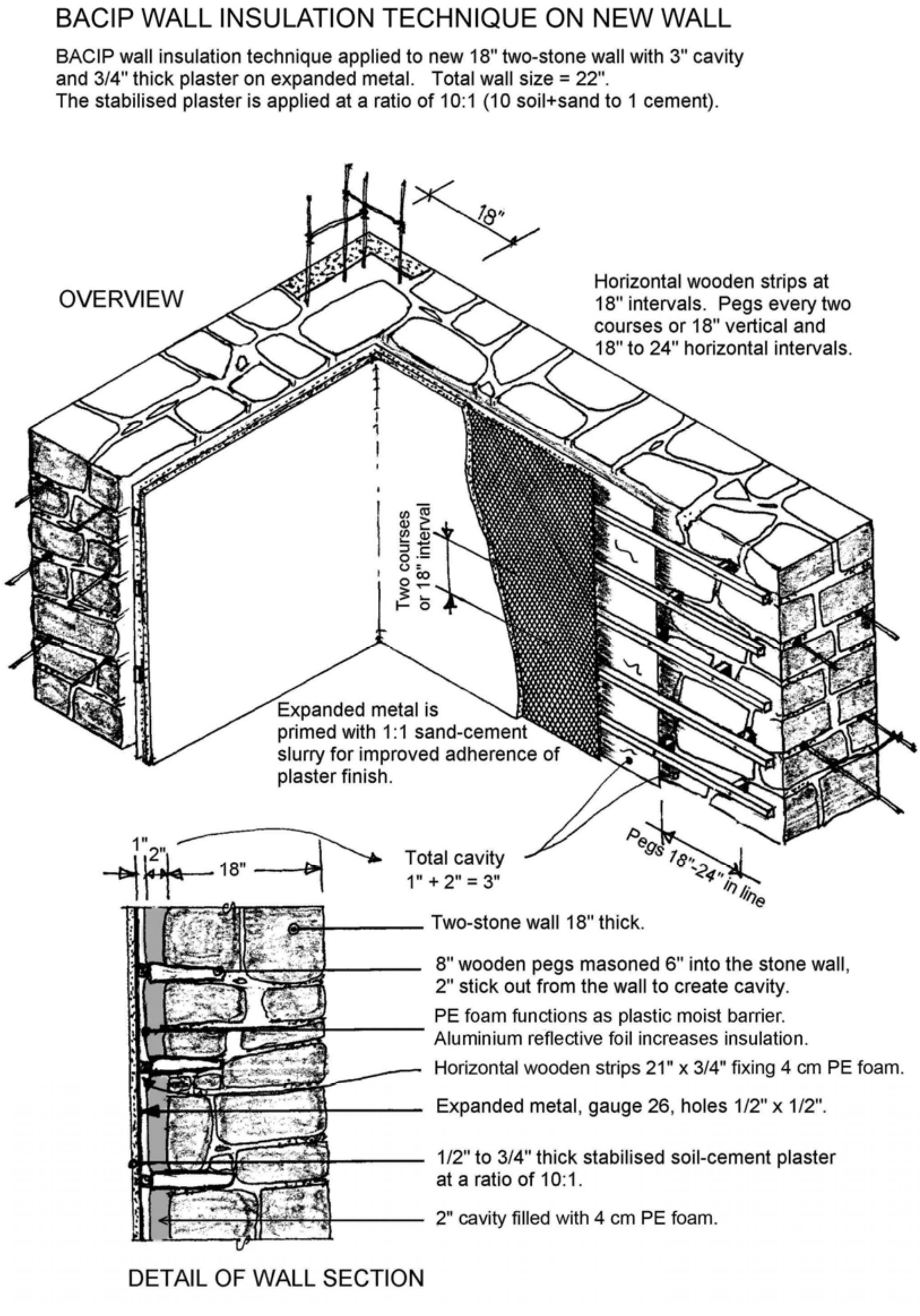
When heat is produced inside a building, the thermal insulation should be fitted on the inside of the walls; otherwise the walls need to be heated first, absorbing a lot of heat energy. On the other hand, heated interior walls of heavy material will stabilize the room temperature. Classrooms, being only heated for a short period, require the thermal insulation on the inside of the exterior walls.

Any material having a lightweight cellular air-containing structure can be used for wall insulation. The insulation value is determined by its thermal resistance value λ in W/mK multiplied by its thickness in meters. From very good insulation material ($\lambda = 0.04$) to good insulation material ($\lambda = 0.1$) are: polystyrene (EPS), sheep wool, glass wool or stone wool blankets, PE foam sheets, air bubble plastic foil, empty clean plastic containers in PP bags, timber shavings or straw or sawdust in PVC bags. Stone, concrete, cement and cement block masonry do not insulate at all as they are thermal conductors.

CLEAN PLASTIC WASTE CONTAINERS IN BAGS IS EXCELLENT THERMAL INSULATION MATERIAL

The thermal insulation can be substantially improved with heat reflective foil, such as aluminium-coated PVC, placed with the reflective side towards the internal cavity and the warm side. The same reflective foil can be used under GI roofs that become very hot in the summer sun.

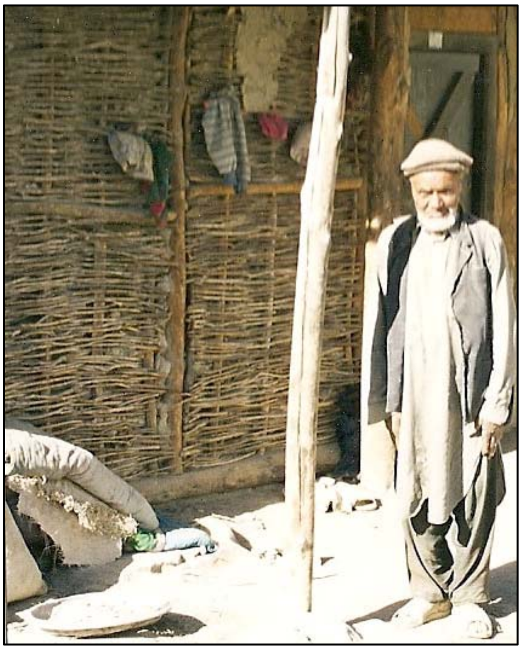
All cavities wider than 2 cm need to be filled with air-containing insulation material to reduce internal air circulation. One design is illustrated below using expanded metal to fix a layer of plasterwork. The same system can be used with a finishing of fibre-cement panels (or plywood).



Thermal insulation of the walls requires that: (1) the vertical airflow in the cavity is stopped by closing the space along the horizontal supports with strips of timber or plastic, (2) filling the cavity with an insulator (PE foam, EPS, straw in bags, etc.). The edible material (for cattle) should be removed from the straw, (3) when the insulation materials is thicker, the insulation will improve, (4) a moist barrier (plastic foil) should be on the warm side of the insulation.

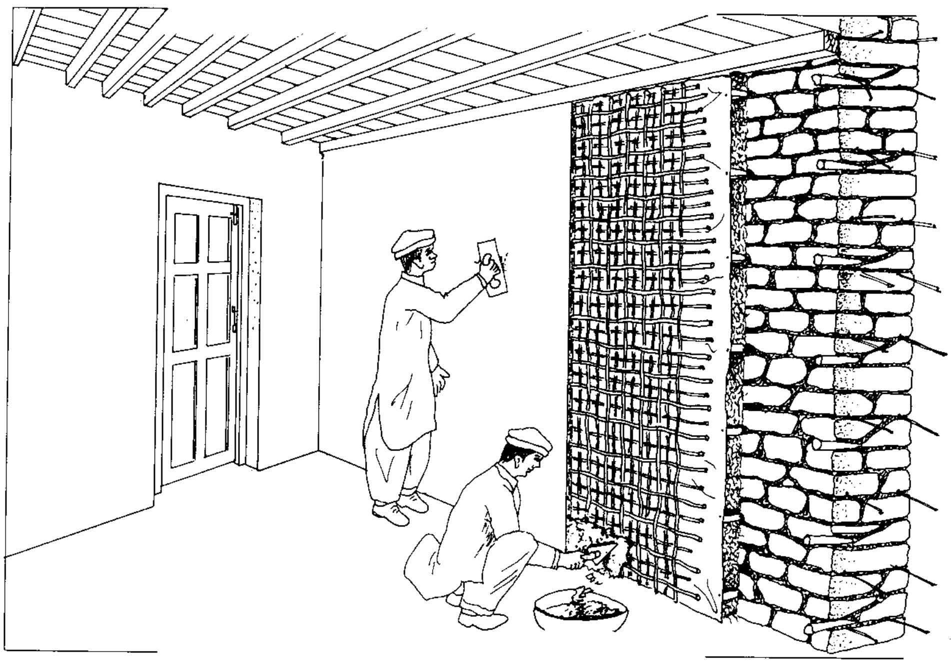
A full wall covering of (reflective) plastic foil on the warm side of the wall construction has an important function. It will reduce humidity passing from the inside of the classroom or house into the cold outside stone wall; thus avoiding condensation inside the colder wall structure. When moisture in a stone or cement block wall freezes, the ice will destroy the structure. In addition, a wet cement block wall has a further reduced insulation value.

For plastered walls, the plastic foil will assist in the curing of the fresh plasterwork. When PE foam (having a closed cellular structure) is used, the plastic is not necessary. For all other porous insulation materials, even smaller plastic bags filled with insulation material, the foil is essential as it acts as a moisture barrier. A reflective aluminium-coated PVC foil with the reflective side towards the warm side will further improve the thermal insulation value of the wall. Some PE foam comes with reflective aluminium foil on one side.



Different plasters have different costs and maintenance requirements. In houses, soil-lime plasters can be used. For the classrooms, a 1/2" to 3/4" cement plaster has been used. To avoid easy damage at the lower section of the walls, the expanded metal wire-mesh and plaster have been doubled up to a height of three feet. At the level of the school tables and the backs of the chairs, a plank has been fitted into the plaster.

WHEN THE WATTLE WALL IS USED INSIDE AND PLASTERED WITH SOIL-LIME, IT WILL BE A DURABLE CONSTRUCTION WITH AN EXCELLENT PRESENTATION

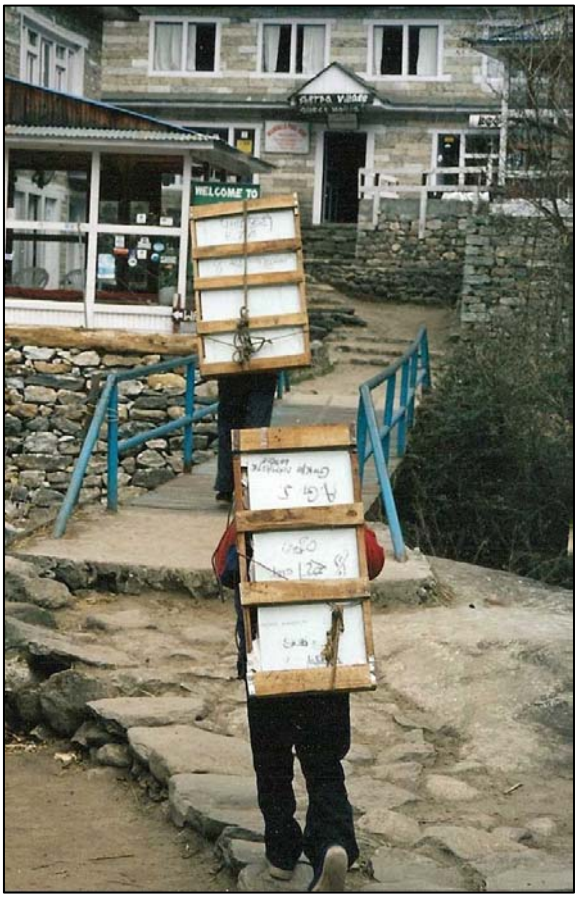


FINISHING WATTLE WALL PANELS WITH SOIL-LIME OR SOIL-CEMENT PLASTER

Double Windows

Solar heat intake of the morning sunlight from the southeast requires large, clean windows. A number of conditions determine the design of the windows:

- ♦ The glass surface should allow a good amount of direct sunlight into the school classrooms and be well distributed over the room. Position of the windows should be high over the entire width.
- ♦ Large windows will cool off the building during non-sun hours, unless they are double glass.
- ♦ The distance between the glass sheets needs to be minimum ½" and maximum 1".
- ♦ For maximum sunlight intake, clean single glass is more effective than double glass because every glass sheet will reduce the amount of light by 5-10%. The inside window should be opened during sun hours for solar heating and closed as soon as the sun is gone to provide insulation.
- ♦ For optimum sun intake, the glass sheets must be regularly cleaned. Therefore, easy access to both sides of each glass sheet is essential, without the need of taking the window apart.
- ♦ Burglar bars should not block the sun, but, if required, should then be placed inside.
- ♦ It is not necessary for all the glass frames to open for ventilation. Some external sheets can stay permanently fixed in the window frame.
- ♦ For the glass frames that can be opened, summer fly screens are recommended. These will keep the classroom cool in the summer because they block the sun.
- ♦ For glass windows not facing the morning sun for heat intake during the winter, wire-mesh protection (against breakage) or fly screens can be fixed permanently.
- ♦ Large glass sheets are vulnerable to breakage, costly to replace and difficult to transport. Therefore, glass sheets larger than 36" x 20" are not recommended for remote areas (photo below).
- ♦ Stone throwing, cricket or other ball sports must be prohibited in the vicinity of the windows.
- ♦ The use of GI sheet covered wooden shutters will provide added insulation and protection at night. In addition, the shutters on the eastern side can function as sun shades during the summer.



Windows should preferably open inwards. Windows opening to the outside will be vulnerable to sudden strong thermal winds which can easily smash them when not very well secured against the wall. For second storeys, securing the windows on the outside wall is difficult.

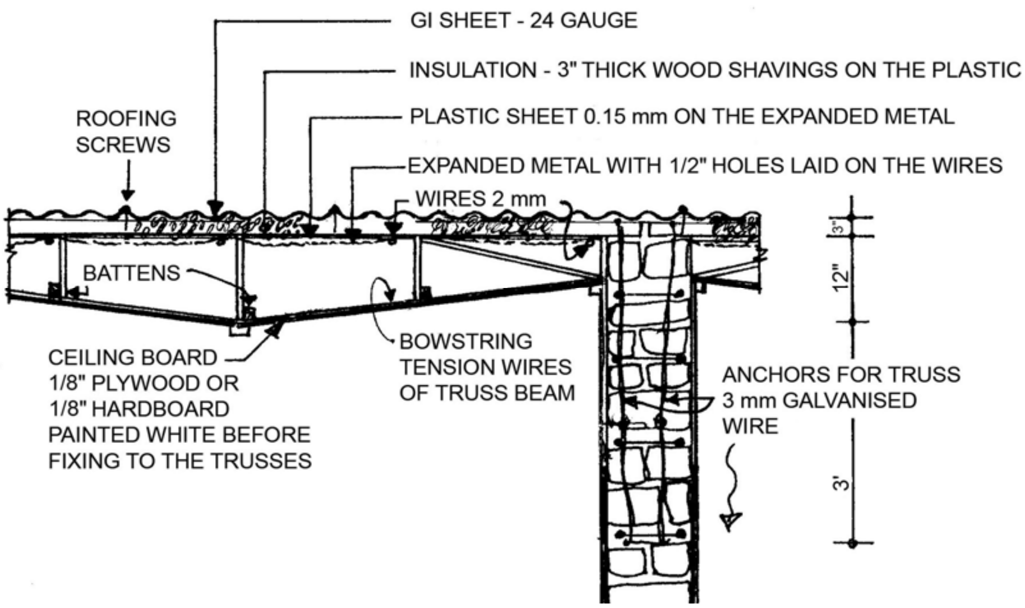
SUN WINDOWS CAN BE IMPROVED UPON WITH SMALLER FRAMES, CLEAN GLASS AND AVOIDING BURGLAR BARS AS THEY OBSTRUCT THE SUN

Roof Insulation

Two types of roofs have been used for the schools:

- Lightweight GI sheet roofs having a 1.5" cement/concrete topping. These roofs can be converted into floors for a future second storey. External insulation on these GI floors is essential; otherwise condensation will occur on the inside, eventually causing corrosion of the sheets.
- Traditional corrugated GI roof sheets. Thermal insulation is applied on the inside to avoid heat loss in the winter and reduce heat radiation during the summer. For more effective blocking of heat radiation, aluminium-coated PVC can be used under the GI sheets.

Both types of roofs are waterproof, but without thermal insulation, will conduct heat at a very high rate, negatively affecting the internal climate during both summer and winter.



DETAIL OF ROOF INSULATION UNDER GI SHEETS (SEE PHOTO PAGE 31)

Existing GI Roofs

GI roof sheets are very hot in the summer and very cold in the winter, passing all heat radiation to the other side. In summer these sheets function like a solar heat collector, creating oven-like temperatures below. BACIP has designed an effective low-cost roof insulation for GI roofs that can be applied to existing or new roof constructions. If the insulation technique is applied to an existing roof, the installation is done from the top by first removing the existing roof sheets and replacing them again after the insulation has been applied; only a number of new roofing nails or screws may be necessary.

The following steps are realised to refit existing GI roofs with thermal insulation:

1. Under the wooden roof rafters, a galvanised wire is stretched over the shortest distance between the rafters making a square pattern. The distance between the support wires and the future GI sheets should be at least the height of the rafters, being 5" or more. The attachment is realised by winding the wires around the rafters.
2. A fine expanded metal mesh (1 cm holes) is placed on top of the wires. The expanded metal is attached and nailed to all sides so animals, such as mice, cannot go through the mesh.
3. A plastic foil (0.15 mm, recycled) is placed on the expanded metal. The foil will reduce the humidity transmission and condensation of humidity on the GI sheets in the winter. The foil will also reduce possible dust from the insulation material, depending on the choice of insulation material.

4. Thermal insulation material in plastic bags, such as loose straw stalks, wood shavings, empty plastic bottles or other insulation material, is placed on top of the plastic foil (3-8" thick depending on the climate zone).
5. To enhance heat reflection, an aluminium-coated plastic foil can be placed over the insulation (shiny side up).
6. The GI roof sheets are (re)placed making sure the wind cannot blow the filling out from the borders of the roof.
7. A suspended ceiling of 1/8" plywood or hardboard is fixed at a short distance under the expanded metal ceiling. It is recommended to paint the panels before applying the plywood or board to the ceiling,

CEILING WITH INSULATION MATERIAL
BEFORE FIXING THE SUSPENDED CEILING

GI Concrete Roofs

GI concrete and cemented roofs are strongly affected by sun radiation in the summer. The temperature of these roofs will become very high, causing expansion to the sides and downward heat radiation. These roofs need to be double insulated – a dense (pressure resistant) insulation layer on the outside to reduce the thermal effect of the sun on the cement roof and a layer on the inside for additional room insulation. The dense exterior insulation needs to be pressure resistant and will add weight to the construction.

The following solutions are recommended by BACIP for GI concrete and cemented roofs:

- Over the cement roof, compact a moist 1" layer of straw and soil mix (1:1 volume) to create a precise slope for draining the water (slope 1:50 = 2 cm/m^1).
- Place a plastic foil (0.15 mm) and a topping of lime stabilised soil of another inch. The amount of lime water is 1/3 the volume of the soil. The concentration of lime-water is 40 kg dry lime per barrel of 200 litre water. This roof cover is suitable for walking on with bare feet.
- A suspended ceiling should be created under the roof.
- The insulating topping should be removed if the roof is converted to a floor for a second storey.

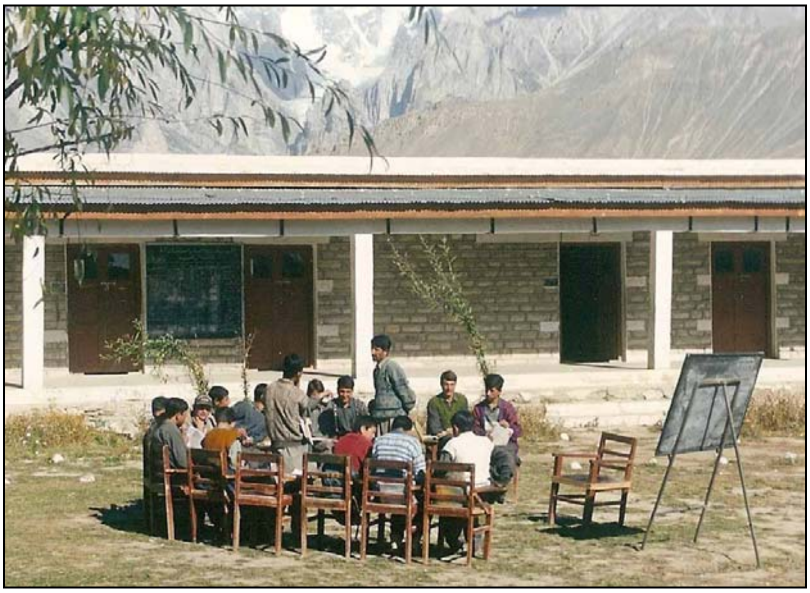
APPLYING WATERPROOFING AND PROTECTION OVER AN INSULATION LAYER

CHAPTER 6 SCHOOL FURNITURE

The school furniture found in existing classrooms was either non-existing (sitting on the floor) or of very poor quality. Often three to four students were sitting on a wooden plank at a long table, also being only a narrow plank and providing minimal space for writing. The current classroom furniture does not allow for a variety of classroom arrangements. The quality of the furniture and the type of joinery applied causes many of the individual chairs to fail at the rear seat connection. Schools are facing high recurrent expenditures for repairing furniture. If sitting on the floor is required, floor mats and PE floor insulation is necessary.

PILED-UP BROKEN FURNITURE IN THE BACK OF A CLASSROOM

The design of strong and durable classroom furniture that can be easily carried in and out of the classroom is useful. Currently, outside spaces are only being used because inside the school building it is either too cold or too hot.



CONCRETE SCHOOL BUILDINGS ARE INSIDE TOO COLD DURING THE WINTER

Rather than wooden planks for sitting and writing, desks with chairs are recommended for improved educational facilities. The furniture design is based on one desk seating two students with individual chairs. Use of the furniture should be flexible and allow for various arrangements to suit a variety of settings, for example group work.

The height of the furniture should be adapted to the body height of the students. BACIP proposes four different table heights and four accompanying chair heights.

For student groups, chair and table dimensions nearest to their corresponding standing height should be chosen. The chair and table height is a fixed percentage (fraction) of the standing height. This means that in one school several heights of furniture should be used. It was observed in several schools, especially in the lowest grades, that small children were sitting with their chin at the level of the writing planks, obviously furniture made for adults.

Standing Height of Students – Boys and Girls Heights Differ Slightly at the Same Age	General Age Groups Related to Standing Heights	Recommended Table Heights = 0.42 Standing Height	Recommended Seating Heights of Students = 0.25 Standing Height
160 cm to 180 cm 5 ft. 3 in. to 5 ft. 11 in.	14 years and older For highest class and secondary schools	Height: 72 cm With table size for two students: 120 cm x 60 cm	44 cm, 8 cm planks seating width 37 cm
140 cm to 155 cm 4 ft. 7 in. to 5 ft. 1 in.	10 - 12 years old Most common chair and table for primary schools	Height: 62 cm With table size for two students: 120 cm x 60 cm	38 cm, 7 cm planks seating width 35 cm
120 cm to 135 cm 3 ft. 11 in. to 4 ft. 5 in.	6 - 8 years old For the first years	Height: 54 cm With table size for two students: 100 cm x 50 cm	32 cm, 6 cm planks seating width 33 cm
105 cm to 115 cm 3 ft. 5 in. to 3 ft. 9 in.	Younger than 6 years For pre-school age	Height: 46 cm With table size for two students: 100 cm x 50 cm	28 cm, 5 cm planks seating width 31 cm

The pine timber of the chairs is 8 cm wide for the highest chairs, 7 cm for the lower type and 6 cm for the small chair. For the smallest pre-school chair, the timber width is taken at 5 cm only, thickness 2 cm. The dimension can be reduced for better timber qualities.

Chairs

The BACIP wooden chair is made of straight planks and is fitted together with synthetic glue and galvanised wood screws[8]. The design is very strong in comparison with locally made furniture, yet light and very easy to copy and manufacture locally.

A simple wooden design for the chair was adopted (see photo below and on page 39). Another design uses 2 x 2 cm square metal tubes in combination with a wooden seat. These designs have demonstrated their strength and low cost. However, the wooden chair cannot economically compete with the low-cost lightweight plastic stackable chairs now commonly available.

The particular features of the design are as follows:

- It is very strong and can be manufactured locally.
- The design has been made in such a way to allow machine production of components.
- Assembling aids need to be made, such as jigs and manuals.
- An assembly board guaranties the correct shape.

If it is not possible to manufacture the chairs locally, the set of planks (with pre-drilled holes) can be purchased as a pre-manufactured package, together with the glue, screws, assembly board and screwdriver. The villagers can then assemble the chairs themselves. This will greatly reduce transportation costs and avoid damage during transport.

THE BACIP CHAIR IS VERY STRONG - BEING TRIANGULAR, GLUED AND SCREWED TOGETHER

[8] In a few cases, the glue was not applied, greatly affecting the strength and image of the quality.

Tables

The BACIP table is of an equally simple design, being a combination of a 2 x 2 cm steel frame and a loose tabletop (made with Formica on MDF[9]). With the tabletops and steel leg frames fitting into each other and forming a flat package, transportation costs are kept to a minimum. An additional advantage of the detached unit is that the tables can be easily stored away when not needed, allowing the classroom to be used for other purposes.

The metal legs of the tables and chairs should have a wider foot to avoid floor damage.

School Board

The basic classroom layout is almost square to allow minimum distance to the school board. One side of the classroom should have a large window surface for maximum light intake, preferably on the left side of the classroom as most students are right-handed. In cold climates, the large window must be oriented towards the morning sun to allow solar heat intake during the winter months when the sun stands at a low angle with the horizon.

The school boards consist of a plastered surface over the whole width of the classroom. The school board plaster is a very fine mix of sand (passing sieve No. 50 = 0.4 mm, retaining on sieve No. 100 = 0.2 mm), white cement and either green or black pigmentation.

To create possibilities for hanging posters or displaying works from the students, a wooden strip can be fitted onto the classroom wall at a height of 6 ft.

THE AL AZAR EXAMINATION HALL INCLUDED SEVERAL COMPONENTS EXPLAINED IN THIS REPORT:
SOLAR WINDOWS, THERMAL WALL AND ROOF INSULATION, COMPOSITE AND BOWSTRING BEAMS

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[9] MDF = Medium Density Fibre board of 10 mm. This material is less vulnerable to humidity than chip wood board.