IMPROVING THERMAL COMFORT BY PASSIVE THERMAL DESIGN:

A STUDY OF THE EFFECTIVENESS AND PRACTICAL APPLICATION OF A RANGE OF STRATEGIES IN PRIMARY SCHOOLS IN PAKISTAN

by
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CONTENTS

Mary Hancock arranged the work in the study and the monitoring was carried out by Mary Hancock, Gul Najam Jamy and Saleem Akthar.
Mary Hancock, Gul Najam Jamy and Mr Masoot carried out project management. Mary Hancock has written the report in consultation with Fergus Nicol.

Cover shows Behari Colony School before modifications in August 1996; the picture on page 3 is of the same school at the end of the project.

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Behari Colony School, October 1998. The school microclimate was much modified in the two years from the beginning of the project. Delegates from the 'Passive Thermal Design for Improved Thermal Comfort in Low Cost Buildings' workshop held in Peshawar toured the modified schools on the second day of the workshop.

EXECUTIVE SUMMARY

Interventions to improve thermal comfort were made and monitored in five existing schools in Peshawar, North West Frontier Province, Pakistan.

The school year starts around the 7 September and finishes in early June. Schools are hot at the beginning and end of the school year. During the months of May, June and September typical classroom temperatures are around 31^{0}C.

Winter conditions are relatively cold and during the winter months of November, December, January and February classroom temperatures average less than 13^{0}C

The project concentrated on ways of improving summer classroom temperatures because this was the problem of most concern to the teachers.

In all the classrooms summer temperatures were reduced. The reductions in summer temperature, averaged for the school day, varied between about 0.8K and 3.5K. The cost of the interventions varied between almost no cost (the microclimatic improvements) and about £200 for the more major building operation of installing of external insulation.
It would be possible to achieve larger improvements in comfort temperatures in new build schools. The best temperature improvements were in classrooms that were built with a favourable orientation (that is south and north facing long window walls.)

The intervention that gave the best improvement in temperature was an awning used to shade the roof of a school. Insulating the roofs, internally or externally was not as effective as the over-roof, because the insulation reduced the heat losses at night.

Best results were obtained through close co-operation with the teachers and children in the schools.

Teaching takes place outdoors in both summer and winter because conditions are often more comfortable outside. Provision of an external space particularly arranged for teaching was a successful strategy. Awnings were provided that shaded both the roof and the external teaching areas. This very successful intervention facilitated a dramatic change to the local microclimate and provided shaded external teaching areas. The provision of the awning created good conditions both for the children and for the planting. Trees were quickly established and by the end of the project were contributing significantly to the shading of the building. (see picture on preceding page)

A conference was held jointly with IUCN-SPCS Unit in October 1998 to disseminate the results. The workshop was well supported by more than forty professionals involved in the production of buildings, both architects and engineers, assembled from the length of Pakistan, Karachi to Gilgit. A group was formed of the enthusiastic delegates to share information and experience in ways of improving building performance at low cost. ENERCON publish a quarterly magazine and it is arranged that occasional articles on building performance will be included.

Chapter 1 Background to the study

A number of considerations underlie this study.

1.1 Traditional buildings in Peshawar are better designed for the Pakistani climate than the modern buildings that are replacing them.

In 1992 a team from the Oxford School of Architecture visited Pakistan in order to develop a project to record the historic buildings of Peshawar. Many of these were being demolished in the rush to put up ‘modern building’. However in pulling down the old buildings the sophisticated tradition of passive thermal strategies, exhibited in buildings such as the eighteenth century 'Sethi Houses' (Qasilbash, 1992)[i1], is being ignored and forgotten in the design of their replacements. This trend is exacerbated by the rapid increase in the use of electric air-conditioning, which purports to provide comfortable conditions no matter how unsuitable the building is for its climate. Electric air conditioning is used to make climatically unsuitable buildings comfortable, at considerable energy and CO_2 cost.

In both summer and winter using devices such as careful orientation to manage or control the solar gain through the windows can greatly increase the proportion of the year that a building is comfortable, without active servicing such as heating or air conditioning. This comfort is provided at no cost, in terms of rupees, energy and carbon dioxide emissions. (CO_2)

1.2 Traditional buildings use less electricity and produce less CO_2

In hot summer conditions poor climatic design of buildings significantly increases their cooling load, the amount of electricity they use and the CO_2 production associated with that electricity use. At a time when Governments party to the Rio Agreement are pressing for the reduction of CO_2 emissions around the world, the increased use of good passive design of buildings is an effective way of reducing these emissions in any country. Energy use in buildings accounts for about 50% of the electrical energy used in Pakistan[2] (in commercial buildings mostly being used for lighting and air conditioning) so there is very good potential for reducing both energy use and CO_2 if passive design techniques are exploited

Passive design techniques are design strategies that help to make the building more comfortable without using fossil energy, for example sun shading devices. Their use in heavily serviced buildings could result in potentially large energy savings and also reduce or postpone the demand for air conditioning in many other buildings (xxx, 1999). [3]

[1] The Sethi Houses, MSc thesis document, Peshawar University, Mrs Rubina Qasilbash
[2] The Potential of Electricity Conservation in the Industrial and Commercial Sector in Pakistan, ENERCON, 1986
[3] Report to DFID Project 3493

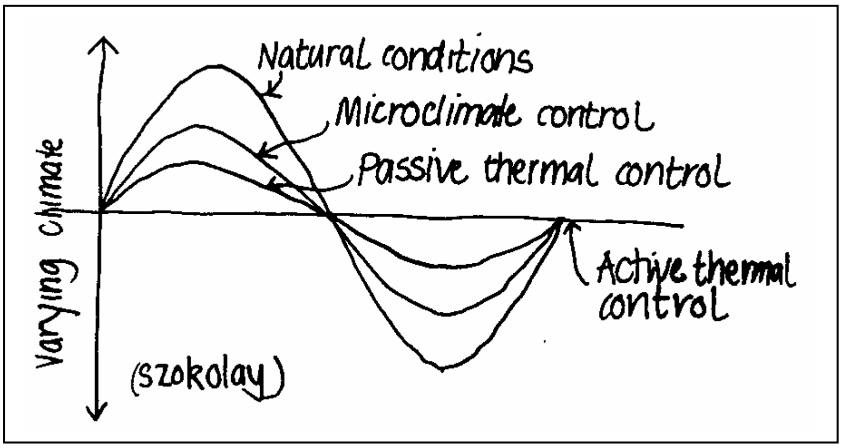

Figure 1 Relationship between climate and passive thermal design, diagram from S Szokolay's 'Building Science for Architects and Builders[4]'.

Figure 1 illustrates the possible reductions in indoor temperature swings that can be achieved by optimum use of climatic and passive opportunities. For example, if a building is well situated microclimatically, further improvements in the comfort of the building could be achieved by making the best use of passive strategies. It will not be possible to achieve precise control of the building indoor climate using passive strategies but it is possible to modify the internal climate so that it has less extremes of temperature and is closer to a comfortable indoor temperature. Yvonne Dean has demonstrated that a seasonal variation in the internal climate is actually good for the health of the occupants of the building.[5] If the best use is made of microclimatic (like the age old strategy of cooling the incoming air for the building by drawing it over a lake or stretch of water included in buildings like the Taj Mahal) and passive strategies (like shading the windows from the sun) the indoor temperature can be more comfortable in a passive building and in a serviced building energy use substantially reduced.

It is acknowledged that the use of good passive strategies can result in large energy savings and increase thermal comfort. Recognising this in a time of concern about Global warming,[6] Oxford School of Architecture started a study of the traditional buildings of the region[7] which led to their work on the potential for the use of historic buildings in Pakistan as bases for the development of eco-tourism in the region

1.3 In hot conditions people increasingly consider more cooling represents more comfort.

In addition there is a tendency for people to associate lower temperatures with increased comfort at hot times of year: a result of the widespread adoption of mechanical cooling and air-conditioning (A/C) systems around the world. The use of A/C has tended to drive down anticipated, or acceptable, internal temperatures in summer time. In order to investigate those temperatures that were found to be comfortable in traditional buildings in the five different climatic zones of Pakistan a study was carried out between 1993 and 1996 on

[4] Szokolay,S (1980) Environmental Science Handbook for Architects and Builders.
[5] University of North London, Yvonne Dean
[6] IPPC report on Global warming, 1992
[7] Roaf et al 1994

'Thermal Comfort ' [8](Nicol et al.1996). This study demonstrated that a range of different temperatures was considered comfortable by local populations adapted to local climatic conditions.

The study also established a link between the temperature a person finds comfortable inside a building and the external climatic conditions that prevailed immediately previously. The authors demonstrate from information collected in the surveys that people in hotter climates are comfortable in hotter conditions than those who live in temperate climates. This link established in Nicol's study between internal and external temperatures and comfort has widened the perceived comfort zone considerably. Strategies such as natural ventilation and shading from solar radiation which were previously discarded in the quest for closely controlled temperatures (as prescribed by the widely used International Comfort Standards such as Ashrae[9] and ISO 7730)[10] can now be resurrected and considered viable.

1.4 Global Warming will make buildings more uncomfortable in Pakistan

Because the Pakistani climate is very hot in summer, buildings tend to produce internal temperatures close to or exceeding the upper limit of comfort. This problem will be exacerbated by any rises in temperature due to global warming. Climate models indicate that Pakistan will be particularly badly affected by Global Warming (IPCC 1992). Global Warming appears to be already observable in the climatic cycle in Pakistan. During the period of the study (1996-1999) mean temperaturesfrom the previous fifteen years, issued by the Pakistan Meteorological Office, have been exceeded each summer. Relatively modest increases in temperature can make the difference between comfort and discomfort [11] at this upper threshold. The application of passive strategies can help to break out from this vicious circle of increasing temperature fuelling increasing need for air conditioning (Roaf et al, 1998) which in turn helps create more climate change.

1.5 The exorbitant price of electricity in Pakistan

Within this background of the Oxford involvement in Pakistan over the 1990s there is the further important issue, the availability and cost of electricity in Pakistan. In the first half of the 1990s the situation was characterised by peak electricity loads exceeding generation capacity, typically on very hot afternoons and evenings when everyone with an air conditioning unit had it running. Costs were then high per kWhr unit. As a result of the various power generation plant contracts handed out by the Bhutto government in the mid-1990s which fixed export amounts and prices, and the fall in value of the Pakistani rupee in relation to the US dollar, the price of delivered energy in Pakistan has increased sharply. Now the costs of electricity to keep a home comfortable cool in summer often exceeds the income of a typical middle class family. This situation has produced a chronic condition of fuel poverty in the summer when none but the rich can afford to keep cool. (September

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[8] Fergus Nicol et al (1994) A survey of thermal comfort in Pakistan towards new indoor temperature standards Oxford Brookes University
[9] Ashrae (1992) Ashrae standards 55- 92 Thermal Environmental Conditions for Human OccupancyComfort Standards American Society of Heating, Refrigerating and Air-conditioning Engineers, Atlanta
[10] ISO (1984) International Standard 7730 Moderate thermal Environments: Determination of pmv and ppd Indices and Specification of the Conditions for Thermal Comfort.International Organisation for Standardisation, Geneva
[11] Roaf, Haves et al , PLEA Conference Proceedings 1998

1999, electricity costs around 4 rupees per unit at a time when the cheapest labouring man is paid about 100 rupees per day for his work. Comparing labouring rates this might be about the same as electricity costing nearly one pound per unit in England). Optimising the passive potential of the building itself and so reducing the mechanical cooling load of the building, as was successfully practised in traditional buildings of Pakistan, seems a practical step towards improving comfort in low cost buildings.

1.6 Brown-outs and black-outs on summer afternoons.

Despite the increased availability of power generally in Pakistan the infra-structure of the National Grid is very poor in places and control systems on the grid undeveloped. At periods of peak electricity use, in particular, the grid often causes brown or black-outs that make the use of air-conditioners impossible. Thus even if a building owner can afford to pay for their A/C electricity it may not be available at peak times. For the thermal environment of all buildings it is therefore judicious to employ passive cooling strategies in the hot summer climate of Pakistan.

1.7 Seasonal variations in climate

At the hottest time of year it is difficult to achieve comfortable conditions in buildings if there is no air conditioning. However this period is relatively short (it only just touches the beginning and end of the school year in Peshawar) and at other times of year comfortable conditions can be achieved in buildings designed to take advantage of passive strategies. Good application of passive strategies can reduce the demands for air conditioning and shorten the number of weeks that it needs to be used.

1.8 Winter Conditions.

Although there is a preoccupation with overheating in summer conditions, a major problem in the unheated Government schools is the cold in the winter. Passive techniques, such as sealing the building and orientating the windows for winter solar gains, could make a considerable improvement in winter comfort.

Chapter 2. Rationale for the Primary Schools Project.

2.1 The need for better climatic design of schools

Pakistan has a wide ranging programme for the building of new rural primary schools funded by a number of bodies including the Pakistan Government[12]. Many new schools in Pakistan appear to be designed with little attention given to simple passive design measures that could significantly improve the internal working conditions and comfort of these buildings, and enhance the educational experience of children in the schools. Primary schools are usually free running (i.e. using no services to make the building warmer or cooler) so improvements in building performance have the direct result of improved comfort for the building occupants.

In winter the climate in much of NWFP is relatively cold (January average daily minimum over 30 years is 3.7^0C, with an average daily temperature of 9.8^0C[13], compares with Kew, England at 2.3^0C and 4.2^0C[14] respectively) and as the Government of Pakistan do not provide heating in the school buildings, passive solar heating of schools could potentially make the buildings warmer on the cold sunny days of winter so increasing the comfort and work rate of the students.

2.2 The knock-on advantages of designing for comfortable conditions in Primary Schools.

Low standards of achievement in Government Primary Schools are a source of concern in Pakistan. This problem can be attributed to a range of factors primarily associated with poverty, a developing management system and the non attendance of teachers and pupils at schools. However the poor environmental conditions common in schools cannot encourage students to attend nor yet help their concentration.

2.3 Inappropriate design advice available for school building

The existing Pakistan Energy Code and the Related Design Manual[15] have very little application in Pakistan because the building standards and the constructional methods proposed by the American authors have little bearing on the reality of building schools in Pakistan today. ENERCON, the Energy Conservation organisation of the Pakistan Government has informally asked Oxford Brookes University to carry out investigatory work on strategies that would increase thermal comfort and reduce energy use, in relation to school design in particular, as a basis to a revised building code.

[12] Aga Khan and Janus both have School building programmes
[13] A review of DES-2 Weather data for six locations in Pakistan, ENERCON report by Akbari, Huang and Ritschard.
[14] Energy in Architecture, The European Passive Solar Handbook, edited by Goulding, Owen Lewis and Steemers
[15] Design Manual for Energy -Efficient Buildings in Pakistan, prepared by ENERCON in conjunction with RCG/Hagler, Bailly, Inc.

2.4 The opportunity for replicability in the application of solutions

Many schools are under construction at this time in Pakistan. Both the World Bank and the Aga Khan Foundation have substantial school building projects so reliable information on effective passive strategies cheap enough to be incorporated in school design could have wide application and enormous impact on conditions in schools. Many Government Primary Schools are built to a model design.(see Appendix 2) It has been agreed with ENERCON that proven improvements in design and detailing (within the limits of the Schools budget) should be incorporated in the Model School information.

2.5 Passive solutions can be low cost.

The use of passive thermal techniques provide an opportunity to create more comfortable internal conditions for building occupants. Some passive strategies cost more in capital costs but make savings over time. Not all passive strategies have a cost implication (building orientation or planting for example) and some actually reduce capital costs[16].by reducing servicing requirements. The opportunity for reducing building costs in the Government Schools is not available as they have almost no servicing cost but, even close to the budget cost, significant improvements can be made in comfort and thus productivity.

2.6 Previous studies are inadequate to provide answers on how to improve the passive design of school buildings in Pakistan

No studies are available that document both the effectiveness and the practical problems of installing a range of passive strategies. Studies have investigated the theoretical improvements by experimental rigs and building simulation[17]

The weaknesses of design advice dependant only on theory and simulation are associated with

- Most simulations are designed to predict energy savings and other factors which are not relevant to Pakistan's situation.
- Simulation tools do not always give reliable design advice.
  Reason can be (a) lack of familiarity of the modeller with the tool, or
  (b) errors built into the model that become noticeable when it is used in a way not expected by the developer of the tool, for example metabolic heat gains from people even when the temperature exceeds skin temperature: probably the developer was not expecting room temperatures in the mid 30's
  (c) small errors in design or operation of tool; when BRE developed 'Energy Designer' it was tested against a large number of similar buildings in similar climate; this level of testing is not possible with more general models.
- Dependence on meteorological office data which is recorded at airports and in open spaces which contrast with the situation of most buildings studied in this project. Measured solar radiation data is not widely available and in any event any climate data is difficult to obtain because of military security at the airports though Iftikhiar Raja's

[16] Elizabeth Fry Building, University of East Anglia, Energy Efficiency Best Practice programme, NPFR 106, BRECSU, Garston, Watford

[17] Albert Malama and Steve Sharpels. (1996) Thermal and Economic Implications of Passive Cooling Strategies in Low Cost Housing in Tropical Upland Climates Architectural Science review, 39 p95

book [18]provides a good source of solar data (sunshine hours and solar radiation) for Pakistan, based on measured data available from six locations. Accurate ventilation information is particularly difficult to obtain; averaged data can conceal wind direction changes in an unhelpful way

- The lack of validated thermal performance data of building materials to program the computer simulations. Equipment for testing thermal performance is not available in Pakistan and so data used in simulation has to be data for similar materials in other countries.
- Building practices in Pakistan and the lack of written education of many builders mean that it is difficult to convince builders of the value of new building practices. The building industry in rural areas is not keen on innovation and therefore the practical investigation of viability and problems at a small scale is particularly important.

The dearth of studies on the subject has stimulated the current research.

2.7 The technology now exists to do such studies, based on building monitoring.

[18] Iftikhar Raja (1996) Solar Energy Resources of Pakistan, pub Oxford Brookes University,

The development of very small automated monitoring devices, such as Tiny Talk loggers[19], has made a detailed investigation of the performance of a building and any modifications

[19] Tiny Talk loggers marketed by Gemini Loggers (UK) ltd, Scientific House, Terminus Road, Chichester, West Sussex.PO19 2UJ Loggers make up to 3600 readings between

very much easier and less intrusive than ever previously possible. Previously in the era of cruder recording systems with hand held devices such a study would have been tedious and time consuming.

Chapter 3 Aims of the study

3.1 To quantify the thermal, comfort, and cost impacts as well as the practical problems in implementing a range of passive design strategies in rural Schools of NWFP, Pakistan.

3.2 To ensure that the builders and building users can understand and effectively operate and include passive systems in the schools. Often passive strategies fail to work as the designer intended. A detailed post- completion examination of innovative strategies shows that in many buildings the effectiveness of design strategies is diminished due to a lack of occupant understanding of the system.[20]

3.3 To produce recommendations that can become part of a design code for new rural school buildings in Pakistan. The strengths and weaknesses of each recommendation will be thoroughly examined to establish practicality.

3.4 To provide a simple methodology for the prediction of building performance in Pakistan that can be repeated in future building, modelling or auditing projects. For instance there is no testing station for the thermal performance of building materials in Pakistan and so assumptions made about material performance are based on figures for similar materials in Europe or America.

3.5 To increase the use of passive design strategies in Pakistan.

[20] Passive Solar Design Netley Abbey Primary School Energy Efficiency Best Practice Programme, GIL 32, available from BRECSU, Garston, Watford, UK

Chapter 4 Method of investigation of school design

4.1 The initial 1994 study

The methodology used in this study developed from a short study funded by the British Council in Summer 1994 and carried out by Oliver Sykes and Mary Hancock. It was reported at the ENERCON Passive design workshop in Islamabad October 1994. Three schools and three basic health units were visited in both Peshawar and Karachi. The Health units in Peshawar were at Nahqi, Warsak Road and Kohat Road and the schools were St Mary's College, and Naqi GBSS. The Health Centres in Karachi were three in the Orangi district in the Aligarh Colony. The schools were two well designed Nasra schools that demonstrated a range of passive strategies including a very thick 'cupboard wall' to the west, and two schools with corrugated roofs in Orangi, Malik Jamal High School and Faran High School.

Teachers and health workers were asked to identify unsatisfactory rooms; these were examined and an effort made to identify any common features. The classrooms that were described as unsatisfactory shared the features:

- rooms with east or west facing windows
- rooms situated immediately under the roof (particularly when the roof was made of corrugated iron)
- rooms without cross ventilation

4.2 Key design issues

From this early study it was apparent that there are a number of key factors in the design of schools that significantly influence comfort in classrooms.

These included: Orientation and shading
Ventilation
Construction
Microclimate around the building.

4.3 Collecting information about the performance of the school, both as existing and as modified

It was decided to investigate these key factors in relation to school design at typical rural schools with a view to informing school design to produce better schools in the future.

Information would be collected in the schools:

- As built
- After low cost interventions designed to improve the climate in the classrooms

Originally it was intended that passive design improvements be included at the design stage in a new school. At that time a wider range of options is presented, particularly orientation. The uncertainties of the Government building programme led us to reconsider this and to plan refurbishment of selected schools. Containing the research in refurbishment has the advantage that we have been able to identify the exact cost of any strategy and to control the programme. Modifications to a range of classrooms in the same school might have been desirable but this was not possible because most of the schools are small, usually with two classrooms. Also because of the general shortage of money available for school improvements in Pakistan, it was thought more fair to share the available money round a number of schools. This strategy, though not part of the thermal strategy, has been effective and the interest and involvement has improved the schools in the programme far beyond the money spent.

Our strategy of monitoring the schools before and after refurbishment enabled us to evaluate the relative effectiveness of a range of different design interventions on the internal climate of the schools.

4.4 Choice of schools

Criteria for selecting schools for refurbishment were:

(a) reasonably well maintained school buildings,
(b) committed and enthusiastic teaching staff,
(c) an established school with evidence that pupils were in regular attendance and
(d) geographic region, because we wanted to chose schools in each of the three education regions of Peshawar.

Schools chosen in August 1996 were:

Behari Colony GBP (Government Boys Primary) School, Peshawar
Sarband GBP School, Peshawar
Sheikh Kali GGP (Government Girls Primary) School, Charsadda
Mohib Banda GBP School, Nowsherra.
Jogiyan GBP School, Nowsherra

Later, in April 1998, when we stopped monitoring at Sheikh Kali GGPS (see notes about removal of insulating bowls) we added Sarband GGPS to the schools.
Monitoring started at the end of August 1996 and continued, more or less continuously, see notes, until June 1998. (See appendix 7, Table of monitored data files)

4.5 Collecting data about the buildings

4.5.1 Understanding the performance of the building.
The effectiveness of the building as a climate modifier can be established by collecting data. Presumptions about building performance can be confirmed or challenged and an accurate picture of the building performance developed. This careful investigation of performance can inform current design and measure, in temperature terms at any rate, the effectiveness of different strategies intended to improve the internal environment.

4.5.2 Monitoring air temperature

The primary goal of the investigation into the effectiveness of passive thermal techniques is to optimise the comfort experienced by the building occupants. It was decided that monitoring dry bulb temperature in the classroom would give a reasonable indication of comfort conditions as temperature is the principal physical variable in the predominantly hot dry climate. Air temperature is also more easily measured and is the most significant indicator of comfort.

Other variables are

- air movement: difficult to measure continuously, and in this range of schools which are very still in hot summer conditions (see plot of air movement at the schools, appendix 1) not very informative. Efforts were made to increase air movement through the schools in the refurbishment strategies and this air movement was measured with kata thermometers[21] and the direction traced with helium filled balloons[22]. Fresh air ventilation is important in heavily occupied buildings such as schools where the air tends to become saturated with the moisture both from sweating (the only physiological cooling available when temperatures in the classroom exceed skin temperatures) and exhaled air. Air movement increases comfort in hot conditions and can be induced with a ceiling fan in any of the schools that have electricity.
- Radiant surface temperature:
- Relative humidity:

4.5.3 Optimising the building performance.

It was presumed that the building occupants, mainly the teachers, would arrange the building functions to optimise the comfort conditions inside the building. No attempt was made to direct the use of the buildings or modifications, except when particular effects were measured for example removing the awning at night.

[21] A kata thermometer measures the cooling of the air; the cooling time between two fixed points on the thermometer and the local air temperature can be used to calculate the rate of air movement - see Basic Principles of Ventilation and Heating, Chapter 3, Thomas Bedford, pub Lewis, 1964

[22] Helium filled balloons were weighted with paper clips to reach a situation of equilibrium balance. These were released and their pattern of movement filmed.

Chapter 5 Programme of field work

Four periods of field work were carried out in the progress of this study: A workshop to disseminate the information gained was held in October 1998 in Peshawar.

5.1 23 August -2 September 1996. - Project instigation
5.2 31st December 1996- January 1997 - second field trip
5.3 15th May 1997 - 22nd June 1997 Monitoring reporting by Saleem Akhtar.
5.4 28th March - 7th April 1998 - Final School modifications
5.5 23rd October- 31st October 1998- Workshop field trip

An outline of the main activities and decisions of each field trip is included here; detailed field trip diaries are included in the Appendix.

5.1 Project instigation 23 August -2 September 1996.

5.1.1 IUCN/ Oxford Brookes/ Primary Education Directorate Collaboration
During the last two weeks of August 1996 Mary Hancock travelled to Peshawar. Our contact in Peshawar, Gul Najam Jamy of IUCN (The World Conservation Union), was involved with the Primary Education Directorate in the NWFP in a proposal to build some environmentally friendly schools. Information was needed on good practice and the Brookes project could provide funding and practical information about the effectiveness of a range of strategies.

5.1.2 Choosing the schools
Through Gul Najam Jamy, introductions were arranged to the Directorate of Primary Education in Peshawar and meetings held with Mr Fazil-I-Manan, Deputy director, Primary Education Project. Site visits to prospective schools were arranged by Mr Manan. Ten schools were visited, five in Peshawar, and three in Charsadda and two in Nowsherra. See schedule on facing page. Five schools were chosen based on the information acquired from our visits. It can be seen that the reasons for rejecting schools were inaccessibility (2 schools) lack of pupils (2 schools) and unstable situation between village and school because of absent teachers and building in poor state of repair.(1 school) Teaching is not a high status job in Pakistan; like many Government officers they are poorly paid but have good job security. In Pakistan teachers are interviewed for, and appointed to a district and not to a school. Some teachers therefore find themselves drafted to schools 20 or 30 miles from their homes, often with poor public transport links. This situation is particularly difficult for women teachers as it is not considered suitable for women to travel alone in village areas. The best schools have teachers from close by, for example Mohib Banda and Behari Colony.

3.1.3 Starting the monitoring.
Having chosen the schools, return visits were made in the following days to measure buildings, daylighting and ventilation rates, and to set up loggers in the class rooms Monitoring started immediately in five schools, recording classroom temperature at 1 metre from finished floor level and at ceiling height. See appendix for information on each school daylight, ventilation and building plans and constructional details.

3.1.4 Memorandum of understanding between Oxford Brookes and Department of Education to agree access to schools.

Subsequent to the first field trip a memorandum of understanding was set up. Oxford Brookes was investing a considerable amount of time and money in the schools project so it was thought desirable to protect our interest. A legal arrangement was made to define the respective fields of responsibility- the Department of Education to allow us access throughout the project and Oxford Brookes to return the school to its unmodified condition if required at the end of the project. This provided the security of a legal framework though work has been carried out with good will on both sides.

Figure 2 Schedule of Schools visited (see following page)

Schedule of Site visits to Schools Sunday 25th August 1996 (before term started) accompanied by Mr Zar Khan, Deputy District Education officer, Mr Mian Nisar Khan, Assistant district Educa officer and Mr Niaz Habib, Assistant sub- division Education Officer and Mrs Zubaida Khalid of IUCN				
	People present	Pupils in school	Strengths	Weaknesses
School number 1 Behari Colony GBPS	Teaching staff Chokidar	233	Keen teachers, reasonable standard of repair, problem with heat and lack of shade,	No water, no latrines, classrooms filled with stored furniture.
School number 2 Peshawar GBPS NO 5 Hayatabad	2 teachers	110 apparently expected	New building	Building work scarcely complete.
School number 3 Peshawar GBPS no 2 Sarband	Chokidar	200	Well maintained buildings, vine giving shade, latrines, running water, keen chokidar	Teachers not present
School number 4 Peshawar GBPS Pista Khar Payan	Chokidar and village elders	Not known	Not known	Absent teachers, building in poor repair Angry representations from village nearly descend to a fight
Monday 26th August 1996 (before term started) accompanied by Mrs Farzana Baqir, Charsadda District Education Officer, and Gul Najam Jamy				
School number 5 Charsadda, GGPS Sheikh Kali	Chokidar, Head teacher	250	Teacher concerned about problems of overheating, reasonable standard of repair, evidence of planting on site no trees.	South facing classroom has floor that is damp and uneven.
School number 6 Naqi, Charsadda, GGPS	Head teacher	Pupils not yet enrolled	New building, large school of five classrooms	Not yet any pupils, very distant from Peshawar on poor road.
School number 7 Naqi, Charsadda,GGPS	Head teacher and chokidar.	200	Good condition	Very distant from Peshawar on poor road.
Monday 26th August evening visit accompanied by Gul Najam Jamy, Mrs Zubaida Khalid, Mr David Abbott (WWF) (World Wild life Fund) and Mr Nasir Sahybzada, Education Oddicer, WWF.				
School number 8 Mohib Banda GBPS	Three teachers, village representative	240 boys	Teachers enthusiasic, buildings in resonable condition, village keenly involved in school.	Hot rooms with no air movement, no water, no electricity, no latrines,
School number 9 Mohib Banda GGPS	Several women teachers, Chokidar, Lupus project rep.	450 girls	Building well maintained The village involvement with the 'Lupus' project had made local people interested in participation.	Two room school much too small so village is campaigning for bigger school.
Wednesday 28 August 1996 (before term started), informal visit organised by Mr Shams, IUCN driver who was keen that his children's school be included.				
Jogiyan GBPS	Village teachers, parent (Shams, driver for IUCN)	280 boys	School in very good condition With cross ventilation, security screens on windows	Not typical model school plan. Windows face east and west

5.2 - Second field trip 31st December 1996- January 1997

5.2.1 Purpose of field trip

Design work for the schools had been resolved and some simulation carried out in the months between the two field trips. The main purpose of the second trip was

- to download the loggers for a second time (in November Gul Najam Jamy had made the first downloading.)
- to discuss the refurbishment proposals with Gul Najam Jamy and the schools,
- to locate suitable materials and workmen to carry out the modifications to the schools.
- To agree prices for the work

5.2.2 Synopsis of field trip activities

Visits were made to all the schools and the loggers downloaded for the second time. There were continuing problems with some of the loggers. Work progressed on the refurbishment details. The Forestry District office was enlisted to arrange planting for the schools, hopefully to be achieved on National Plantation Day, 7/8 February 1997

5.2.3 Visit to Missionary Schools and Aitchson College, Lahore.

I returned home via Lahore and the Bishop of Lahore, Sammy Azariah's, Schools project to advise on passive building strategies for Missionary Schools being developed in Lahore, undertaken by Felicity Hill working for VSO (Voluntary Service Overseas).

5.2.4 Progress with tenders for building work

Subsequent to the field trip, reduced prices by local tradesmen were received for the enclosing wall at Behari, and the terrazzo floor at Sheikh Kali. These pieces of work, and the placing of the clay pots on the roof were executed by local workmen, supervised by Gul Najam Jamy. The awning at Behari School was fixed in place. However certain jobs did not progress. The window replacement work and the roof insulating at Mohib Banda, and the airconditioning tiles at Sarband were not installed. Jamy was promoted in IUCN and the Environmental school project was abandoned due to lack of funding. The political situation was difficult with Government elections and ongoing disruption from the Taleban.

5.2.5 Work schedule for the five schools- see facing page.

Figure 3 Work Schedule as agreed on second field trip (see following page)

ODA / OBU / IUCN NWFP, Pakistan Schools project 23rd January 1997

School	Maintenance	Ventilation	Construction	Planting
GGPS Sheikh Kali, Charsadda. (classroom with south facing windows)	Reglaze windows Provide new insulated concrete floor. (Builder to allow for reducing doors and rehanging) Provide decorating materials		clay pot insulation laid on existing roof	Two or three deciduous trees in yard to provide shade (jacorenda, simel, sheshum), protected with steel tree guards. Located in agreement with teachers but preferably centrally to provide useful shade in the future.
GBPS Mohib Banda, Nowshera (three classrooms in line)	Refurbish windows to rooms 1 and 3 (i.e. reglaze and replace ironmongery) Provide paint for decoration. Upgrade neighbours wall facing south windows to improve reflected light i.e. paint white.	Fit steel security shutters to refurbished windows in classrooms 1 & 3 middle room - Supply and fix six new timber windows with security shutters and fly screens (four as replacements to existing windows, two new windows with lintels on north side, including forming structural opening, to provide cross ventilation	West classroom (room 1) - insulate roof internally. (2” low density polystyrene (thermopore)to be glued to underside of slab) East classroom (room 3) - insulate roof externally (existing concrete slab covered with sheet damp proof membrane with 2” high density, 30 kg/cu m, polystyrene placed on top, held down by a layer of bricks.)	
GBPS Behari Colony Peshawar (classroom with north facing windows)	Reglazing north facing windows Arrange alternative storage of school furniture (?) Provide decorating materials.	Provide two extract fans on south elevation to achieve night ventilation. Fans to be sized to achieve 20 ach from each fan with switching arranged to allow time delay and use of one or two fans. Provide new steel framed fly screens to windows on north elevation (four windows)	Provide brick security wall, 6 ft high Provide latrines (environmental budget) Supply and fix metal hooks on existing roof and on security wall to hold awning to cover both roof (to limit direct solar gains) and yard area (to shade children)	one dozen trees to provide future shade.(tree types mixture of simel (salmalia malabarica), Bakan (melia azacarach) and shisham (dalbergia silsio), to be provided after construction of wall. Trees in vulnerable positions to be protected with steel tree guards. Should we include provision for watering?

School	Maintenance	Ventilation	Construction	Planting
GBPS Sarband Classroom with east facing windows Classroom with north facing windows		Adjustable insulated shutters to east facing windows to reduce problems of sunlight and improve security, see detail, four windows, one pair of shutters to each window.	Provide proprietary ‘air conditioned roof’ to north facing classroom.	
GBPS Jogiyan, Peshawar		night ventilation using existing windows -will this require some special payment to watchman?	Supply and fix Roofkool proprietary glassfibre insulated roof to classroom 2. Paint the roof surface white cl 1	

5.3 Field trip by Saleem Akhtar 15th May 1997 - 22nd June 1997.

5.3.1 Monitoring

Saleem arrived in Peshawar on the 21st May 1997. His friend Sajid Khan, also an architect from Dawood School of Architecture practices architecture in Peshawar and was interested to be involved in the project. Together they carried out monitoring of the school buildings.

5.3.2 Behari School.

The wall was built and the awning in place by May 1997.
Fans were installed but no timers. It had been intended that the fans ran just in the coldest part of the night to pull in cold air (say 4.00 - 7.00 a.m.) but this was not achieved. Running the fans was unsatisfactory because of poor electrical connections. Staff did not report favourably on fans. Best achievable air speeds were 0.2 m/sec adjacent to the windows, and around 0.1 m/sec away from the windows. Staff reported that the awning made the classroom and yard area considerably more comfortable. They speculated that it was reducing the temperature by 3 or 4 K. Saleem carried out a monitoring exercise removing the awning at night for three consecutive nights in the hopes of increasing the heat loss by radiation to the night sky. In theory this should be the best option with a second roof or insulation[23] reducing the solar radiation gain in the day and then increasing the radiation losses from the slab by exposing it at night. Removing the awning at night was quite difficult, as the awning was heavy and awkward. The awning was damaged and muddy because it had blown off the roof in a storm. The latrines had not yet been constructed, mainly because agreement had not been reached about the most appropriate installation.- see School description in Appendix

5.3.3 Sarband GBPS

Loggers at Sarband could not be downloaded in the Spring of 1997 because of problem with village people and driver. Insulated blinds had been installed in January but no logging of their performance was achieved. The loggers were removed from the classrooms by mistake and remained in the desk at IUCN until March 1998.
Airconditioning tiles had been purchased and stored but were not yet installed on site.

5.3.4 Sheikh Kali, Charsadda.

Reglazing work, clay pots and terrazzo floor were all complete. Reglazing of windows, although helpful in winter, does not improve conditions in summer because the windows are usually left closed at night. Steel window frames open inwards making a hazard for children sat on the floor though it was not of great concern to the teachers- perhaps because the children have learnt to avoid the sharp corners. Teachers were pleased with new floor and the reduction in humidity (previously the hessian mat which the children sit on for their lessons was damp and very smelly) but have not noticed any change with the installation of the clay pots. Generally the classrooms are extremely hot, apparently 79 children are crammed into one classroom. (Girls are more likely than boys to remain in the classroom. The teachers were concerned that the outside area was overlooked by the two storey boys school which was located to the east of the girls school site.) Saleem carried out a set of measurements to test if the position chosen for the loggers gave a reasonable representation of the conditions in the room - i.e. air temperature- see section on Monitoring.

[23] Givoni, B. (1976) Man, Climate and Architecture

5.3.5 Mohib Banda

Reglazing was completed in two of the three rooms(in the middle room we had intended to install new timber windows and timber louvered security screens but the prohibition of schools and other government buildings from using timber made this difficult) Security screens were installed along the south wall in the east and west classrooms. The reglazing work made the classrooms more comfortable in winter but, particularly in combination with the security screens appeared to make the classrooms hotter in summer. The shutters can only be opened and unlocked from outside in the alley way between the school and the next building. This is a bit of a bother. It had been presumed that the teachers would arrange the classroom to achieve optimum conditions, but their perception of optimum conditions was not always environmental. On visits to the classrooms the keys to the shutters were not always to hand so children worked in the poorly ventilated classroom with electric light. There is another problem with the security screens- once they were installed the neighbours preferred the screens to be shut, to give their homes better privacy.

Since the January field trip the Chokidar had become nervous about knocking big new window holes in the wall and so the new windows for cross ventilation were no longer an option. It was agreed that we would make brick sized ventilators- a row at the top of the south wall and at low level on the north wall. A brick was replaced with an open steel box. Externally there was a fly screen, internally a cover plate so that the ventilators could be packed with our polystyrene offcuts and closed in the winter. (It seemed unlikely that the offcuts would last very long as the children were much entertained to bite the polystyrene and listen to the squeaky noise) Apparently this high and low level ventilation generated some air movement where there was previously very little, though even with these ventilators the air movement across the room at both high and low level did not exceed 0.2m/sec (the external wind speed was 0.34 m/sec). Ventilation measurements were made on the 13th June 1997. Extra logging measurements were made from 29-31st May. On 30th May 20 extra children were brought into the middle class room from 7.00 a.m. - 10.00 a.m.

5.3.6 Jogiyan.

The only work proposed at Jogiyan was the painting of one of the classroom roofs white. This had not happened at the end of May when Saleem arrived but happened in the first few days of June. Painting the roof white was difficult as the surface was very porous: lots of paint was used even though the roof finish was brick.

5.4 Final School modifications Fourth Field Trip 28th March - 7th April 1998 -

5.4.1 Aims of field trip:
- To complete modifications to the schools
- To download loggers
- To plan the workshop to disseminate the information gained about passive techniques.

5.4.2 Synopsis of field trip activities
Arrive in Peshawar on Sunday 29th March 1998 for meetings on Monday (in April 1997 the weekend moved from Friday and Saturday to a rather uneasy arrangement of a bit of Friday for some businesses and schools, followed by Saturday and Sunday for most businesses; this to put Pakistan in line with world trade.)
Jamy had been promoted to the Director of IUCN in Peshawar and so was increasingly busy. It was agreed that we would appoint a local manager to tie up the ends of the project. Jamy recommended Mr Masoot who has been a representative for a paint company for many years. It was hoped that Mr Masoot would continue to manage the work for several months.

The days are spent organising the remaining work with Masoot, and setting up contacts, space etc for the workshop which is planned for the end of October '98
Meetings in Islamabad with Arif Alueddin and Dr Raman Chaudrey, Director-General of the Meteorological Office in Pakistan.

5.5 Workshop field trip 23rd October- 31st October 1998
Mary Hancock, Fergus Nicol and Susan Roaf.

The workshop was arranged to raise the profile on Passive thermal design, to disseminate information gained during the project and to set up new ways of fostering the interest in Passive thermal design.

See appendix for Workshop programme.

Chapter 6 Collecting Data

6.1. Choice of logger

Small computer programmed loggers have increased the amount of data that can be easily collected. With Tiny Talk loggers it has been possible to collect hourly temperature data in a range of rooms and develop a very close profile of the building performance. The loggers are accurate to one third of a degree. Loggers (Tiny talk) that would record 1800 readings (75 days worth of hourly data) were chosen. Loggers are now available (Tiny tag) that can collect much more data before resetting. This would be a significant improvement as down loading the loggers in that remote part of Pakistan proved to be a problem and the down loading is a high-risk time for the data. Logging positions were located at 1m from finished floor level and at ceiling height.

6.2 Choice of monitoring position was influenced by:

6.2.1 the desire to cause minimum disruption to activities in the classroom

There were two aspects to avoiding disruption- security and preserving sight lines.
The teachers were concerned that their charges might steal or fiddle with the loggers- so they were keen to see a secure arrangement and in most cases we installed the logger close to the teachers desk. If it had dangled in free space it might have collected more accurate data but it would have been more susceptible to interference. It would be quite difficult to collect information about temperature conditions that was truly representational; probably the conditions vary depending on distance from window, whether the class is rural and so sits on the floor, or urban and therefore equipped with desks and on how closely other children are grouped around. In winter the conditions experienced by a child may be less severe than the monitored data suggests because of the local microclimate set up in a tight group of children- similarly conditions in summer may be worse than the measured data suggests. It was disappointing that the teachers did not believe that it would be worthwhile to explain the purpose of the loggers to the children as this seemed a good way to interest the children in the survey work. Other possible links with classroom work that were proposed included a file kept by the children noting weather conditions but this was also deemed too difficult.

6.2.2 the need for security for the logger

The logger was placed in a padlocked box for security reasons. It was easier downloading the loggers if they were not attached to the wall because the logger could be taken to a desk- rather than holding the computer and logger

6.2.3 the need of optimum data collection to represent conditions in the room.

Two loggers were used in each of the classrooms studied.
Heights of 1m (head height for a child) and ceiling height were chosen
It was desired to measure air temperature and not temperature of the building mass, so the loggers were not fixed directly onto the wall but were isolated from the structure by placing them in black spray painted cake tins.

6.3 Monitoring results

A range of tests were carried out to validate the data collection. It was important to establish

(1) that the measured data represented the classroom conditions
(2) the climatic variation between the schools
(3) the duration of data needed to draw conclusions on performance i.e. how long a construction needed to be monitored to average out the effect of previous weather conditions and establish the performance of a particular strategy
(4) the accuracy and calibration of the loggers.

6.3.1 Do the wall mounted loggers represent the air temperature conditions in the room?

A test run, when the children were not in school, was carried out. Loggers were positioned to investigate the diurnal temperature range of the air mid-classroom and to compare it to the wall mounted logging information.

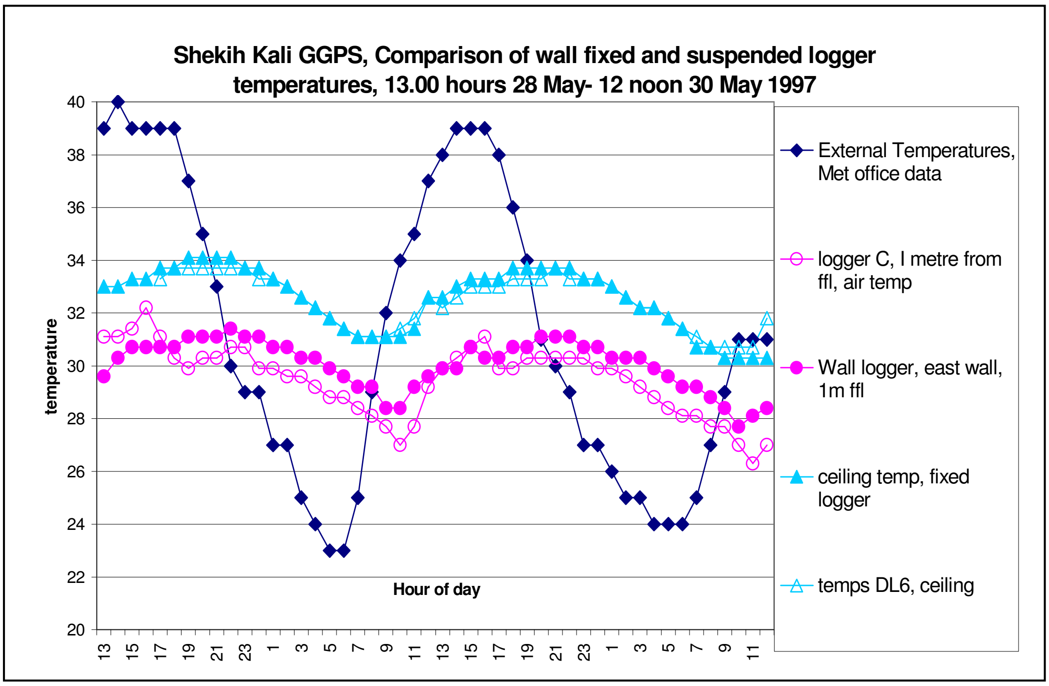


Figure 4: Sheikh Kali GGPS. Temperature Comparison of wall mounted and free hanging loggers 28-30th May 1997. Average temperature difference at low level in 24 hours is 0.6K, in school day 8.00-13.00 is 1K

It can be seen, figure 4, that the two temperatures one metre from the floor, wall mounted (east wall) and hanging in free space, are within 1 K of each other. It is unfortunate that in this school the biggest difference occurs during the school day, probably because the sun shines onto the east facing wall first thing in the morning. It would seem to be a fair assumption that this is the largest difference during the school day between temperature obtained free hanging and close to wall as this school has loggers fastened to the east external wall.

It is not clear whether the measured data hanging in free space actually represents the conditions that the children experience (because of grouping of the children etc.)

Examination of the monitored data does not show clearly for each school which were school days and when the children were in class. It might be expected that if a large number of children were in a classroom of approximately 37 square metres that the temperature would rise.(except in the case that the classroom temperature was close to or above skin temperature; in that case metabolic losses would be in the form of evaporation.) Peaks during the school day in the Mohib Banda data might be explained by children crowding round the teachers desk close to the logger.

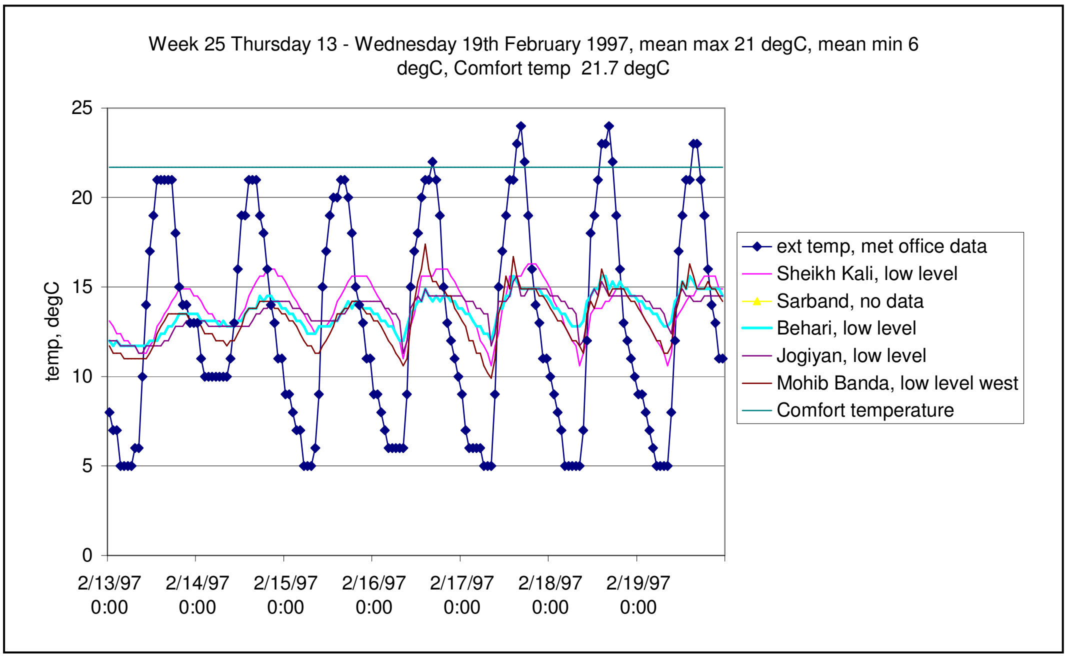


Figure 5 Temperatures in Classrooms week 25, starting Thursday 13 February. Weekend days are Friday and Saturday (i.e. day 2 and day 3)

This could be attributed to a combination of:

(1) the numbers of children who attend school every day are considerably less than those on the register (based on observation of school visits)

(2) the external spaces are frequently used for teaching.

(3) there is very considerable air movement in the classroom, (air movement measurements seem to indicate an air change rate that could not exceed 10 air changes per hour but this is possibly achieved summer and winter),

(4) the children are so still that their metabolic rate is very low.

The close grouping of the children probably makes their environment warmer in both winter and summer. It is assumed however that improvements in the open area adjacent to the teachers desk (where the loggers were generally fixed) result in similar improvements for the children.

6.3.2 Can the data from each of the schools be directly compared with data from other schools?

The temperatures recorded in the schools varied considerably- for example some classrooms were always cooler than others. Local climate variations could make a difference to the apparent performance of different classrooms and it was desirable to establish how much local climatic variation influenced the apparent performance of the building

External temperatures were recorded locally in four places

- Mohib Banda School (on a north facing wall under the veranda),
- Sheikh Kali (on a west facing wall, shaded with a bunch of dried grass
- Sarband (on a northern reveal of a south facing veranda: It was stolen before the first downloading of data so this information is not plotted.)
- in central Peshawar (on a column at the IUCN in a north facing veranda.)

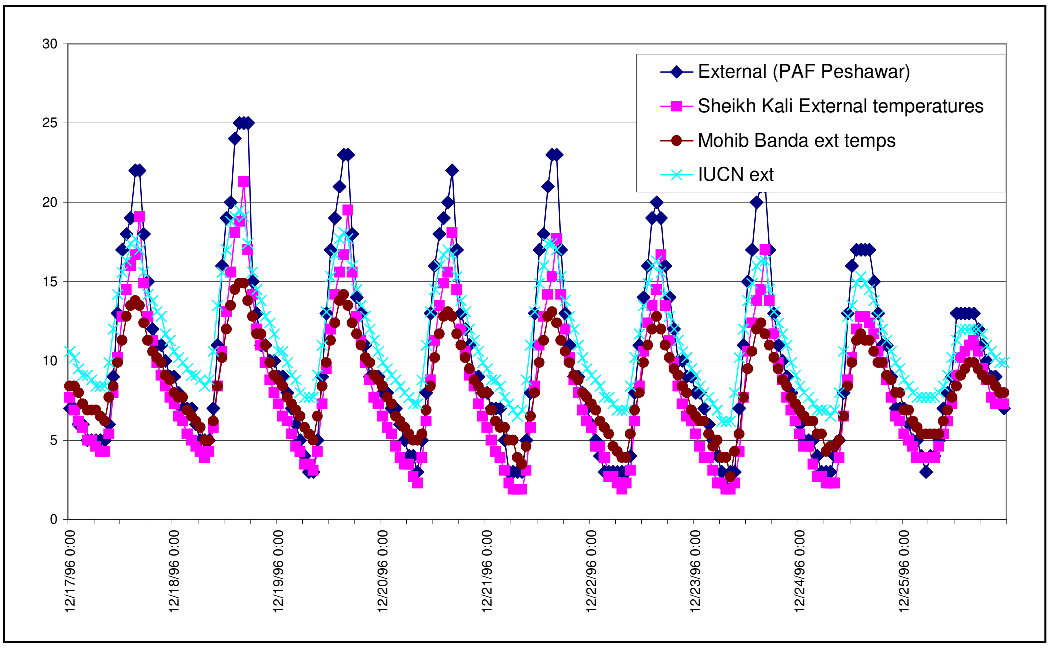


Figure 6:Comparison of locally recorded external air temperature and Meteorological Data, week 17 starting Thursday 19th December 1997

This information is compared to the hourly Meteorological data in the graph (figure 6) Generally data collected adjacent to the buildings has less diurnal variation than the airport data. Sheikh Kali shows nearly as much temperature variation as the Meteorological data- this logger was mounted on a west facing wall, shaded from the sun with grass and bits of twig. Sheikh Kali appears to get colder at night than the airport; the Charsada area is very damp, the fruit growing area, with lots of small rivers which might influence the local temperature. The other two loggers were mounted in more sheltered situations with a veranda roof restricting night time radiation losses. The IUCN logger was less sheltered than the one at Mohib Banda so the data appears to demonstrate that there is less temperature variation in the city than in the outlying area.

In this data it appears that the temperatures recorded relate more to the installation position of the external logger and less to the climatic variation and the urban heat island. The measured data at each of the sites is therefore inconclusive and the temperatures in the schools cannot be directly compared.

In the study it became clear that the schools were not as simple as had first appeared and that comparing the performance of one school with the performance of another included too many variables to draw a very useful conclusion. So variations in temperature in a school can best be compared to earlier conditions in the same school. In subsequent studies it would clearly be desirable to establish the comparative temperatures in the various areas.

Chapter 7: Presenting data: how much data is needed to draw robust conclusions?

What is the duration of data needed to draw conclusions on performance i.e. how long does a construction needed to be monitored to average out the effect of previous weather conditions and establish the performance of a particular strategy?

7.1 Collecting and comparing data for one day.

In many situations data can only be collected for a short period of time. Does one day give an adequate idea of the performance of the building?

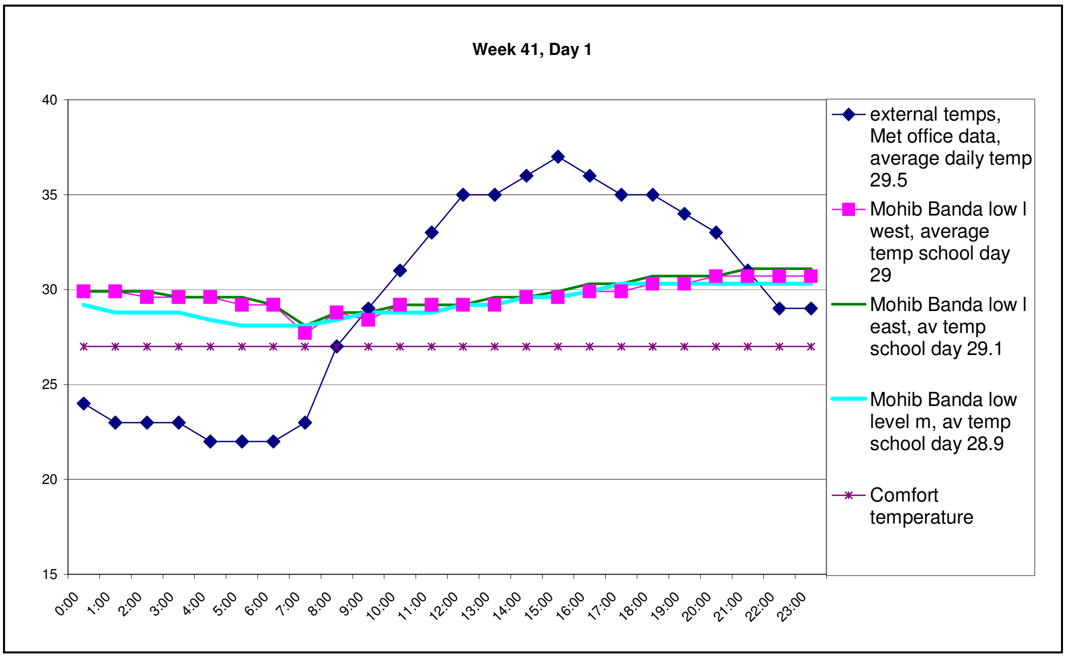


Figure 7 Mohib Banda Classrooms, week 41, day 1 June 1997

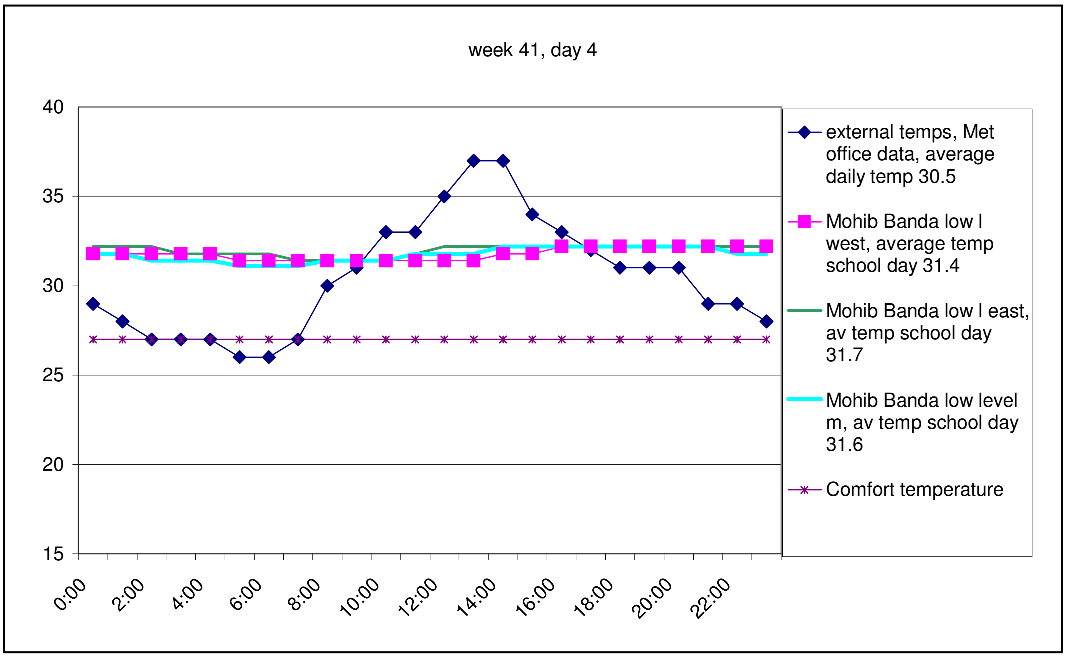


Figure 8 Mohib Banda classrooms, week 41, day 4

Comparison of the two graphs, figures 7 and 8, shows that they appear to tell a different story about the performance of the classrooms. In figure 7 the classrooms are cooler than the average daily temperature, in figure 8, a day in the same week, the classrooms are more than 1K hotter than the average external temperature. The classrooms start the day at different temperatures (30^{0}C and 32^{0}C) and finish at different temperatures(31^{0}C and 32^{0}C) It appears that daily data gives an unrepresentative picture, very much influenced by the weather in the preceding day and probably by other climatic factors such as rain or wind speed. It seems reasonable to conclude that the data is not representational of the building performance.

7.2 Collecting and comparing data for one week

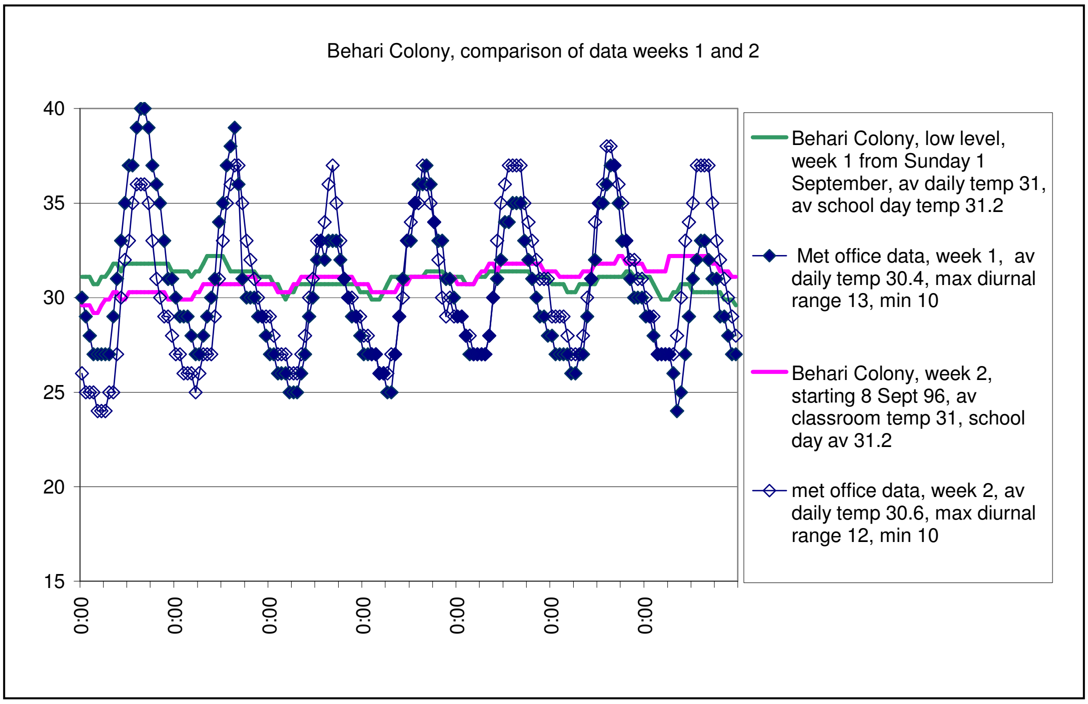


Figure 9 Behari Colony. Comparison of weekly temperature data

It can be seen from figure 9 above that there is close correlation between the conclusions one might draw about the performance of the classrooms looking at two consecutive weeks. The relationship between internal school day temperature and external temperature is 0.2K different in the two weeks, which seems to allow for variation in the way the building was used, climatic variation (wind direction and speed) but tells the same story about the building performance. The maximum and minimum diurnal ranges in the two weeks are very similar, perhaps because they are two weeks in the same season.

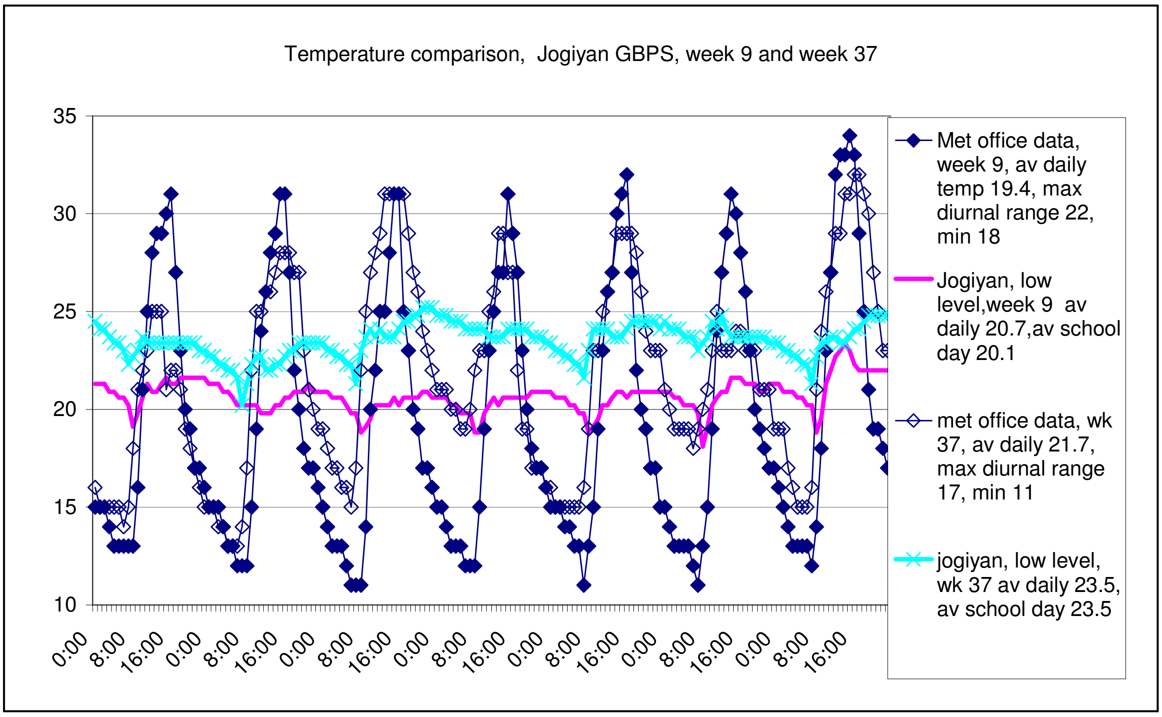


Figure 10 Jogiyan school. Comparison of weeks 9 (starting 24 October 1996) and 37 (starting 8 May 1997)

It can be seen from figure 10 that the graph appears to describe different performances in different seasons. The difference between the average external temperature and the classroom in week 9 is about 1.3 K where the difference in week 37 is 1.8 K. Temperatures in the school day are in excess of 1K different in the two weeks considered. Clearly the weather is different in the two weeks, week 37 has some days where the diurnal range is only 11K. It appears that averaging temperatures in one week of data can not always provide reliable data for comparing effectiveness of construction. Further investigation of which data range to choose (i.e. average day, 6.00 a.m., 8.00 a.m. or scatter diagrams) to some extent resolved this problem - see data conclusions)

7.3 Collecting and comparing data for one month

See Appendix 'Choosing the Method of data presentation' for investigation into accuracy using monthly data. Monthly data did not appear to give a more accurate conclusion about the performance of the building. The information gained from averaging one reading per day over a week seemed to provide a good indication of the performance of the intervention when compared to the average daily external temperature. The method would also facilitate hand measurement using a standard thermometer if readings were kept to this minimum level.

7.4 The development of an effectiveness score

What is the best way to present or describe the improvement achieved by a particular strategy? Schools are too small to have identical rooms with different treatments so it seems important to have some way of setting a number to the improvement achieved with a particular strategy. A number of ways of setting a value to the effectiveness of a strategy have been investigated.

7.4.1 Important criteria for presenting a measure of effectiveness of a particular strategy are that:

- applied to schools or other simple buildings it should help people, builders and building owners, to anticipate the improvement in comfort associated with a particular strategy.
- it should be a fair and accurate assessment of the performance of the building, modified or unmodified
- as far as possible it should be easy to replicate in future investigations of building and intervention performance.

This effectiveness rating has been difficult to achieve. The performance of the classroom in late summer conditions is not entirely the same as the performance in early summer, although the temperature ranges are similar. Perhaps there are significant differences in

- wind direction and/ or
- relative humidity and/ or
- way the building is used

7.4.2 A range of ways of evaluating the data were carried out:

- Average classroom temperature compared to average external temperature, considered over one day or one week or one month..
- Average classroom temperature compared to the external temperature or the average classroom temperature when the classroom is in use (i.e. 8 - 13 hours) or average temperatures at a particular time of day?
  6.00 a.m. is usually the coldest external temperature; a temperature taken in the classrooms before the teachers arrive would reduce some teacher induced variations but would be difficult to achieve as no one is in school at this time.
  8.00 a.m. average classroom temperature because this is the time classes start and therefore indicative of the start of the school day.
- Peak temperature before and after intervention in occupied hours?
- Scatter diagrams plotting external temperatures against internal temperatures can be plotted and the formula calculated. In this way a typical performance related to an external temperature could be plotted.

These variations have been plotted looking for the best fit of the data collected.

It appears (see appendix: Choosing the method of data presentation) that only a broad conclusion can be drawn and that either an average daily temperature, a 6.00 a.m. average, or an 8.00 a.m. average all compared to external daily average can give a reasonable indication of the effectiveness of the building intervention. Data collection for different building types and hours of occupancy would influence which strategy was most appropriate. Collecting the data for one month does not alter the apparent performance of the buildings. It could therefore be suggested that a week of temperature taking at say 6 am or 8.00 am might produce very similar results to the monitored data, considering the performance of schools. (all compared to Meteorological data averaged over the week) This simplification of the data collection might be helpful because this data, at say 8.00 a.m. could be collected by the teacher when he/she arrives for work, taking measurements for just one week in hot summer conditions.

Using the 8.00 a.m. average classroom temperature compared to average external temperature produced the most consistent results and so this method has been used to evaluate the overall thermal effect.
It can be seen from the charts following (figures11 and 12) that six classroom temperatures were related to the external average temperature and compared in two different weeks. Five of the classrooms (before intervention) demonstrate consistent results. The classrooms (Jogiyan, Sarband, Sheikh Kali, Behari, Mohib Banda east and Mohib Banda west) experience the same relationship between average external (Meteorological Temperature) and internal weekly average temperature at 8.00 a.m. to an accuracy of 0.3 K or better. The remaining classroom , Mohib Banda middle shows a difference of 0.6K with no modification. It might be that the cooler classrooms either side influenced this reduction in temperature or that other changes were made in the use of the building- for example that the teachers got interested in optimising the performance of the classrooms. The Tiny talk loggers record only to the nearest 0.3K so the results can only be expected to be accurate to about 0.5 K.

	Jogiyan	Sarband	Mohib Banda Middle	Sheikh Kali
Before modification				
Average daily external temp for week	**Week 3 28.2^{0}C**	**Week 1 30.4^{0}C**	**Week 33 20.6^{0}C**	**Week 1 30.4**
8.00a.m. Internal temp, averaged over one week	**Week 3 28.9^{0}C**	**Week 1 31.8^{0}C**	**Week 33 20.7^{0}C**	**Week 1 30.7**
Difference between inside and outside	**0.7K hotter inside**	**1.4K hotter inside**	**0.1 K hotter inside**	**0.3 K hotter inside**
Different season, still before modification				
Average daily external temp for week	**Week 37 21.7^{0}C**	**Week 2 30.6^{0}C**	**Week 41 28.8^{0}C**	**Week 2 30.6^{0}C**
8.00a.m. Internal temp, averaged over one week	**Week 37 22.9^{0}C**	**Week 2 31.8^{0}C**	**Week 41 29.3^{0}C**	**Week 2 30.9^{0}C**
Difference between inside and outside	**0.8K hotter inside**	**1.2K hotter inside**	**0.4K hotter inside**	**0.3 K hotter inside**
	After white painting roof	After introducing shutters on east win.	**Different season, still before modification**	**After insulating roof with clay washing pots**
Average daily external temp for week	Week 91 31.8^{0}C	Week 91 31.8^{0}C	**Week 93 31.2^{0}C**	Week 40 30.4^{0}C
8.00a.m. Internal temp, averaged over one week	Week 91 31.8^{0}C *	Week 91 31..8^{0}C	**Week 93 31^{0}C**	Week 40 28.2^{0}C
Difference between inside and outside	Same as outside	Same as outside	**0.2 K cooler**	2.2 K cooler inside building
Overall classroom improvement	About 0.8K cooler	1.4K cooler	**Inconclusive 0.3K cooler but no intervention**	2.5K cooler

*this data interpolated from ceiling temp averaging 1.1K higher than at low level

Bold lettering indicates two sets of data with same conditions, i.e. before modification a comparison to verify analysis

Figure 11 Chart comparing temperatures, before and after intervention but at different hot seasons, to verify analysis of data.

	Behari	Mohib Banda East	Mohib Banda West
Ext daily av temp for week Met data	Week 1 30.4^{0}C	**Week 33** **20.6^{0}C**	**Week 33** **20.6^{0}C**
Initial av 8.00 am classroom temperature Averaged for week	Week 1 31.2^{0}C	**Week 33** **21.3^{0}C**	**Week 33** **21.1^{0}C**
Comparison of internal and external temperatures	0.8 K hotter inside than average external temp	**0.7K hotter inside**	**0.5K hotter inside**
After intervention	Wall and awning	**No intervention, different season**	Ventilation grilles
Ext daily av temp	Week 39 28.7^{0}C	**Week41** **28.8^{0}C**	**Week41** **28.8^{0}C**
Final av 8.00 am classroom temperature Internal daily av	Week 39 26.9^{0}C	**Week4** **29.2^{0}C**	**Week41** **29.4^{0}C**
	1.8 K cooler than ext av	**0.4K hotter inside**	**0.6 K hotter inside**
After intervention	Improved microclimate &awning	Internal insulation	External insulation
Ext daily av temp, daily average for week	Week 91 31.8^{0}C	Week 93 31.2^{0}C	Week 93 31.2^0**C**
8 a.m.Internal daily av, averaged one week	Week 91 28.9^{0}C	Week 93 30.8^{0}C	Week 93 31.2^0**C**
Comparison of internal and external temperatures	2.9 K cooler than ext average	0.4K cooler inside	Same as outside
Overall effect of intervention	2.9 - (-0.8) =3.7 K cooler inside (Compares with 3.47K obtained from scatter diagram analysis	0.4-(-0.4) =0.8K cooler inside	About 0.5 K cooler inside

Figure 12 Overall thermal effect of intervention

Chapter 8 Description of the Design interventions:

Strategies investigated include

8.1 Bowls on roof (Sheikh Kali installed March 1997 and Sarband GGPS installed April 1998

8.2 External Window shutters (Sarband, installed March 1997)
Air conditioning tiles (Sarband, installed April 1998)

8.3 Roof and ventilation air shading with awning (Behari, completed March 1997)
Wall modifying local microclimate. (Behari, March 1997)

8.4 White painting roof (Jogiyan, carried out June 1997)

8.5 Internal insulation (Mohib Banda east) (installed late March 1998)

8.6 External insulation coupled to roof improvement work (Mohib Banda west installed late March 1998)

8.1 Bowls on the roof

Sheikh Kali washing bowls installed on roof in late March 1997, removed mid June 1997
Sarband GGPS Washing bowls included on roof mid April 1998)
One of our first interests was to encourage innovatory use of existing materials. Gul Najam Jamy was interested in the possibilities of clay pots, sun dried, holding a cushion of air against the roof.
The Sheikh Kali school always has lots of children studying in the classrooms. The girls sit on a hessian mat on the floor. I never saw the children actively engaged in any activity except listening though the arrival of an English architect probably produced an atypical situation. The floor was damp (Charsadda, the fruit growing region of Pakistan, has lots of streams) and the hessian mat was smelly. Quite a lot of the windows were broken and the frames were wired so that they did not open. The windows opened inwards. Outside the windows which faced south, about three feet away, was a wall approximately 6 foot high. The room was dark because of the poor state of decoration and the dirty fly screens.

Work carried out at this site included refurbishing the windows and reglazing, providing a new terrazzo floor and insulating the roof with clay pots. It might be expected that the replacement of the damp floor and the glazing would make conditions better in winter but worse in summer, acting against the insulation on the roof. It was undesirable from the view point of evaluating the strategy to carry out improvement works that acted against each other (from a thermal view point) and made the effect less clear. However it seemed unreasonable to work at the school and not tackle the central problem of a damp floor.

Cost of insulating roof (clay pots, transport and labour)		Rs 5,386
Cost of other work:	reglazing windows	Rs 2,100
	New terrazzo floor	Rs 33,000

Average daily external temperature in week 2; 30.6^{0}C
Average daily classroom temperature week 2 before work: 31.3^{0}C (i.e. av. 0.7^{0}C hotter than external temperature)

Average daily external temperature in week 40: 30.4^{0}C
Average daily classroom temperature in week 40: 29^{0}C (i.e. average 1.4^{0}C cooler than external temperature)
Average improvement comparing 8.00 a.m. temperatures: 2.5K cooler after intervention than before.

Strengths: the material was local, easily available and replaceable. Mr Khan, one of the drivers at IUCN was pleased to get us a price for the bowls from a neighbouring potter and he organised the hire of a small lorry. Carrying the bowls to the outlying school was difficult as the road was poor but once on site the job was straightforward. Placing the bowls on the roof was carried out by a local labourer
Weaknesses: The main problems are that the insulation is not continuous, circular bowls fit together leaving quite big gaps not covered and the walls of the bowls are quite a substantial hot-bridge. At Sheikh Kali mud was packed between the bowls to improve the insulation. In May 1997 the teachers reported that the pots did not make much difference to the comfort of the classroom. However when I was on site in March 1998 (after the bowls had been unfortunately removed) the teachers seemed more enthusiastic!
They were susceptible to being removed and disposed of - and a hundred good washing bowls on a roof would, I suppose, remain an attraction. The bowls are also heavy. I believe that good solutions could be arranged using specially cast clay tiles with lugs to lift them from the roof. At the workshop one manufacturer had been involved in the production of clay panels with one inch lugs to lift them from the roof- this would be a desirable thing to try, particularly if we could achieve slightly deeper lugs..

Because the bowls were removed from the roof , apparently by an over zealous government contractor, a similar installation was made at Sarband GGPS in April 1998. Unfortunately the logger recording in an adjacent classroom disappeared so the results were inconclusive.

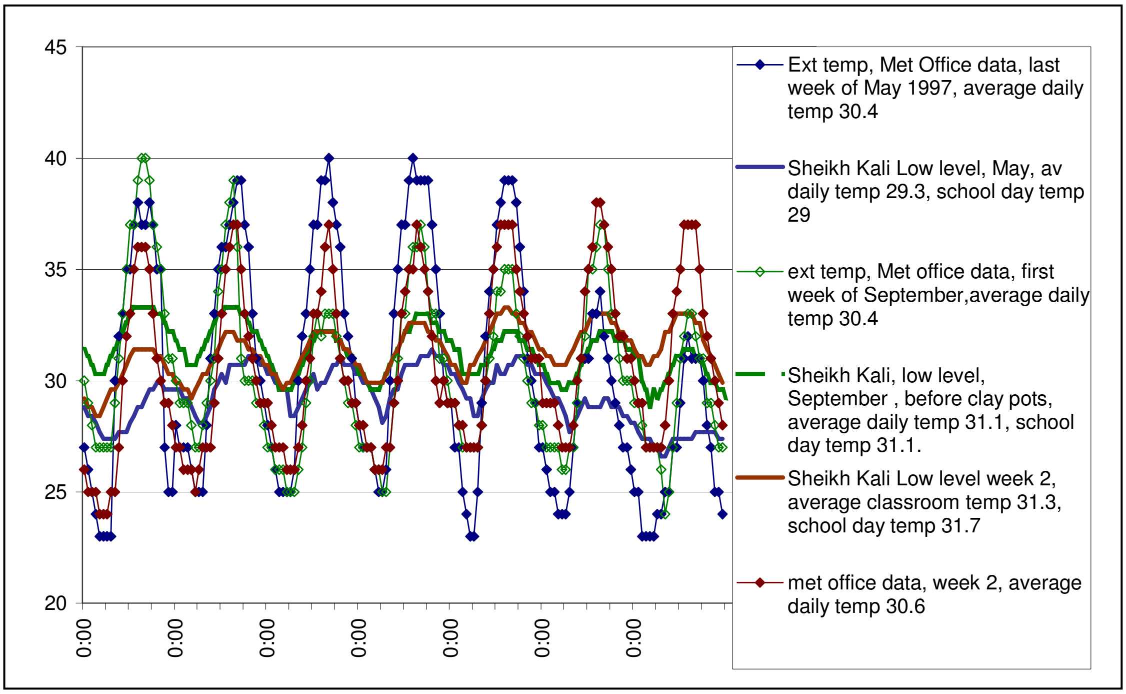


Figure 13 Comparison of Classroom temperatures, Sheikh Kali Weeks 1,2 & 40

Appraisal from Monitoring.
The clay pots seem to make a significant difference to the classroom temperature. Weeks 1 (school started during this week) and 2 have been plotted to investigate if there are any differences in classroom temperatures with children present. These weeks have been compared with the end of the summer term, the hottest time of the year. After the clay pots

are fitted the classroom is on average cooler than outside, before it was on average hotter. The average school day temperature in the hottest time of the school year averages 29^0 C
The lukewarm response to the clay pots, expressed to Saleem is difficult to understand, particularly as the story was different when I visited a few months later.
Appraisal from simulation: no accurate simulation possible

8.2 Window shutters at Sarband GBPS

Visits to this primary school are always conducted with the chokidar; he is keenly interested in the building and the teachers are not local.

This school is in good condition. The veranda which faces south had vines creeping over it for shade when I first visited in August 1996. The school has brick built latrines(the only school of the set to have latrines) which I believe the children are allowed to use.

The site was open to both daylight and breeze though this situation is changing (in 1999 someone is building a house close by which will reduce this openness)

One classroom faces north (where near the end of the job we installed some air conditioning tiles) and one classroom faces east. The east facing classroom was very dark because newspaper had been stuck over the windows to try and reduce the glare and heat from the east sun. Insulated shutters were designed for this room- opening a bit like a row of externally opening casement windows but all hinged on the same edge. These have not been very successful. The chokidar has not cleaned the glass so the room is as dark as before. The screens are closed a lot of the time because children who cannot afford the few roupees a term to go to school, hang about outside disrupting the classes. For this reason the chokidar has always wanted a wall to enclose his site but we have resisted this as too expensive and environmentally detrimental as the wall would have to be close to the windows.

Cost of insulated screens, painted: Rs 2000 per window plus transport (4 windows)
Cost of other work: no maintenance or other work to east facing room

Average daily external temperature week 2, 30.6 ^{0}C
Average daily classroom temperature 32.3^{0}C
Average daily temperature (school hours) 32.3^{0}C (i.e. 1.7K hotter than av ext)

Average daily external temperature week beginning 17 May 98, 31.8^{0}C
Average daily classroom temperature 33.2^{0}C
Average daily temperature(school hours) 32^{0}C (i.e. 0.2 hotter than av external)

Temperature improvement comparing 8.00 a.m. temperatures: 1.4K cooler inside with shutters.

Strengths: The insulated shutters should reduce build up of heat in the classroom before the class arrive. The angle of the screen could then be chosen to exclude the sun but let in sky light.

Weaknesses: It was quite difficult finding the polystyrene to insulate the shutters. Shereen Khan had to be very careful making the welded steel joints not to get the heat close to the polystyrene. The shutters are not used in the way intended by the designer because of other problems that had not been sufficiently appreciated

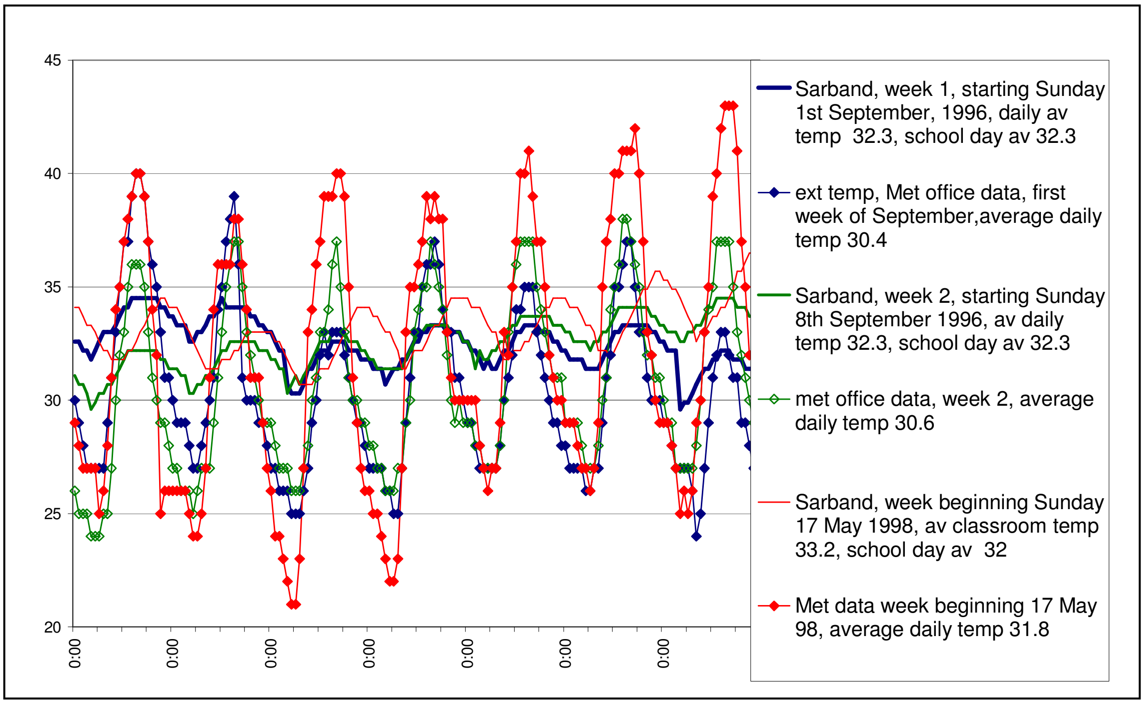


Figure 14 Comparison of temperatures at Sarband GBPS weeks 1, 2 and May 1998

Appraisal from Monitoring.
The start of the school term on 7 September 1996 appears to have made no difference at all to the classroom temperatures. Although it appeared that the shutters were not being used to their full advantage, examination of the monitored data supports the idea that they have reduced the classroom temperatures in the school day by excluding the morning sun. Interestingly the daily peak seems to be shifted by the presence of the shutters. These were a cheap intervention that does not in any way lead to deterioration of the building fabric and do in fact contribute helpfully to the building security as they are padlocked shut at night. The insulated shutters make a reasonable substitute for timber shutters which cannot be applied to schools at the present time. At Mohib Banda on a shaded south wall we applied uninsulated corrugated shutters which have performed less well than the ones at Sarband. The effect of these shutters could be enhanced by optimisation of their use.

Sarband- Air conditioning tiles, installed April 1998
Proprietary tiles were obtained from Islamabad. These tiles are apparently much used by the Army. They were bedded to the roof by a local mason, using a cement mortar and the recommended white grout.

Cost of tiles Rs 35 each
Total cost of tiles, transport from Islamabad, materials and labour Rs 18,780

Strengths: the tiles are light and easily applied. They seem to be very effective in reducing the temperature of the ceiling.
Weaknesses: Their performance in winter conditions or over a longer period of time has yet to be investigated.

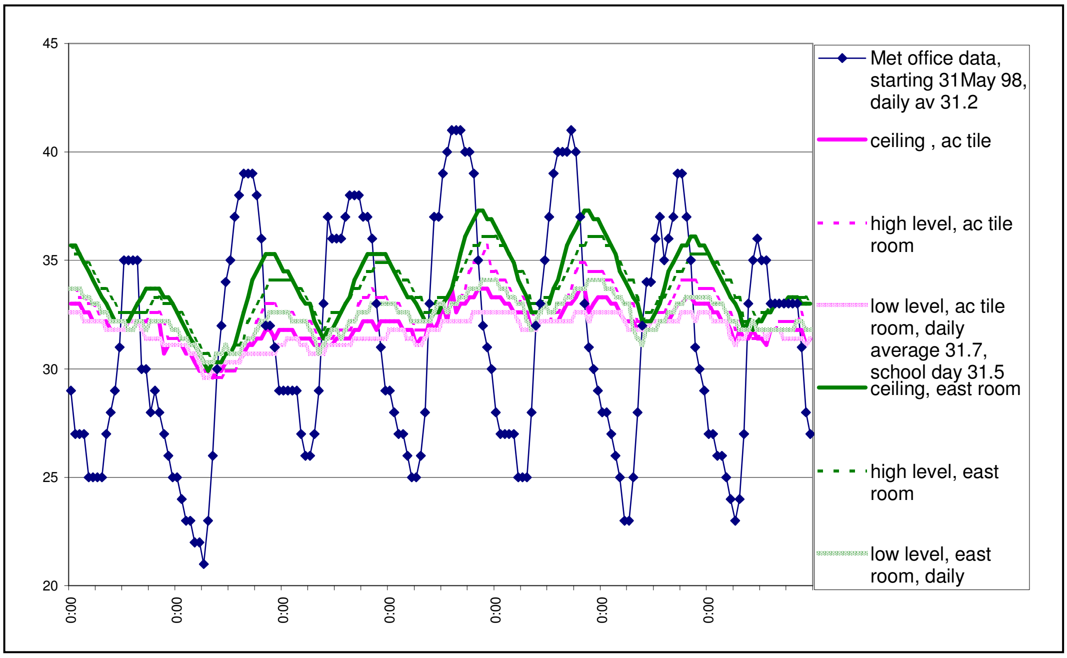


Figure 15 Sarband GBPS Week beginning 31May 1998, Comparison of Classroom temperatures.

It can be seen from the graph, figure 15, that the air-conditioning tiles are acting to cool the classroom- the ceiling in the north facing room is cooler than the air at high level!
The temperatures in the two classrooms are similar thought the north one (with the air conditioning tiles) is cooler by around 0.5K

8.3 Roof and ventilation air shading with awning (Behari, completed March 1997)
8.4 Wall modifying local microclimate. (Behari, March 1998)

Behari was the first school we visited in August 1996. The teachers were enthusiastic and quite a large group turned out for the meeting in their school holidays to discuss the work. The classrooms were in reasonable repair. A lot of the window glass was broken and had not been replaced. The fly screens were filthy, and so very sharply reduced lighting levels in the classroom. (see measured lighting levels in appendix) and also air movement (see air movement measurements in appendix). They were also ripped with quite large holes and therefore presumably their effectiveness was reduced. The air in the classrooms was very still and it seemed a priority to generate more air movement in the classroom. The classrooms were used to store school furniture and for several months I suspected that very little teaching went on at the school- subsequently I realise that a lot of good and careful teaching does take place but not usually in the classroom. At most times of year the external spaces are more comfortable. In 1996 the school had no water supply and no shading to the south facing yard. Younger children were sent home early on hot days because it was too hot for them to sit out in the sun. The teachers particularly wanted a wall to enclose the school and latrines. Originally I was not keen about the enclosing wall as it seemed a bit separated from the purposes of the project but their persistence was rewarded and a boundary wall was constructed for a good price by a man contacted by the chokidar (and related to the boys in the school) The wall was considered part of the thermal comfort project because it held up the edge of the awning over the yard area. It was originally intended just to place an awning over the roof to test the effect of a second roof but this was not what the teachers wanted- because the children needed to be shaded - so two were provided in the project.

To increase the air movement two strategies were adopted- new fly screens securely fixed so that the windows could be left open at night- and two large fans intended to pull air through the building at night. These fans have not been a great success- power and electricity supply and wiring are not very reliable and although it was originally specified that these should be on time switches so that they could work in the coldest hours of the early morning, these did not materialise.
The fly screens were replaced but unfortunately the school decided to refix the old screens on top of the new ones so that there are now two fly screens to each window which has tended to reduce rather than improve daylight and ventilation. I believe that it is not acceptable to dispose of Government property.

Cost of awnings:	Rs 6,400
Cost of wall, including gates:	Rs 29,560
Reglazing windows	Rs 2,100
Fans, supply and fix	Rs 7,500
New fly screens	Rs 2,600

Week 2	Average classroom temp in school day	31.2^0C
	Average met office daily temp	30.6^0C
Week 39	Average classroom temp in school day	27.9^0C
	Average Met office daily temp	28.7^0C

8.00 a.m. data — Awning alone: (i.e. before microclimate had developed) 2.6K cooler
Awning plus development of microclimate: 3.7K cooler

The awning: Strengths
awnings are easily available and cheap. It was a quick job for our metal worker, Shereen Khan to make fixings to attach it to the parapet. The awning provided shading to the roof, shading for the children and favourable shaded growing conditions for the young trees.
The awning: weaknesses
The main problem with the awning is that it is quite a lot of work to either take it down or put it up. Once the awning was in place it has stayed up, except for the three days when it was carefully removed at night. It would be sensible to remove it in winter, to benefit from the solar radiation, but there is a problem with anything demountable- where can the item be stored? In the schools there are no storage areas whatsoever so a removable item is difficult to deal with and likely to be lost. An awning has a relatively short life.

The wall. Strengths:
The best thing about the wall is that it served several purposes- it improved security, it stopped animals prowling on to the site, it reduced the interruption caused of passers-by, it protected the planting and it held the children in the area of the school.
The wall: weaknesses
The only problem with the wall was the expense of building it. Foundations and a solid construction are needed as no doubt the children will play on it and round it.

The fans: strengths
In some circumstances, with a reliable electricity supply and sophisticated wiring the fans might be quite useful.
The fans: weaknesses
In circumstances such as Behari the expense of the electricity and the difficulties of supply tends to discourage their use.

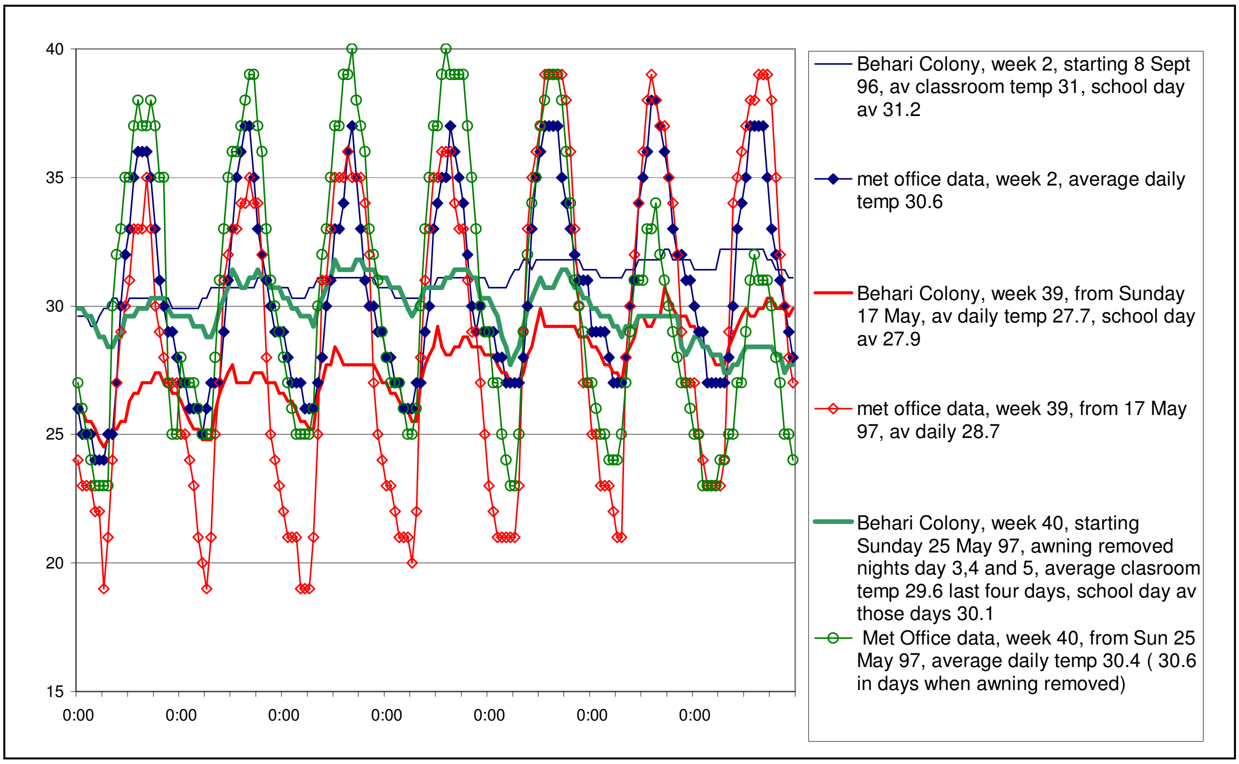


Figure 16 Behari Colony School, weeks 2,39 and 40. Evaluating effect of awning and of removing the awning at night

Appraisal from Monitoring

The awning is successful in lowering the temperature in the classroom by more than a degree in relation to external air temperatures. Removing the awning at night, whilst theoretically helpful in increasing radiation to the night sky does not show an advantage in this brief sample- the problem is that there are too few days to test.

There are several conclusions that one might draw- providing what the teachers felt was needed has been successful. The cheap price we obtained for the wall was through the school's contacts. When the wall was constructed the teachers and chokidar got together and levelled the yard which has provided a more serviceable surface for the boys to run about- it was previously extremely uneven. They have managed to get a tube well, and that combined with the wall and the shading has provided very good growing conditions for a variety of plants and trees. By October 1998 the area was well shaded with trees and quite transformed from the parched area that existed in 1996. The awning for the yard will become less useful in years to come as the trees increase. It can be seen from the graph below that comparing original temperatures with those achieved in 1998 when the planting was substantially grown, shows the classroom to be in excess of 2k cooler in the school day. This extra degree cooler (from May 1997) seems to be attributable to the planting which has grown fast in the hot climate of Peshawar.

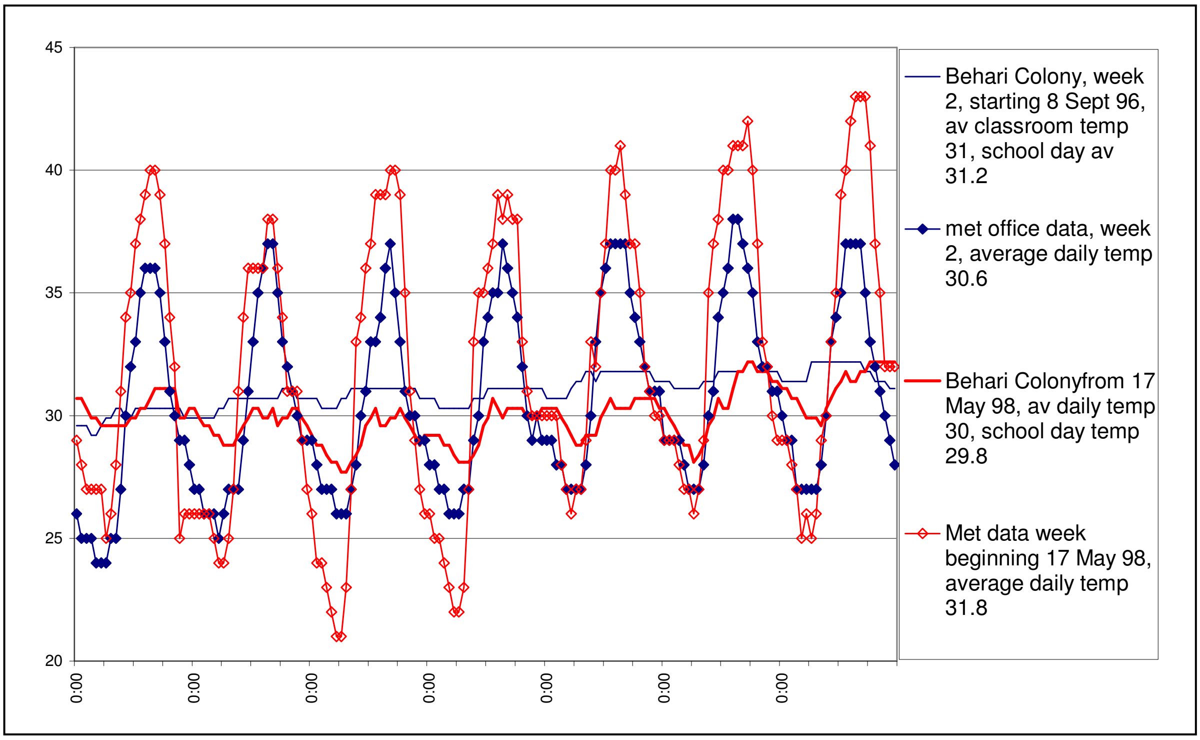


Figure 17 Comparison of temperatures week 2 and week beginning 17th May 1998

8.5 White painting roof (Jogiyan, carried out June 1997)
The school at Jogiyan is in excellent condition, the best of the schools in the project. The classrooms are well decorated, the glass in the windows complete and clean. There are mature trees in the school yard. The classrooms are unusual in primary school buildings in that they have windows on opposite sides of the classroom, providing cross ventilation. The only problem with the school is the east-west orientation of the windows. It was decided to test the effect of white painting the roof at this school.

Cost of white painting: Rs 2715, no other work carried out

Average daily external temperature in week 3 28.2^{0}C
Daily Classroom average for week, low level 30.4^{0}C, school day average 30^{0}C
Daily classroom average for week, high level 30.8^{0}C, school day average 30.3^{0}C
i.e 2.1 K hotter than outside
Average daily external temperature in May 1998 (i.e. one year after painting) 31.8^{0}C
Daily classroom average, high level, 34.1^{0}C school day average 33.1^{0}C
i.e. 1.3 K hotter than outside.
8.00 a.m. averaged data: Improvement of 1.4K
Strengths: The white painting was relatively easy to apply to the top surface of bricks on the flat roof. Paint and labour were easily available. The paint neither conceals faults in the roof nor could cause any damage.
Weaknesses: We had expected the paint coat to be cheap but it was special paint and the surface was very absorbent so this was not particularly cheap. The coat has not lasted very well. By April 1998 the roof needed another coat of paint. After one year the paint surface appears to be making a difference to the classroom temperature of a little more than 0.5 K (trouble with the lower logger at Jogiyan meant that data is interpolated from ceiling data.)

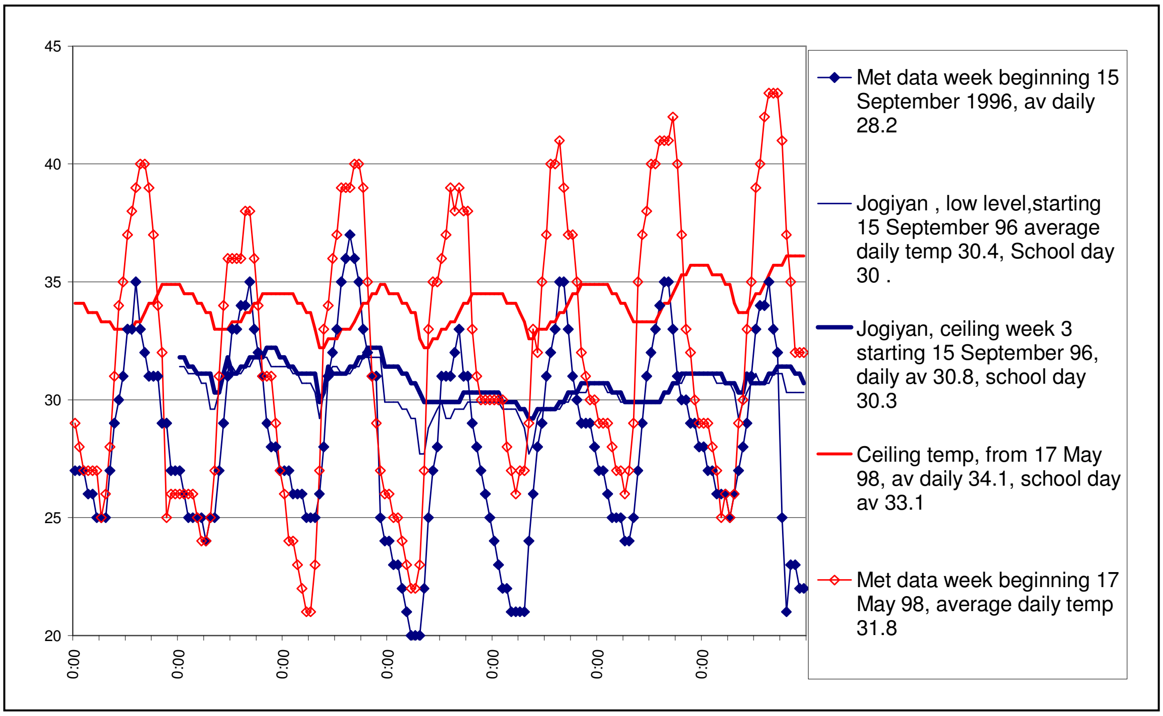


Figure 18 Comparison of ceiling temperatures, Jogiyan , before and after white painting roof.

Appraisal from Monitored data:
After one year the effect of the paintwork is fairly modest (appears to be about 0.7K) Trouble with the loggers meant that no low level temperatures were recorded in 1998.

8..6 Internal roof insulation (Mohib Banda east) (installed late March 1998)
8.7 External roof insulation coupled to roof improvement work (Mohib Banda west, installed late March 1998)

The village at Mohib Banda was already involved in a 'LUPUS' project, linking the village to Luton with exchange visits co-ordinated by IUCN so the village organisation was up and running when the opportunity of participating in the project was offered. Work at the school, which is situated close to the Kabul river, was nearly always assisted by a good group of village men and the teachers who were local. Lots of the school boys also turned up to help and because their life experience involves working from an early age, they were very useful and happy moving bricks onto the roof or passing up materials. The families of the teachers seemed to be mostly local farmers and the teachers worked on the farms or giving extra tuition after school to augment their Government pay.

The school was in average condition; quite a lot of the window glass was broken and the decorative condition was poor. During the course of the project, a tube well was obtained and a connection was made to the electricity so that the school had electric lights and the possibility of fans. Fans would be a significant improvement in this school because the air is very still. The school yard is small and there are no latrines, nor yet room for them, but lots of waste land adjoins the school. This is the biggest of the schools in the project with three similar classrooms in a row which were used to test different roof strategies. There had been some problem with the concrete roofs leaking and over the course of the project, before any intervention, the concrete roof slabs deteriorated. This was not surprising when the roof details were examined- the roof would only drain when the depth of water on the whole roof exceeded about 3 inches. Mud had been placed on the roof as insulation but it had never been properly laid and sealed so the water was absorbed rather than running off. In the three classrooms it was intended to test internal insulation, external insulation and the effect of increasing the glazing to provide cross ventilation. Original plans were for timber windows with louvered timber shutters which would seem a good solution in this climate- dealing with the need for ventilation as well as security. Government regulations restricting the use of timber in Government supplied buildings meant that the timber windows could not be pursued and the teachers and chokidar got nervous about knocking substantial holes in their school building. The roof options were pursued but the extra windows rematerialised as ventilation blocks at high and low level along opposite edges of the classroom. Mohib Banda is a long way from Peshawar, near Nowsherra so getting building materials to site was difficult. Materials and labour mostly came from Peshawar but this was largely for convenience of organisation. Builders merchants do not have transport in Peshawar so having bought any material (carefully looking for the lowest price) one has then to start the negotiations over again for the transport. This is all quite time consuming!

The teachers at Mohib Banda spoke good English so this improved communications.

The improvements were tackled in two stages. In the spring of 1997 glazing and windows were repaired and the ventilators installed in the west room. Monitoring did not start in the west room until January 1997, there were problems with the only low level logger in the autumn months of 1996 (It is interesting that almost all the problems occurred with the low level loggers- this might suggest that the problems were associated with children investigating the contents of the logger boxes.)

Overall effect: the results generally for insulating the roofs were disappointing. Neither roof produced more than 1K improvement in temperatures- it seemed to be that the insulation reduced the heat loss from the heavy structure during the night, particularly with the insulation on the outside.. The internal insulation in the east classroom performed slightly better than the external insulation in the west classroom.

Week 33, from 10 April 97, windows reglazed and shutters provided		
Average external temperature(Met Office data) 20.6^{0}C		
	Average school day temperature	8.00 a.m. average classro temperature
West classroom	21.6	20.7

Week 41, from 1 June 97, middle classroom unmodified, east and west class rooms with refurbished windows and uninsulated shutters, west classroom with ventilators.		
Average external temperature (Met office data) 28.8^{0}C		
	Average classroom temperature, school day	8 am average classroom temperature
Middle classroom	29.7^{0}C	29.3^{0}C
West classroom	29.6^{0}C,	29.4^{0}C
East classroom	29.7^{0}C	29.2^{0}C

It appears that the refurbishment of the windows and the uninsulated shutters have not increased the temperature of the east and west classrooms because the middle, unmodified, classroom has a similar temperature. Possibly the temperature of the west (end) classroom was originally higher than the others; the ventilation grilles leave the temperatures of the three similar.

Week 93, June 98, middle classroom still unmodified, west classroom externally insulated, east classroom internally insulated.		
External average temperature, (Met office data) 31.2^{0}C		
	Average classroom temperature, school day	8 am average classroom temperature
Middle classroom	31.5^{0}C	31^{0}C
West classroom	31.7^{0}C	31.2^{0}C
East classroom	31.1^{0}C	30.8^{0}C

The temperatures of the three classrooms are still very similar after the roof insulation work.

Cost of window work refurbishing 8 windows, new shutters and fly screens £300:
Cost of ventilation grilles: £57
Cost of internal roof insulation £178
Cost of external roof insulation: £54

Strengths: Windows needed maintenance work. Glass in the windows made the classroom warmer in winter and was welcomed by the teachers. Steel stutters were installed to the south facing windows in the west and east classrooms (which were never in the sun because of the close proximity of an adjacent house) as the teachers had experienced problems with vandalism. It is difficult to see why people try to break into the school buildings because there is almost nothing of interest or use in the classrooms- but

vandalism is an ongoing problem. The shutters have prevented vandalism to the glass or fly screens.
The ventilators were small enough to be very little structural threat and could therefore be included in many schools. Our metal worker had made a good job of the ventilator boxes, which filled the whole depth of the one brick wall, with a cover on the inside and wire gauze fly screen on the outside. The teachers were pleased with the effect and could feel the air movement across the lower part of the room (where the children sit on the floor for their lessons)

Weaknesses: Glazing the windows tends to make the buildings hotter in the summer if they are not opened. As the windows open inwards the sharp edges of the opening lights are a danger to the children's heads as they stand up from the floor-but this was not something that the teachers seemed worried about. The shutters also tend to make the rooms hotter, particularly if they are not opened early in the day to encourage ventilation. The shutters open outwards to lie flat against the outside wall and for night security are padlocked from the outside. Sometimes the child responsible for opening the shutter forgets the keys- this has happened twice during my site visits so perhaps it is a fairly frequent occurrence. Then the rooms are dark and stuffy and the lights need to be turned on. I believe also that the teachers are not keen to open the shutters because they give additional privacy to the house adjacent to the school.
The ventilators were much smaller than one might desire to install. Because the ventilators were small the covers, intended for winter (which pivoted round out the way) and the insulation intended to fill these holes (loose in the cupboard when I left) were not taken very seriously. Probably the ventilation holes will tend to make the building cooler in winter.

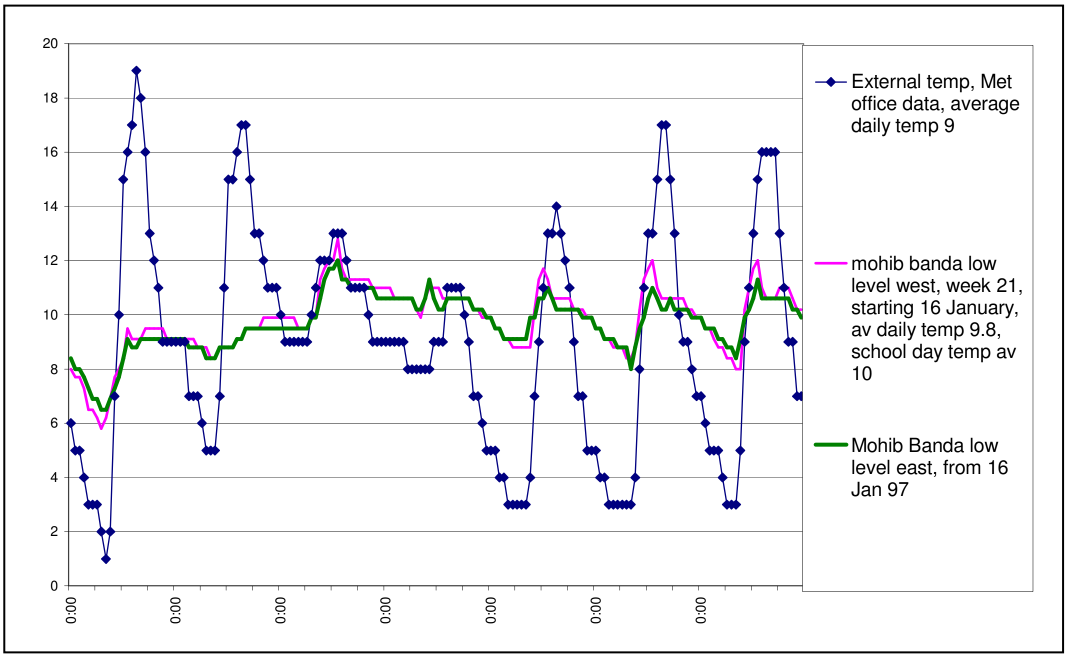


Figure 19 Mohib Banda Classrooms, week 21 starting Thursday 16th January 97

The classrooms are very cold in January. It can be seen from the graph, figure 19, that the east one is warmer in the morning and the west in the afternoon but the difference is generally less than half a degree. At this time many of the windows had no glass and the school day temperature is about 1K higher than the external daily average.

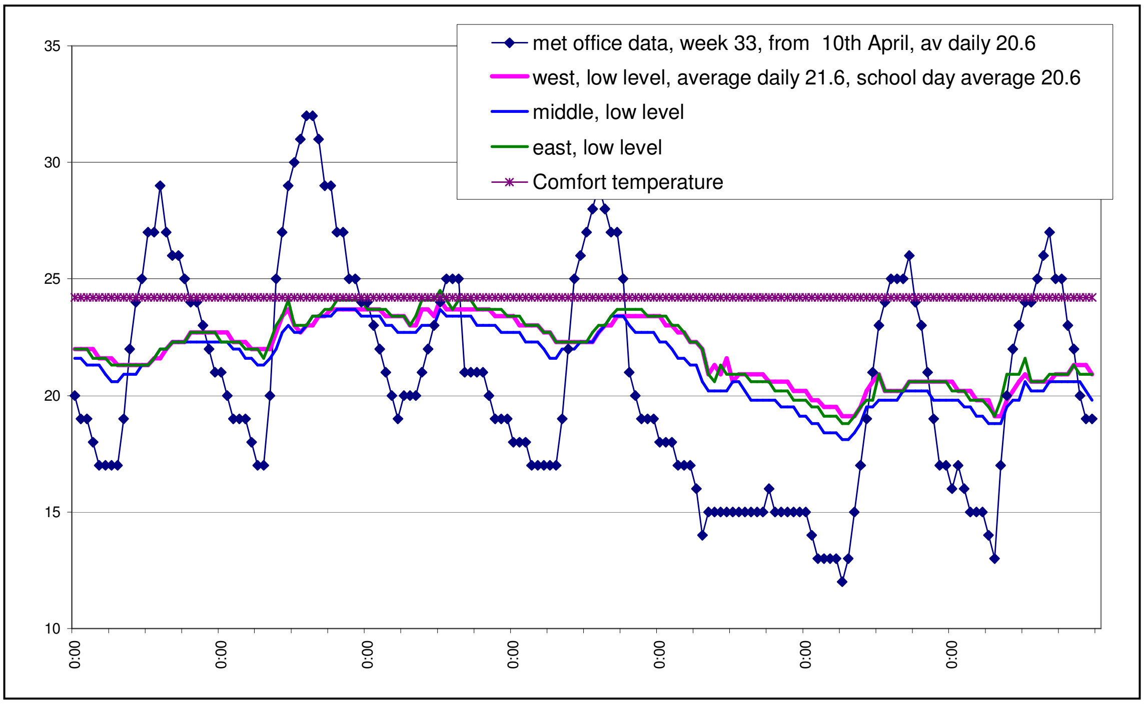


Figure 20 Three classrooms at Mohib Banda, week 33, from April 10th 97, Shutters and glazing on east and west windows.

Even with glass in the windows and shutters the temperature in the school day in the west classroom is only just over I K warmer than the average daily external temperature: the building is not holding much heat from the children.

Mohib Banda Roof insulation work, April 1998.

The roofs were finally insulated in March and April 1998. The west classroom has an externally insulated roof and the east one that is internally insulated.
Insulating the roof externally gave the opportunity to upgrade the roof to improve its water resisting characteristics. The roof had tended to leak . It was stripped back to the concrete slab, screeded to give falls to the newly cut drain holes and then the top of the slab coated with bituminous paint. Vapour barrier was laid over the paint and then the polystyrene placed on top. To hold the polystyrene down brick tiles were placed on the polystyrene and the joints filled with mortar. It was an expensive and time consuming job and not entirely successful in its efforts to water proof the roof. This was disappointing as builders generally have the firm impression that thermopore (polystyrene) insulation makes a roof leak.
The internal insulation was completed comfortably in two days by Sheeran and a labourer. The polystyrene panels were each fixed to the ceiling in two places with short bolts and rawl plugs.

Strengths: The external insulation should improve the performance of the roof, protecting the waterproofing from the heat of the sun and therefore hopefully lasting longer.
The internal insulation was easy and cheap to apply.

Weaknesses: The weight of the screed and brickwork makes external insulation unsuitable for certain roofs- roofs are not designed and built with the same safety standards as in

Britain so it is difficult to anticipate what extra load might be appropriate. It is not unusual to see roofs that have buckled and collapsed, particularly with prestressed concrete beam roofs.
The internal insulation prevents visual inspection of the condition of the concrete slab and might therefore lead to deterioration passing unnoticed until it was quite significant.
Although polystyrene is frequently used as an internal insulating material in Pakistan, particularly in the cold Northern area, I am unsure of the fire retarding characteristics of this material as purchased- untreated it is of course very unpleasant in a fire giving off acrid toxic smoke. A thin layer in a classroom that is otherwise not flammable is perhaps a reasonable risk.

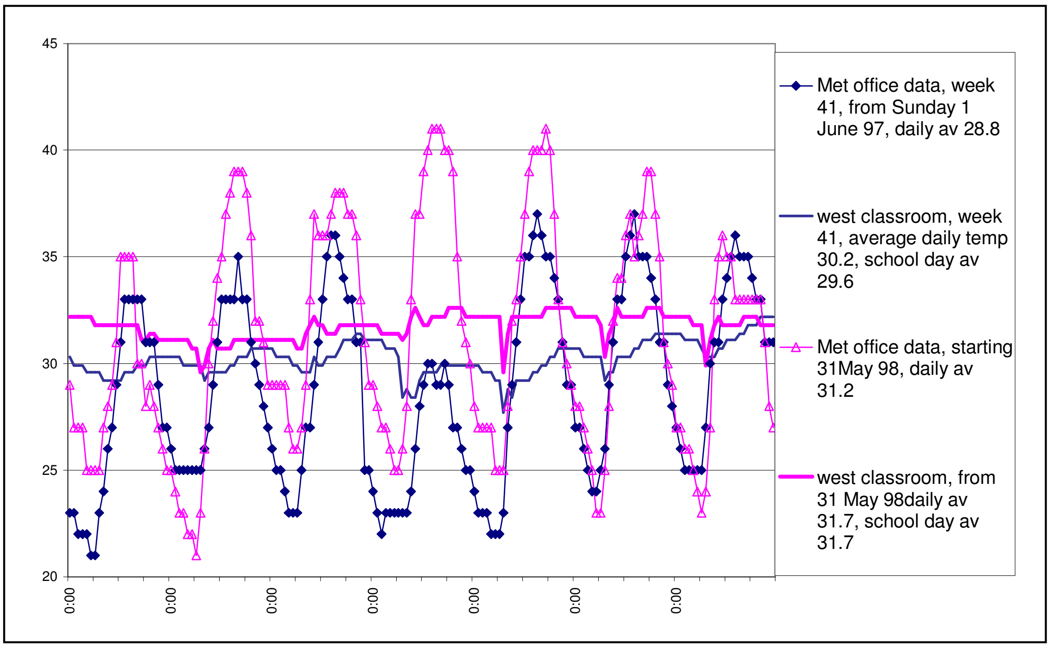


Figure 21 Effect of external insulation at Mohib Banda, summer conditions

.Appraisal based on Monitoring:
In 1997 the daily classroom temperature was about 1.4 K hotter than the external temperature average and the school day temperature about 1.0 K hotter. In 1998 the daily classroom temperature is about 0.5 K warmer than the external average and the school day average temperature is similar. The cool day in the middle of the 1997 week is probably a rainy day so this would have depressed the temperatures in the following days, improving the average classroom temperatures. The effect of the external insulation seems to be a reduction of about 0.5K in the school day, averaging to approximately 1K over 24 hours.

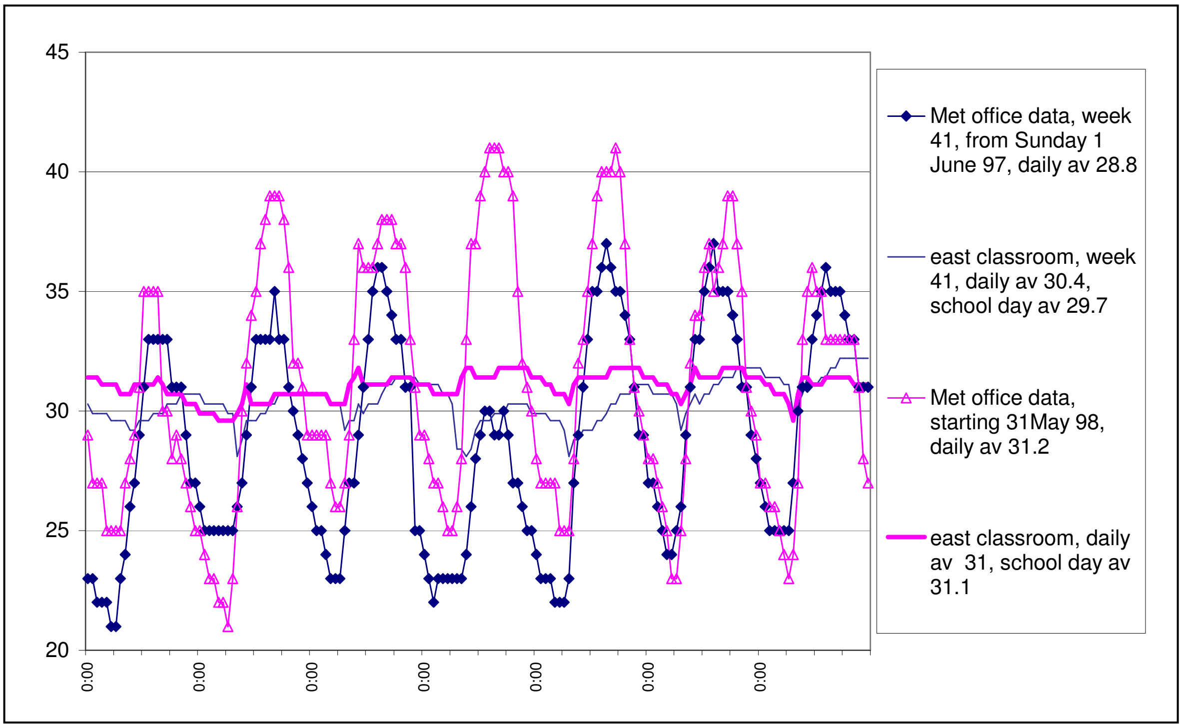


Figure 22 Mohib Banda, east classroom, effect of internal insulation, summer conditions.

It can be read from the graph above which compares temperatures before and after the internal insulation was applied, that the internal conditions after insulation was applied are cooler than previously. In 1998 the average internal conditions, both 24 hour average and school day, are very slightly less than the external average. Before the insulation the temperatures were similar in the school day to the west classroom, i.e. about 29.7 and over the whole day a little warmer on average. It should be noted that using the classroom temperature as an indicator of comfort underestimates the increase in comfort achieved by reducing the radiant surface temperature of the ceiling. Macfarlane[24] suggests that in hot conditions thermal comfort temperatures can be reduced where internal surface temperatures are reduced.

[24] Macfarlane, W.V. (1958) Thermal Comfort Zones, Architectural Science Review. Vol 1 no 1

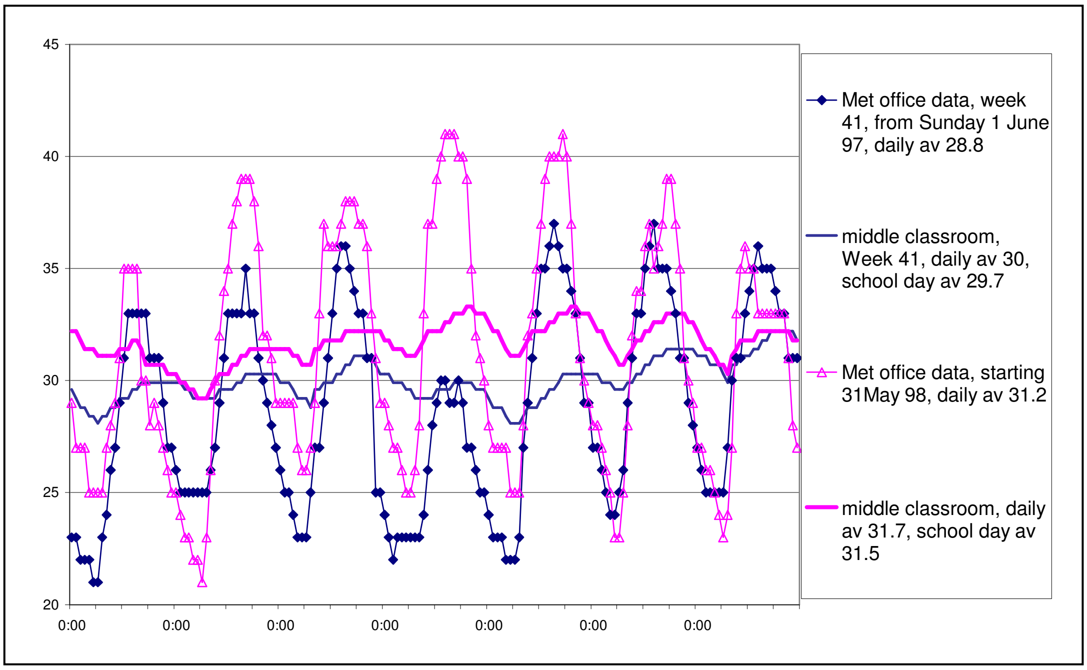


Figure 23 Middle classroom where no work was carried out.

It is disappointing to note from the above graph that the temperatures in the room where no work was carried out are very similar to those where the roof has been insulated. The classroom temperatures in 1998 are lower than those recorded in 1997 (in relation to the external temperatures) Reasons for this are not very clear. The rooms on either side are a little cooler- perhaps because of the insulation, but it seems likely that weather conditions, air movement particularly have influenced this result.

Overall the conclusion on the insulated roofs is that they are not demonstrated to be as effective as anticipated in summer conditions. The insulation tends to reduce the heat loss by radiation and conduction at night so although the slab does not get as hot, its opportunities to cool down are reduced. If it was possible to achieve good ventilation rates at night, it seems likely that the insulated high thermal mass solution might work better.

This conclusion is not that reached from the simulation exercises where insulating the roof appeared to be the best option, with or without ventilation. It seems likely that the simulation tools are biased towards cold climate decisions.

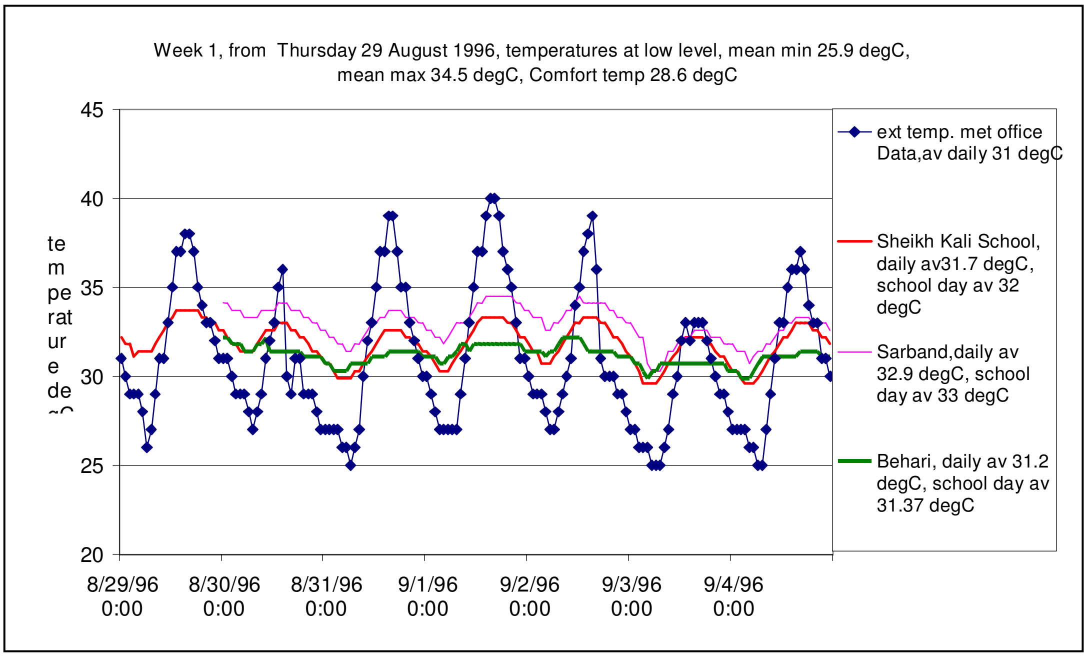


Figure 24 Temperature of the classrooms at the beginning of the project, August 1996. Jogiyan was not initially monitored and the logger at Mohib Banda had some malfunction.

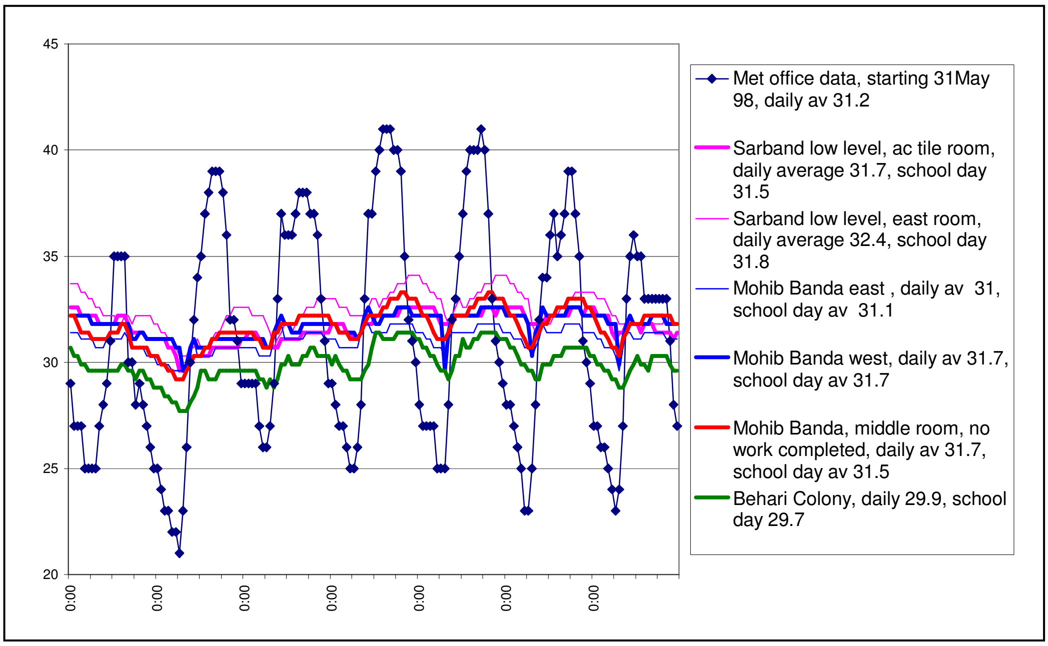


Figure 25 All schools compared at the end of the job, week beginning 31 May 1998

Conclusions about thermal comfort are based entirely on temperatures recorded. Some anecdotal comments are included from the teachers. My early experience with the project led me to conclude that because schools were grateful for the interest taken and the help improving conditions in the classroom, they were disinclined to look critically at the conditions achieved.

Comparison of the two graphs (figures 24 and 25) demonstrates that the summer classroom temperatures generally are lower after the interventions, particularly as the average external temperature is slightly higher in week beginning 31 May 1998. It can be seen from the graph (figure 25) that in the hottest of the summer school conditions (end of May) only the most successful of the interventions returns a temperature less than 30^{0}C. These classrooms, with their still air, are too hot. If effective fans and cross ventilation were included in the design of primary schools, this temperature could be acceptable.

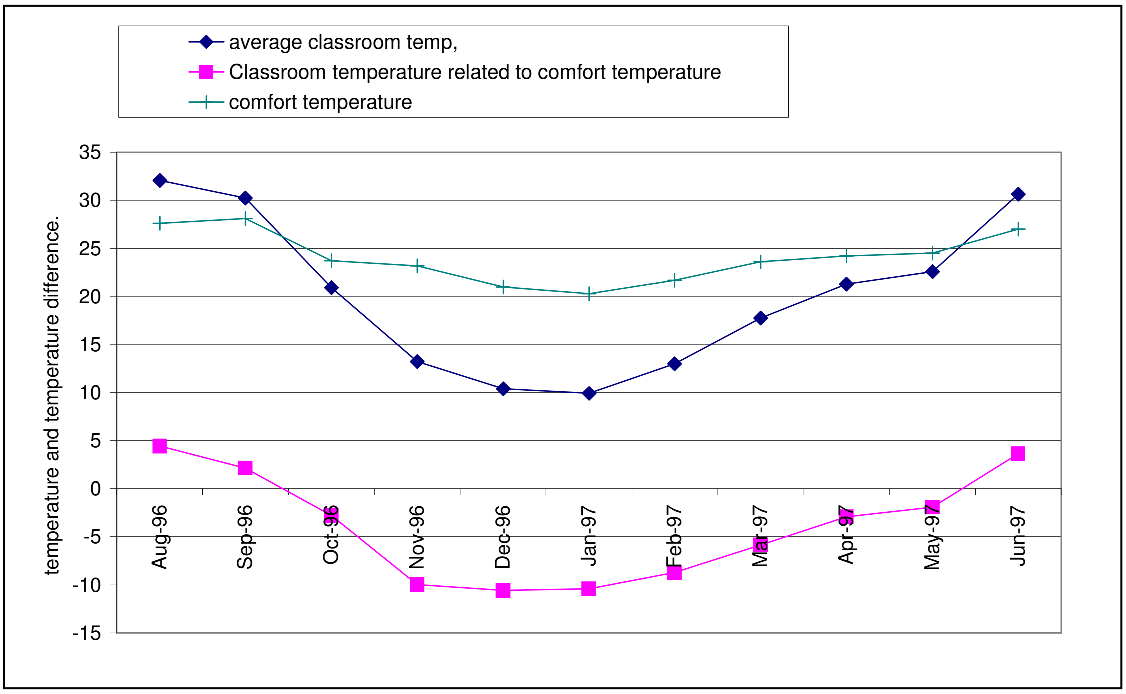


Figure 26 Weekly average temperatures in classrooms averaged over all schools at four weekly intervals

Figure 26 is plotted from the monthly classroom data information (see Appendix) It can be seen from the graph (figure 26) that the temperatures in schools on average fall considerably below 20^{0}C for five months of the school year. In November, December, January and February the average temperature does not exceed about 12^{0}C. Children do not generally have very warm clothing and in all of the schools children sit on the floor. Why are the teachers not more concerned about this?.

Comparison of the solar radiation table (figure 27) with Olggyay's bioclimatic chart (figure 28) seems to provide part of the answer. People can be more comfortable outside than indoors when the temperature is low, if there is adequate solar radiation. However detailed investigation of solar radiation data suggests that on average it is unlikely to be comfortable outside before mid-morning in the winter unless the children were warmly dressed or running about.

Mean Monthly hourly Global Radiation watts / /m^2

hour	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
8	258	192	97	42	42	81	183	311	400	422
9	453	372	264	183	178	256	372	494	564	586
10	578	517	406	322	311	400	525	650	703	722
11	653	594	514	439	433	531	633	758	806	822
12	706	658	569	489	489	606	683	808	856	858
13	706	639	578	486	492	617	683	783	794	842

Figure 27 Monthly hourly solar radiation data for school calendar, developed from 'Solar Energy Resources of Pakistan' [25]

Direct solar radiation is quoted by Iftikhiar Raja at about two thirds of the global radiation (shown in figure 27) 50 watts of direct solar radiation has the same effect as about 1^{0}C elevation in globe temperature so it could be expected that around 10 a.m. the temperature outside in the coldest winter conditions would be comfortable provided that the day was sunny and the site sheltered from the wind.

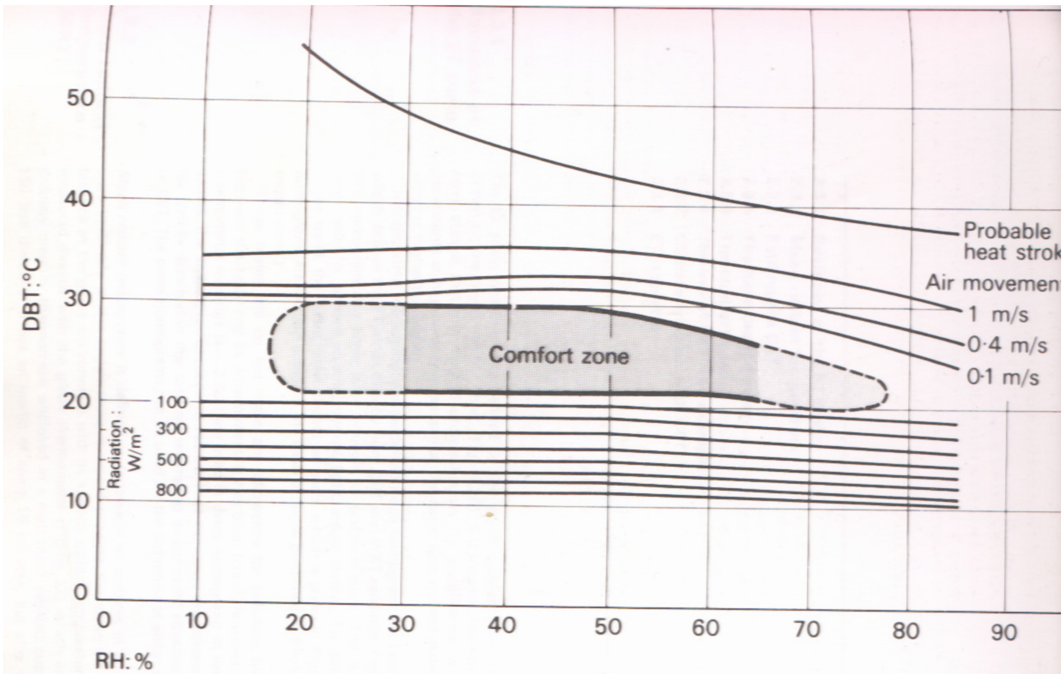


Figure 28 Bioclimatic chart for men at Sedentary work wearing 1 clo clothing, chart by V Olggyay[26]

Olggyay's chart supports this conclusion though the air movement rate is not specified. Externally the climate, by mid-morning at any rate, in a well sheltered area is probably more comfortable than in the heavy thermal mass classrooms.

The children are likely to be uncomfortable at school at the beginning of the day, either indoors or outside. In the outlying villages heating is difficult because of the

[25] Raja Iftikhar, (1996) Solar Energy Resources of Pakistan, Pub Oxford brookes
[26] Koenigsberger et al (1974) Manual of Tropical Housing and Building

lack of suitable fuel: a tray of smouldering charcoal is the warming device favoured by the chokidars in the schools at night.

Chapter 10 Tools used for the simulation of the schools.

In addition to the field measurements the model school was simulated on both 'quick' and 'IES' programs in order to evaluate the theoretical impacts of design alterations. Quick simulation was carried out both before and after the practical refurbishment work .

10.1 The chosen Tools.

'Quick' was chosen to simulate the schools as it seemed a suitable model. It is particularly suitable for independent zone spaces, that is no zone influencing the temperatures in an adjacent zone. As the name suggests it is very easy to programme the data- information about the dimensions and locations of the walls, floor and roof is fed into the model and constructions can be chosen from a library of materials. Climate data required is hourly temperatures and solar radiation levels; hourly data was not easy to obtain before data became widely available from the Meteonorm[27] disk! Other inputs include occupancy levels, ventilation and infiltration rates, and internal loads (both convective and radiative) The model simulates a hot day or a cold day, representing a run of similar days in succession. The model is particularly suitable for a steady climate where successive days are similar. Detailed investigation of the climate in Peshawar suggests that it is not as steady and similar as might be expected.

10.2 Hot day simulation using 'Quick'

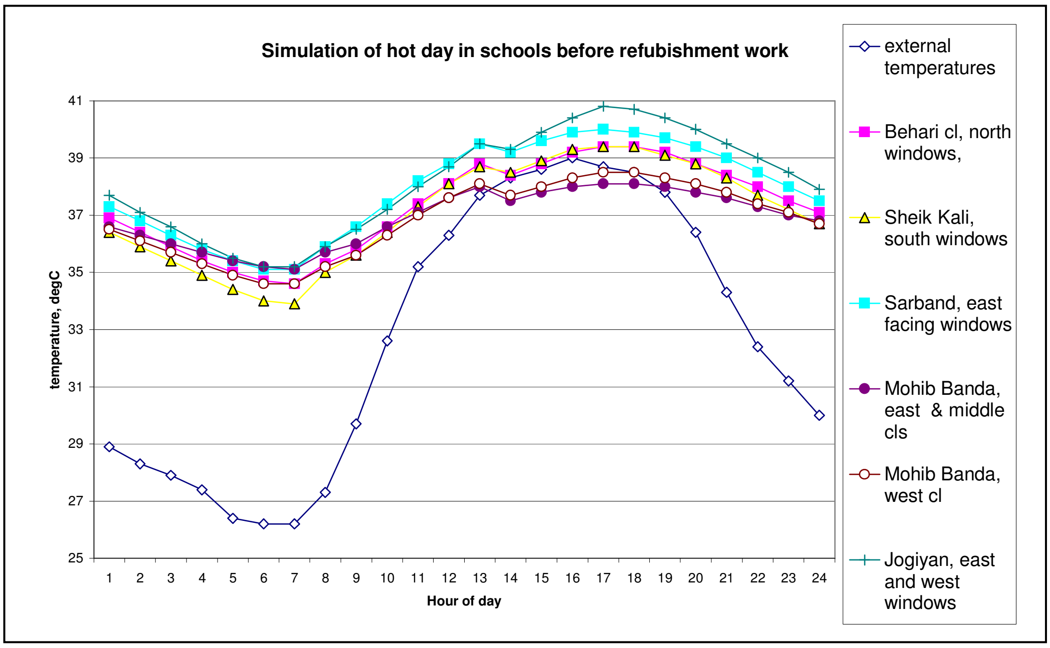


Figure 29 Simulated data: one hot day

Simulation of the hot day has produced classroom temperatures that settle very close to the extreme of the diurnal variation. This suggests that data input was not correct. Possibly the ventilation rate is considerably underestimated. Results from this simulation do not encourage confidence in the possibility that thermal comfort can be provided in these classrooms in hot summer conditions.

[27] World wide climate data now available on CD

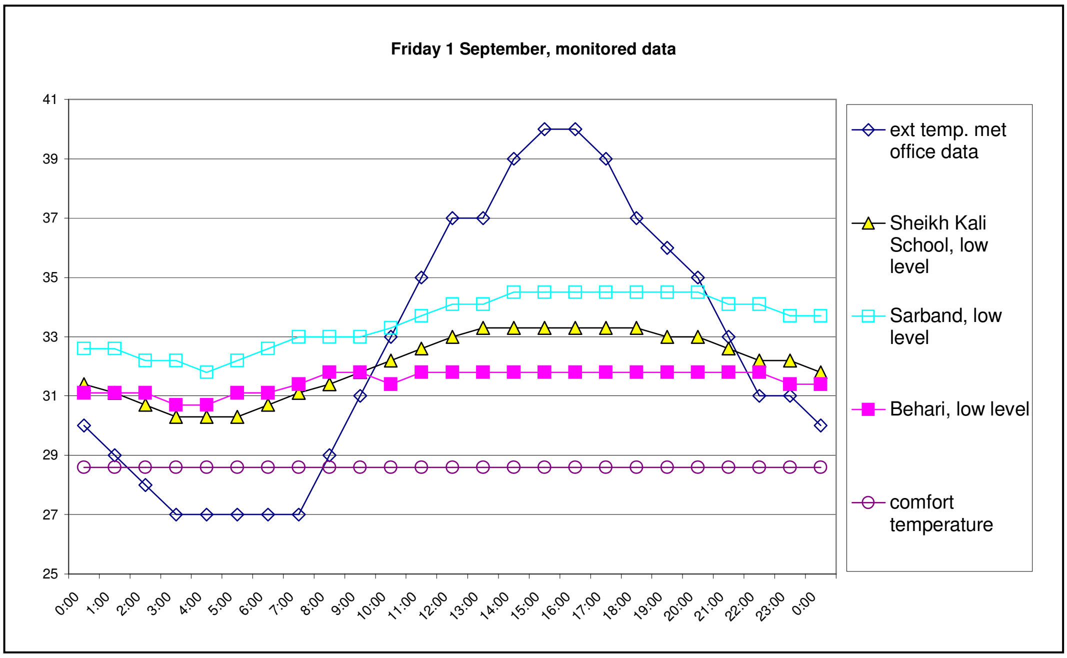


Figure 30 Monitored data, one hot day at the beginning of the project (data for Mohib Banda and Jogiyan not available)

Comparing the simulation and the monitored data, the order of the schools in temperature terms was similar though the schools as built are more steady in temperature than the simulation and cooler. Behari Colony classroom with north facing windows was coolest, Sheikh Kali school (a girls school so the classrooms were used more) with south facing windows was next and Sarband with its east facing windows was the hottest. (Sarband simulated varies between 36-40 but the monitored building varies only between 32 and 34) The effect of this simulation is to make passive strategies appear less viable because the building temperatures seem very high.

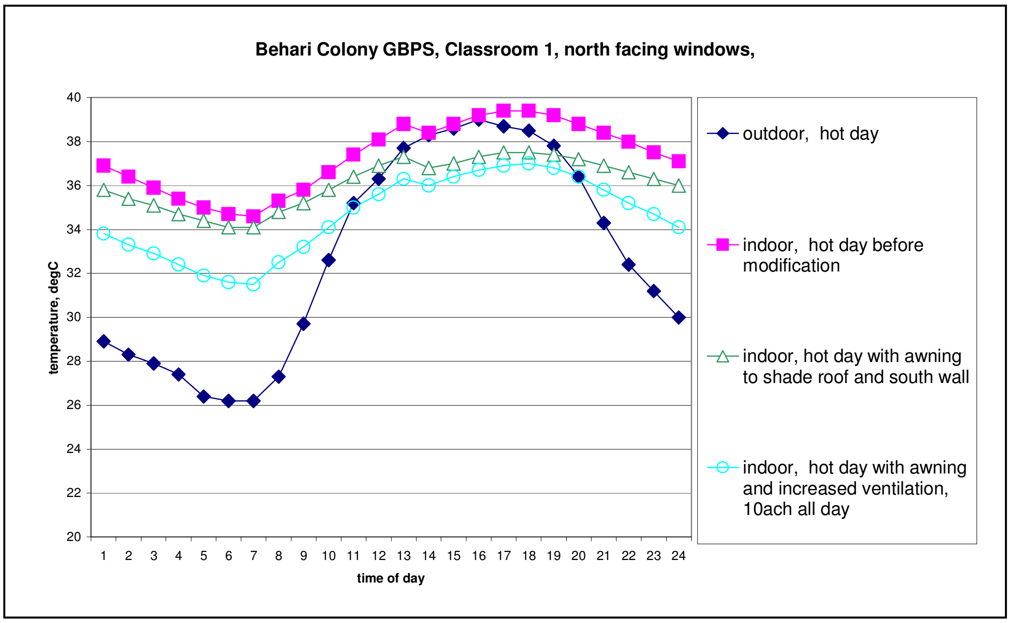


Figure 31 Behari Colony, Simulation, hot day

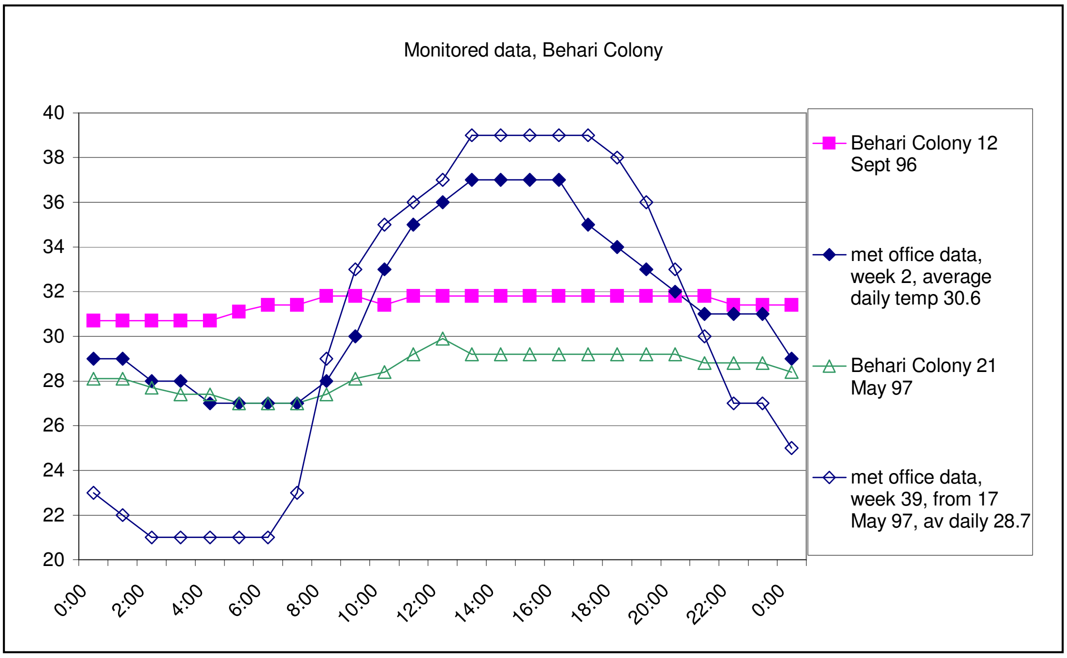


Figure 32 Behari Colony , Monitored data, Hot day, a typical day from week 2 and from week 39

The temperature improvement from the awning in the simulated study is in excess of 2K including 10 ach ventilation which is possibly achieved with the existing window openings (see measured ventilation rates at Behari (appendix). The monitored data indicates a larger improvement, around 3K, particularly considering that the 1996 day was cooler

10.3 Cold day simulation

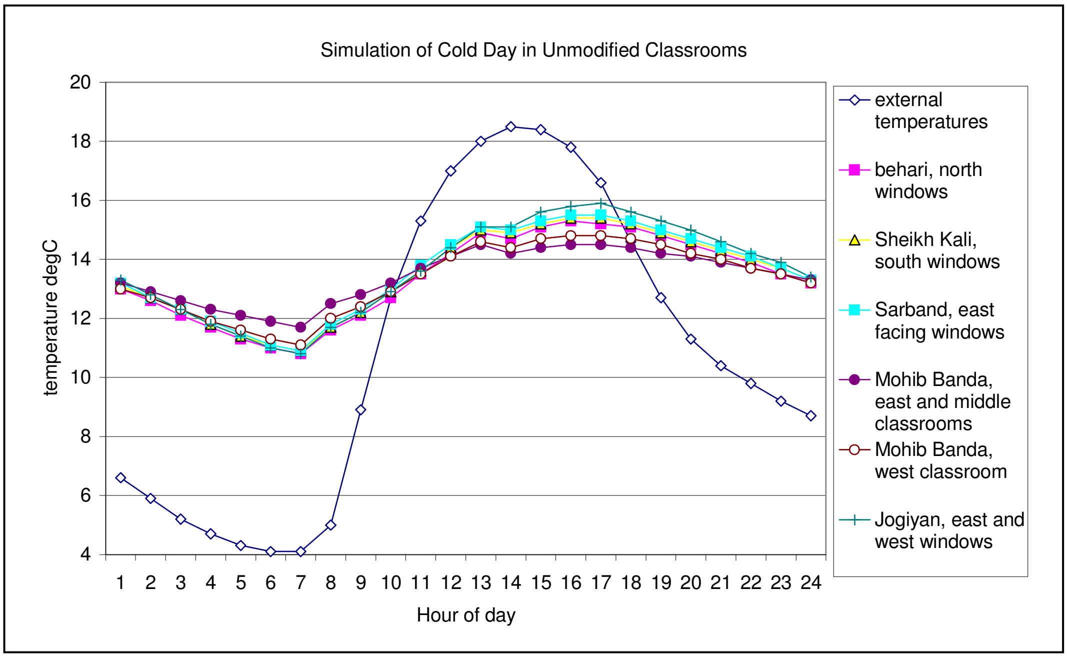


Figure 33 Simulation of cold day in classrooms before refurbishment

In the cold day simulation classroom temperatures are within about 1K of each other through the school day. During the twenty four hours the classrooms are never more than 2K apart.. These facts are also applicable to the monitoring though the monitoring temperatures sit much lower in the diurnal range. Sheikh Kali (with south facing windows and by this time a dry floor) is the warmest classroom except during the school day when it appears that Behari Colony is warmer.

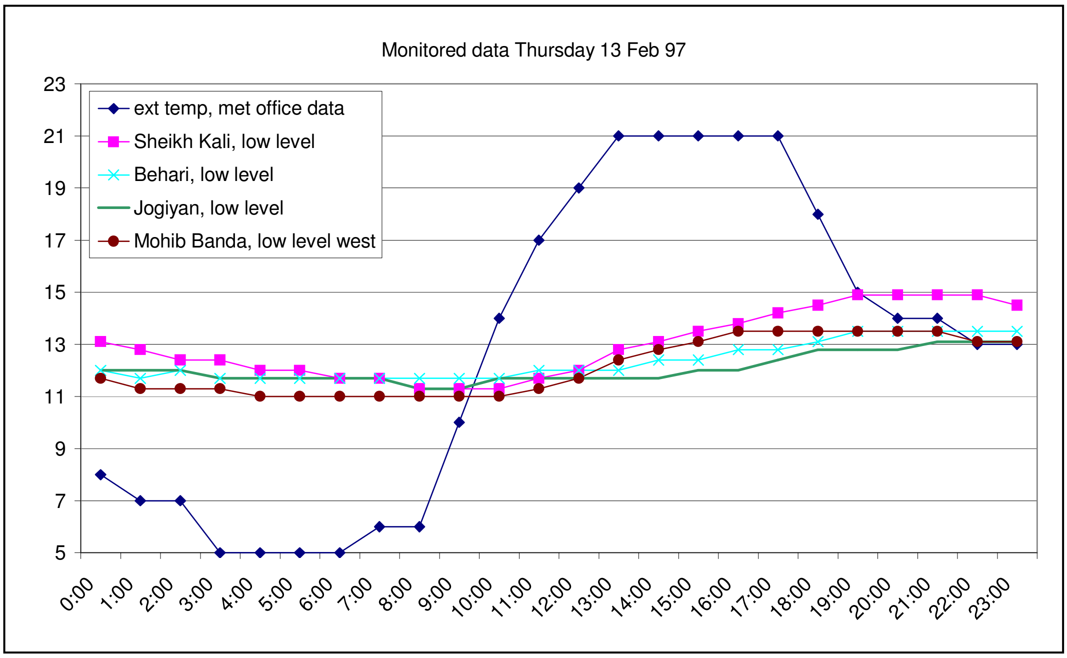


Figure 34 Monitored data- one cold day

10.4 Comparison of 'IES' and 'quick'

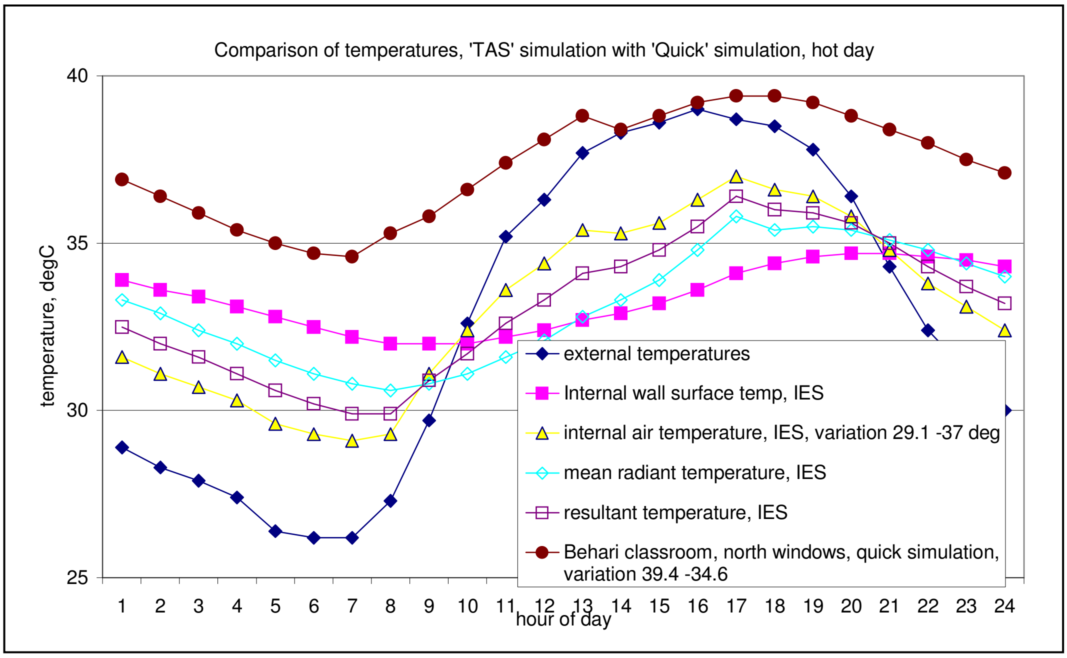


Figure 35 Comparison of quick and Tas (IES) simulation

When the monitored data was collected it became clear that 'Quick' simulation tended to make passive strategies look less viable because the temperatures fluctuated more in the simulation than the real buildings and also the temperatures seemed to be shifted towards the top end of the diurnal range. To test if this was a feature of 'Quick', a misunderstanding in the operation of 'quick' or a problem with the data, the schools were also simulated using the model IES and the same data. It can be seen that the IES temperature variation is larger (about 8K compared to about 5K using 'quick' but the temperature, although above the average of the diurnal range, is closer to that monitored.
The new windows version of 'quick', 'Building Toolbox' which was available at the end of the project seems to give results closer to the monitored building results. Discussion is in progress with the developers of 'Quick' (Prof Matthews, University of Pretoria) to investigate if the programme was misused or was routinely overestimating room temperatures.

10.5 The new 'Building toolbox'

Building toolbox is a 'windows' style replacement of the ‘Quick’ simulation tool. Even on the approximate 'preliminary investigation' version of the model, the school, though hampered by the fact that to fit the model it had to be described as a house or an office, returns results which correlates quite closely with monitored data.

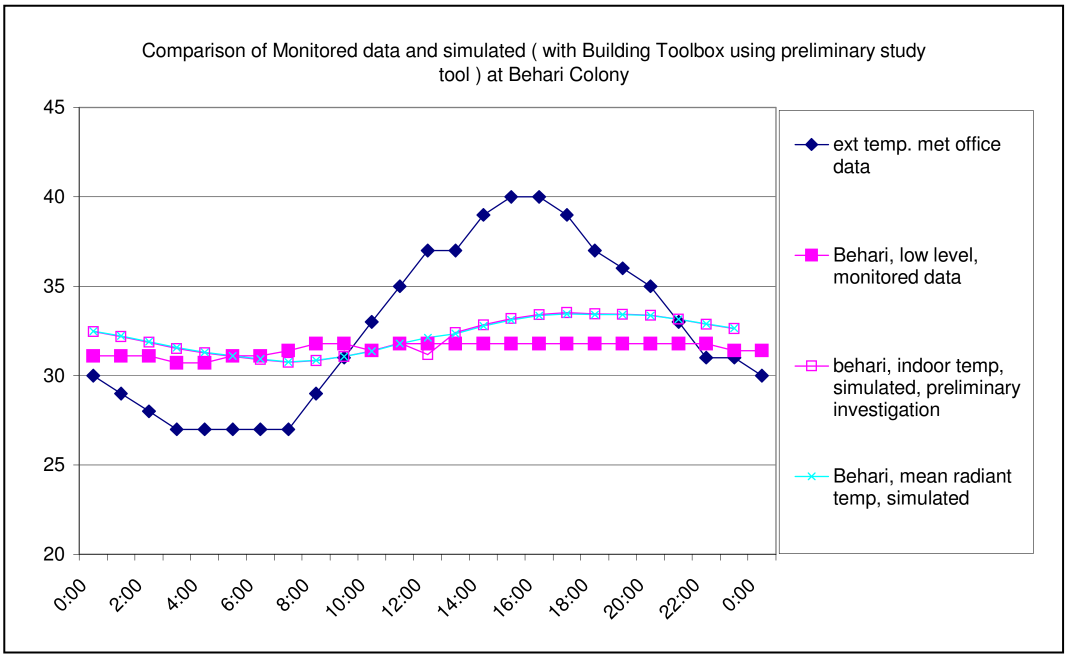


Figure 36 Monitored and simulated data compared; simulation tool using meteorological data for temperature of May 21 but standard averaged solar radiation data as measured data was not available

The increased temperature in the afternoon, comparing simulated data to monitored could be attributed to the fact that ‘house’ mode was used which would presumably include both people and domestic loads in the house through the day.

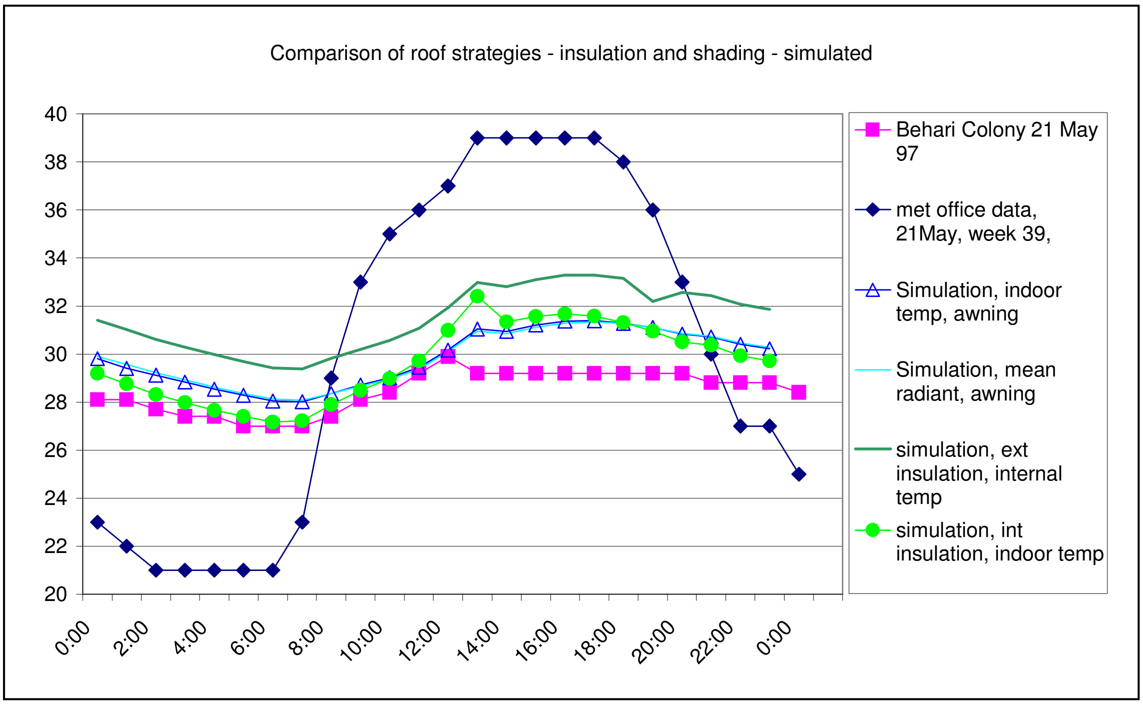


Figure 37 Simulation using 'Building Toolbox'

The simulation , figure above, gives a much more optimistic simulation of the building performance. It is interesting that in the simulation the awning performs better than the insulated roofs; this was not previously the case with the dos version of 'Quick'. In the monitoring the awning returned lower temperatures than the insulated roofs; this phenomena of the insulated roof tending to reduce the overnight cooling of the thermal mass slab is referred to by Richard Hyde[28] in relation to 'following the conventional wisdom of not using insulation in the roof of houses in Cairns to promote night cooling'

[28] Hyde, R. and Docherty, M. (1997) Thermal Performance of Housing in Hot humid tropics of Australia Architectural Science Review 40 p105

Chapter 11. CONCLUSIONS

The work concentrates on the school year which starts in the first week of September and finishes in the first week of June, earlier if the weather is very hot.

	Cost	Weaknesses	Strengths
Bowls on the roof	Rs 5,386= £82	Easily removed, insulation not continuous, heavy, probably reduces winter temperatures.	Locally available, perform quite well, typical temp reduction 2.5K. This figure was unexpectedly high as teachers had not noticed much improved comfort
External window shutters	Rs 8980 = £138	Operation of shutters needs to be optimised for best effect	Easy to fit, contributed to security, probably improve winter temperatures, typical temp reduction 1.4K in east facing room
Air conditioning tiles	R11,000 = £169	Winter performance not known, may cool building in winter, durability not known	Easy to fix, light, appear to be effective.
Awning to shade roof	Rs 7930 = £122	Not long lasting, desirable to remove in winter but problem of storage.	Light, no permanent damage to roof, very effective, temp reduction 2.6K
Modification of micro-climate with plants, etc	No direct cost but wall and awning enabled plants to get started well	Trees need careful positioning to avoid shading the building in winter conditions	Cooling by transpiration, effective, also improved quality of external spaces. In only one year of growth, temp reduction of 1K.
White painting roof	Rs 3060 (second time) =£47	Did not last long,	No additional load to roof, not concealing roof problems, typical temperature reduction 0.8K
Internal insulation	Rs 3500 = £54	Insulation conceals possible problems with roof leaks	Improves comfort in both summer and winter, easy job not effecting waterproofing, modest improvement in summer, approx temp reduction of 0.8K
External insulation	Rs 11,606 = £179	Totally (screeds, bricks topping etc) external insulation is heavy and time consuming.	Installation can be used to improve waterproofing characteristics of roof, not very effective, temp reduction approximately 1K

Figure 38 Costs and concluding evaluation of interventions

Interventions were made and monitored in all of the five schools. The main criteria for choice of strategy was a desired to cool the classrooms in summer. In all of the schools classroom temperatures were reduced in summer conditions by the modest interventions. In some cases (Behari Colony, Mohib Banda and Sheikh Kali) the reduction in temperature is more remarkable because maintenance strategies such as glazing replacement, that would actually have tended to increase summer temperatures, were also carried out. This same maintenance is also reported to have improved winter conditions though, except in the most extreme case of Sheikh Kali where the improvement due to the new terrazzo floor is clearly recorded, before and after data is not available to verify the results.

11.1 Orientation At both the beginning and the end of the job, in summer conditions the coolest school is Behari Colony. The classroom was built with north facing windows and a south facing veranda. Sheikh Kali, a classroom with windows facing south, performed well in both hot and cold conditions once the damp floor had been replaced.

It is appears that the intervention strategies were most effective when combined with the advantages of good orientation (i.e. a classroom with long window walls facing south and north) It would be desirable if more careful thought was given to orientation when siting schools.

11.2 I Strategies: Summer conditions

11.2.1 Roof and external space awning, Behari Colony The strategies for thermal comfort at Behari Colony, where the largest improvement was monitored in summer temperatures, include an awning over the roof of the building and one over the external teaching space. Shading the external teaching space, although not measured by the logging devices was a successful strategy for increasing the comfort of the children and teachers. Previously in hot summer conditions the youngest of the children had had to go home early on hot days as by mid morning it was too hot for them to sit out in the sun.

11.2.2 Changes to Microclimate, Behari Colony During the course of the project a tube well was obtained and this, along with the provision of an enclosing wall in this project, has given the teachers the opportunity to significantly change the local microclimate. It has changed from an arid, bakingly hot area to a pleasant shaded garden in only two years. The teachers were pleased that it was cooler than previously. Changes in the microclimate have had a very substantial positive impact on the day to day working conditions of these children.

11.2.3 Clay Pots, Sheikh Kali The clay washing pots were inverted on the south facing room at Sheikh Kali. The monitored data suggests that this strategy was as effective as the awning though the result was not as much appreciated by the teachers. (The clay pots were unfortunately removed early in the project by an over zealous building contractor, see text, so information is not complete)

11.2.4 External and internal insulation of roof using thermopore, Mohib Banda.
Although there have been reductions in temperature in the classrooms with insulated roofs, the roof insulation strategy using thermopore both internally and externally has not produced the anticipated(and simulated) effect. The presence of the insulation tends to reduce the night time heat loss. Externally the insulation has the disadvantage that its application tends to considerably increase the roof load.(because of the need to provide a screed to falls under the insulation) Insulation, applied internally, prevents inspection of roofs that are in many cases not reliably waterproofed and constructed.

11.2.5 Air conditioning tiles, Sarband The air conditioning tiles applied to the north classroom at Sarband school seem very effective. The tiles are a thin, light proprietary tile developed by the army. Insufficient data was obtained to verify the result but it appears that the tiles are effective in reducing the ceiling temperature. Their application to the north facing room at Sarband has not managed to pull the classroom away from being one of the hotter ones in summer.

11.2.6 Painting the roof surface white, Jogiyan Painting the roof surface white had an effect that appeared to be about equal to the effect of the roof insulation. It was much easier to execute than the external insulation though the porous nature of the roof meant that it absorbed a lot of paint and also that the surface was not durable.

11.2.7 Insulated shutters, Sarband The insulated shutters were popular with the chokidar as they increased security of the classroom. In summer conditions they reduced temperatures. It seems likely that winter temperatures were improved by the shutters though unfortunately this data is not available.

11.2.8 Ventilation strategies In all of the classrooms the air was uncomfortably still. Externally, in the village areas, there is very little breeze. Simulation studies indicated that increased air movement, particularly at night would be effective in reducing day time temperatures. Three strategies were investigated:

11.2.8.1 Night ventilation by opening windows, Behari. New reinforced fly screens to improve security and thus facilitate opening the windows at night were provided at Behari Colony but these were not successful in achieving night ventilation, and the one side ventilation available would not have achieved suitable rates for purging the building.

11.2.8.2 Night ventilation by fans, Behari. Two extract fans were purchased and installed at high level on the wall opposite the windows at Behari Colony. It had been intended that these were operated on a time clock to pull air through the building at the coldest time of day but the electricity supply was never reliable and the time clocks unavailable.

11.2.8.3 Stack ventilation with high and low level openings, Mohib Banda Ventilators were installed in the west classroom, at high level in the window wall and at low level on the north facing veranda. Because teachers were worried about the structural stability of the school these ventilators could only be small (brick sized) Although the teachers thought they provided a little air movement the effect was not sufficiently large to modify air temperatures in the classroom.

11.2 Strategies: Winter conditions

Winter conditions remain cold in the classrooms and it does not seem likely that modest passive strategies can make the schools comfortably warm because of the very substantial thermal mass, the poorly sealed rooms, the short time of occupation (mornings only) and the lack of significant incidental gains. Heating in the village schools is difficult because of the lack of fuel and appliances; comfortable conditions are more easily achieved outdoors, in the sun when the weather is cold. Maintenance strategies and shutters help to raise winter classroom temperatures. It is clear from the monitored data that the Shiekh Kali classroom with its south facing windows was warmest in winter (when the floor was resolved) If schools are to achieve acceptable conditions by passive means, it will be important that classrooms are orientated with their windows facing south.

11.3 Monitoring

The job lasted too long. It was difficult to keep up the momentum for downloading the loggers over more than a year. Logging such a large number of buildings spread over quite a wide area with difficult access (not least because there is very little available in the way of maps!) made the project more difficult. It might have been better to have a group of schools (if they had been available) grouped closely together so that the issue of varying climate was avoided. All the data has been processed presuming that comparison with the central airfield data is applicable. The schools are all within a 15 mile radius of the airfield.

Collecting ‘good’ data on the building performance was difficult. A wall mounted logger (mounted at 1 metre) with insulation tucked between the logger and the wall seemed the optimum arrangement, given our requirement to collect data over a long period. This does not entirely represent the conditions experienced by the children grouped together on the floor but it was expected that improvements monitored at the wall would give similar improvements for the children. The logger was placed for security near the teachers desk; possibly some peaks in the data are due to children gathering at the teachers desk.

11.4 Other influences on the success of the project:

The influence of the teachers was very significant. At both Behari and Mohib Banda, the teachers got involved in physical labour, clearing and levelling. Those schools gained more from the project and appear quite transformed with a new microclimate developing of plants and trees that will help to improve air quality and temperatures. It is interesting to note that the average temperature at Behari Colony had further reduced in the year 1997-98 when the only changes were increased planting. A change in the microclimate may last longer than changes in the building fabric and can be achieved for very little cost but it does require the commitment and interest of local people at the school.

It is beyond the scope of this building study to speculate on improvements in the way teachers are appointed, but it has been clearly noticeable that where local teachers are appointed to the village school, they are able to provide a better service than teachers who travel from other villages.

11.5 Approach to school improvements.

My research was mostly directed to ways of cooling the schools because this is the problem that the teachers worry about. One of the teachers reported that 'you can escape from the cold, by going outside, and getting the children to run about, but the heat is inescapable.'

The hottest classroom temperatures during the school year were in September and June, at the beginning and end of the school year, when temperatures exceeded 30^0 C.

In the school year there are only three months where the average temperature exceeds the comfort zone defined by the adaptive model, and then only by less than 5^0C . One would imagine that this problem could be resolved with more ventilation and the use of fans. Two things might distort this view. The weather and temperatures change quite dramatically at the end of May: things get very hot where only two weeks previously temperatures were reasonably comfortable. Is it the sudden step in temperatures that makes the heat unacceptable? The high levels of solar radiation also make the summer conditions more intolerable. Schools are closed in the hottest time of the year to avoid the worst of the summer heat and the children can be observed splashing in streams and rivers when they are free from school and other duties!

From the data collected it seems that winter conditions might be a more a problem than overheating in the summer; temperatures in classrooms average less than 13 degrees (in the school day) in November, December, January and February. (the two weeks holiday at the end of December reduces the cold period)

11.6 Use of external spaces.

In schools where children are taught sitting on the floor, it is easy and desirable to move outside for substantial periods of the year, both summer and winter, particularly if external spaces with opportunities for shade in summer and solar gain in winter are available. The only limitation to this use of external space is the shortage of available space for teaching outdoors. Classes are quite often grouped close together and the teachers manage to overcome problems of noise.

It was observed that:

- much of the teaching takes place outside sat on the ground and
- generally both assistants and teachers tend to teach quite small groups of children, not usually more than about 20-30.
- classrooms are often used for storage (elderly desks and chairs, gravel etc were stored in the classrooms because no stores were provided and also because teachers are reludctant to dispose of Government property.)

11.7 Problems associated with the design and siting of school buildings.

In all of the schools monitored (except Jogiyan) the veranda is on the opposite side of the classroom to the windows; this, along with the fact that if one of the two classrooms is well orientated the other is bound not to be, is an unfortunate consequence of the L-shaped plan.

The model school plan (L-shaped) generates both orientation and ventilation problems.

To provide comfortable conditions in summer cross ventilation must be available along the length of the classroom.

Classrooms that are build with their windows close to other buildings (to maximise the site potential) without cross ventilation will inevitable experience poor ventilation opportunities and low lighting levels. The result is that most classrooms manage to be uncomfortable for the larger part of the school year.

Although the children are taught outside in both summer and winter, a building is seen as an essential part of a school, particularly as schools are modelled on successful private schools such as St Mary's in Peshawar or Aitchson College in Lahore. It is perceived that a school needs a building to be a 'good school' and for many practical reasons, storage, etc this is true.

Certain unsatisfied basic requirements can be identified from observation of the schools:

- external space that could be sheltered from the sun and rain would often be more comfortable than the classrooms.
- planting and trees could substantially improve the air quality and temperature
- storage spaces
- an enclosing wall
- latrines

11.8 Workshop to disseminate results.

In October 1998 a workshop was arranged in Peshawar to disseminate the results. The workshop was well supported and it appears that some architects and engineers are keenly interested in ways to make buildings more comfortable. Some schemes have already been built and others are in construction that aspire to produce more comfortable conditions at minimum energy cost. It is important these designers are supported and informed and that case studies of their work be available to inform others. A group was formed at the workshop with the intention of furthering these aims. The group were pleased to receive the support of ENERCON, through Arif Aluaddin, who publishes a quarterly magazine. The magazine has carried items about the workshop and the results and it is hoped will serve as a source of information on proven low cost methods of improving comfort in buildings.

Chapter 12. Future developments:

12.1 Dissemination of information on effective strategies

Some architects and builders in Pakistan are keenly interested and involved in schemes to improve building performance. It is important that schemes are monitored and evaluated and information disseminated to those interested so that only the most effective strategies serve as models for future building.

12.2 Modest revisions to the model school for improved thermal performance.

12.2.1 More durable over roofs The study demonstrates the effectiveness of the second roof and covered teaching area. As executed in this project the cover is not particularly graceful or long lasting. Further work could identify ways of providing a low cost solution to this problem.

12.2.2 More encouragement to schools to provide planting and trees The effect of improving the microclimate is demonstrated by the school at Behari Colony where summer conditions were both cooler and more pleasant.

12.2..3 Schools built with more thought for orientation and crossventilation. The study demonstrates the effectiveness of good orientation. None of the schools had the combination of favourable orientation and cross ventilation. A pilot project of a school built in traditional materials like the school at Jogiyan but with north and south facing windows and an over-roof would be very desirable. It would perform better than any of the schools studied and could achieve acceptable conditions in summer. Winter is more difficult: careful design of windows and veranda to catch solar gains would be necessary if comfortable winter conditions were to be achieved.

12.3 More major revisions: inclusion of Basic Health units in School provision

In the previous study funded by the British Council[29], the thermal performance of Basic Health Units was also investigated. Basic Health Units are intended as medical care for village people with a doctor and a health worker located in a small purpose built centre. As a minimum they comprise a treatment room and a nurses room. Some of the units had a few overnight beds. These bigger units were more used and therefore appeared more successful. The provision of the smallest Basic Health Units has not been successful. Doctors and health workers felt that considering the thermal performance of the buildings was unnecessary when other large operational problems were unacknowledged. At the time of the study, it was very difficult to actually locate the Units because they were not well known to local people nor signposted. Accurate detailed maps giving this sort of information are not generally available. Local people have not been confidant that the Units could provide essential treatment when urgently required because of poor staffing and equipping, and so in an emergency have been disinclined to waste time going to the units but have proceeded to the nearest hospital.

It would seem very desirable to combine the provision of a primary school with that of a basic health unit:

- Children and young families are the biggest users of free health services.
- The presence of a Health worker on the school site could be very helpful with hygiene, preventative medicine and first aid.
- The school site is known to most members of the community.

[29] Presented to the ENERCON Passive thermal design workshop, Islamabad, October 1994

- The capital cost of providing the two services in one building would be lower than providing the two separately.

12.3.1 Proposal for a revised model school

It might better fit the needs of many village communities in this or similar climatic zones if the 'model' provision of two large classrooms was replaced with :

- an office or staff room,
- a health workers room
- a store
- latrines
- external classroom spaces, enclosed and sheltered both from the sun and the monsoon
- an enclosing wall
- a water supply

Within this provision the microclimate could be arranged to be suitable for outdoor work including pleasant planted areas with reduced dust, cooling from the transpiration of the plants and some of the calmness associated with a less harsh environment.

This would improve the educational opportunities available to the children of Pakistan. Improvements to the microclimate and surroundings have been achieved at Behari Colony with very modest cost but were dependent on the considerable enthusiasm and time commitment of the teachers.

In the simulation studies, lightweight well insulated buildings appear to be a good solution for schools that are occupied for only a short period of the day but there are very few materials available in Pakistan for this type of construction. Sheet steel is widely available and might be used to make composite panels, sandwiched with thermopore (polystyrene) like the insulated shutters at Sarband. Further investigation of lightweight strategies is required.

12.4 Improved external temperature measurements.

In this study all classroom temperatures have been related to the Meteorological Office data recorded at the Airfield in Peshawar. From the limited amount of data collected (see chapter six) it seems that some climatic variation exists between the schools.
In subsequent studies it would clearly be desirable to establish the comparative external temperatures in the various areas. To achieve accurate information a Stevenson's screen would be required. Having provided a good ventilated shelter for the external logging devices it is then important to find a safe and representative place to locate the sensor. It is difficult to find a place in a school that is both representative of the local temperatures and also secure, though the garden of the chokidar or a local teacher might be suitable. Because the temperature recorded seems very sensitive to adjacent buildings etc. it would be desirable to mount the Stevenson's screen on a post, preferably at one metre height in an open area. It is easier to find a secure place at roof level than at ground level though roof level temperatures are susceptible to re-radiated heat. More work is needed to achieve accurate external temperature measurement.

APPENDIX 1 .

1.1 Government schools in Pakistan

Most Government primary schools in Pakistan comprise two classrooms. Schools are built to a model plan (figure 3), each classroom is 16 x 25 ft, and 10'6" high. Generally in the Peshawar area schools are brick built, with an external brick skin of approximately 9" thick, plastered internally. The roofs in the area are flat and in modern buildings are usually reinforced concrete, 5" thick finished with either mud or bricks externally, and white washed on the inside. Windows are mostly simple metal frames, single glazed. Doors and door frames are timber.The side hung casements open inwards because of the fly screens externally. The inward opening lights are dangerous for the heads of the children; the flyscreens tend to harbour the dust and very sharply reduce lighting levels in the classrooms

This standardisation of design makes the buildings particularly suitable as test buildings and also means that any proven improvements in design strategy could be widely disseminated.

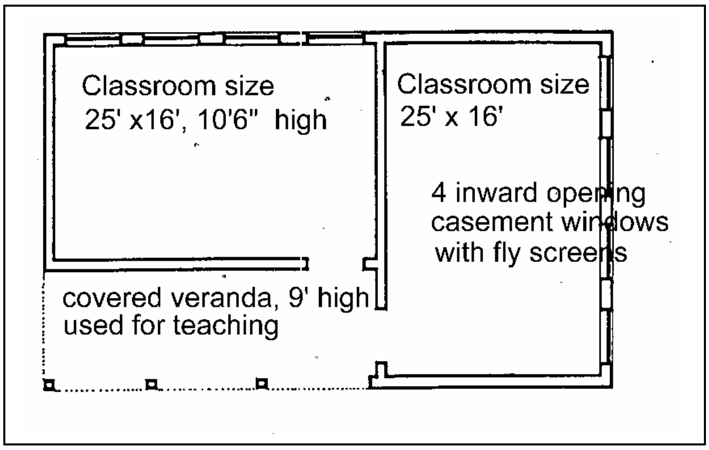


Figure 39 Plan of Model school. Orientation is not usually considered an issue in the siting of school.

Materials available are limited; in 1996 the Government passed a resolution that no timber should be used in School or Health buildings because of the extreme shortage of timber (timber is used in northern areas for fuel and has been considerably over exploited) The brick school buildings contrast with the surrounding village buildings which are usually made of mud. Schools have the advantage that they last longer: mud buildings require extensive maintenance immediately after each rainy season.

The Government funds the building of schools but the site has to be donated by the village. Thus the Education department have only a modest control over the choice of site (by power of veto) and it is not unusual for unfavourable sites- well away from the village centre or adjacent to graveyards etc to be adopted. These two classroom schools cater for upwards of 200 children, divided into groups that are taught, some inside and some outside, by teachers and assistants. Conducting lessons outside is very common; often conditions outside are more comfortable than inside both in summer if shade under a tree is available (Kramer, 1960) and in winter when the thermal mass of the buildings tend to reduce temperatures, even when the sun shines. Children sit

on the concrete floor, usually on hessian mats. Teaching is quite formal and the pupils seem much more passive than their European counterparts.
Children only attend school in the morning. Culturally it is unacceptable to have mixed schools in Pakistan; the primary schools selected include two girl's schools(GGPS) and four boys (GBPS)
The school year starts at the end of August, has a short break in December, extra holidays for Eid, and continues till the middle of June. If the weather is unusually hot (as has been the case in both 1996 and 1997) school will stop when the hot weather pattern is established (1996, mid May)

Government schools do not have any heating devices though most of the teachers regard the summer heat as a much worse problem than the winter cold: In winter there are several strategies to get warm: wearing more clothing, increased physical activity or going outside into the sun. By comparison the summer heat is relentless and inescapable. Electricity is now available at all the schools in the project and ceiling fans are used almost universally to increase thermal comfort in summer.

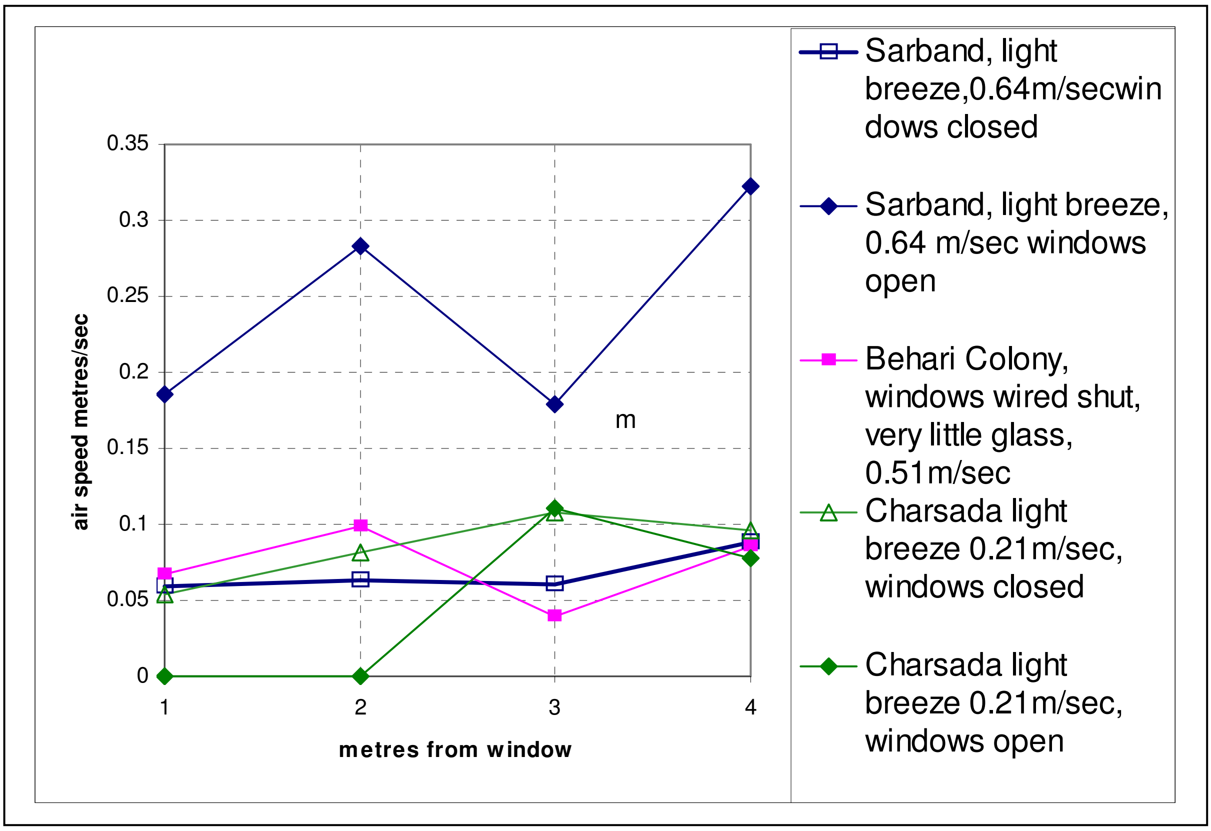


Figure 40 Summer ventilation rates at three schools, August 1996, internal measurements with Kata thermometer, external measurements with vane anemometer.

Most schools had two fans per classroom. These help to make conditions more comfortable for the children.
Ventilation with fresh air from outside is important in these schools because of the number of children in the space. When the temperature rises above normal skin temperature (around 32 ^{0}C) instead of losing heat to the space most of the heat losses will be through evaporation of moisture on the skin so the ventilation is critical, even if the outside air is hot, to aid cooling. (A different strategy would be adopted in a room with few occupants because in that circumstance the internal air might be cooler than outside and would not be saturated, so ventilation during the heat of the day would be unhelpful.)

It can be seen from the above graph that on typical days in August 1996 there was very little natural air movement in these classrooms, Crossventilation in these three schools is poor (see plans, Appendix 2) and at Sheikh Kali and Behari the windows are located within a few feet (a metre) of the boundary wall.

In country districts such as Mohib Banda where malaria is common because of the many areas of stagnant water, the provision of fly screens is seen as essential. The use of fly screens does not seem altogether logical as the doors have no screens and classes are taught with the doors wide open at most times of the year. At best the screens stop mosquitoes and other insects from coming into the building at night. Fly screens are undesirable when seeking to maximise ventilation rates because they substantially reduce ventilation rates, particularly when the mesh is dirty. Australian research demonstrates a non-linear resistance to airflow- the resistance is greater when the wind speed is low. Part of Professor Aynsley's table[30] is reproduced below:

Wind speed through clear opening	Wind speed through wire screen (porosity 80%, 5.5 wires/cm) %wind speed reduction	
	Clean screen	Dirty screen
0.5m/sec	0.25m/sec (50%	0.18 m/sec (64%)
1.0m/sec	0.55 m/sec (45%)	0.40 m/sec(60%)
1.5 m/sec	1.06 m/sec (29%)	0.85 m/sec (43%)

Figure 41 Table showing effect of Insect screens on natural ventilation wind speeds.

Aynsley suggests that to maximise ventilation rates in rooms it is desirable to fix the mesh at the outer edge of verandas. 'As well as increasing the area through which the breeze can blow this strategy also creates an insect free veranda.' This strategy is unlikely to be practical in schools where the mesh would be easily damaged and in any case during daylight hours mosquitoes are not generally a problem.

Strategies to increase ventilation have not been very successful. Those responsible for the schools were not keen to see large holes made in the building fabric. The ventilation blocks at Mohib Banda resulted in air movement of approximately 0.15m/sec average at low level which was an improvement.

It is essential that cross ventilation is provided in the school classrooms if the classrooms are to be useful. Fans to generate air movement within the classroom are not enough, though they do make the space more comfortable, as there is a need to carry away moisture laden air when the classroom is in use

At the start of the project only one school, Sarband, had latrines.
At Behari Colony the teachers hoped that the thermal performance project could provide latrines(this met with some resistance as they were not within my brief, and we looked for other sources of funding.) They wanted flushing latrines which did not seem a very environmental solution- not desirable because no sewage processing or drainage system exists. A pour flush latrine, which uses less water, seemed a better solution. Pour flush latrines usually have a porous tank underneath the latrine so that the solids remain but the liquid migrates away. In Pakistan this installation is acceptable if the pit is located away from any well. The site available for the latrines at Behari is quite restricted and it was proposed that two or three latrines are installed (one kept

[30] Aynsley,R. (1996) Natural Ventilation in Passive Thermal Design , Environmental Design Guide Royal Australian Institute of Architects

locked for the teachers and one or two for the children.) There is a significant problem keeping latrines clean and fit for use. No one is keen to be involved in the cleaning. A dirty latrine can be much more dangerous to the health than the traditional practice of relieving themselves on any odd parcel of land. The NGO (Non Government Office) that installs latrines has good literature instructing people on the way to use them and keep them serviceable- they also go and carry out teaching programmes with children. At Behari the teachers expected to take responsibility for the cleaning of the latrines as a condition of their installation.

Appendix 2 Plans of schools. Scale varies to fit sheet: all school classrooms are same size (i.e. 16 feet x 25 feet) Orientations are arranged to give north direction up the page.

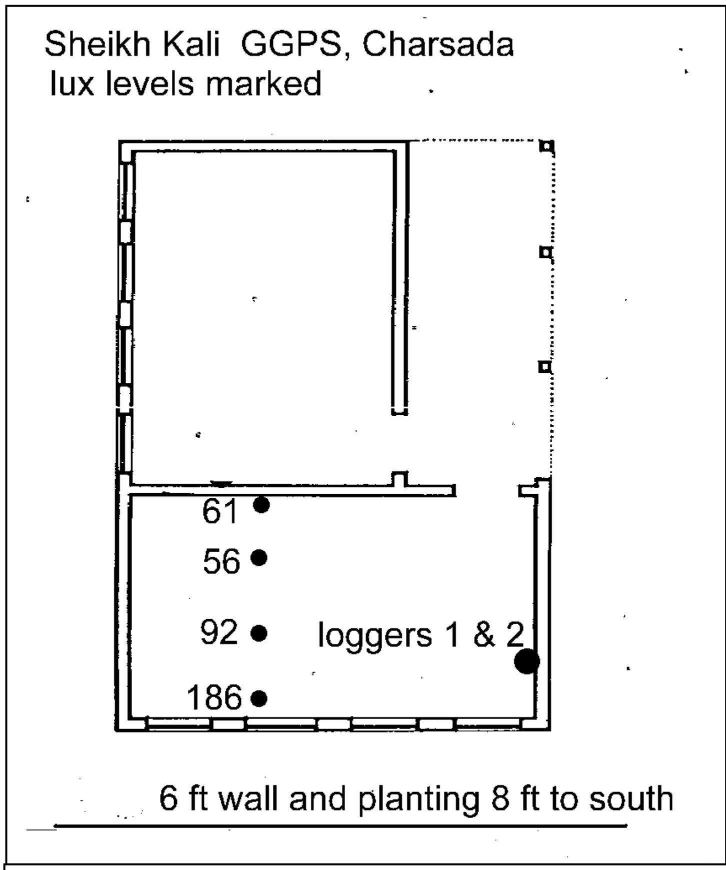


Figure 42 Sheikh Kali GGPS

Clay pots were mounted on the roof of the south facing classroom. To improve the insulative effect mud was packed between the unturned washing bowls.

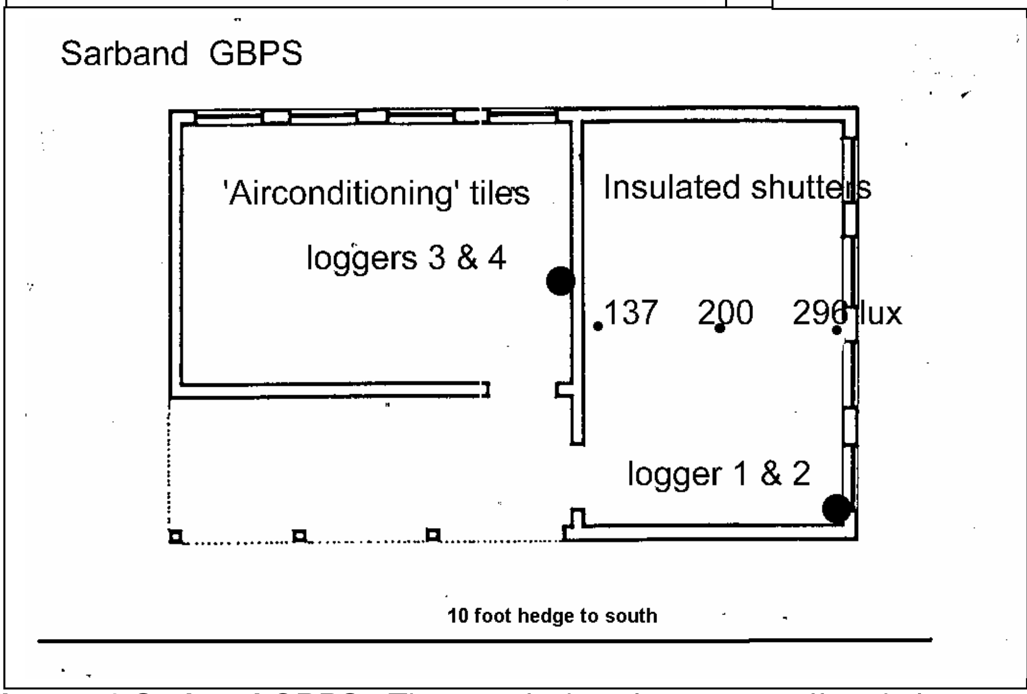


Figure 43 Sarband GBPS. The east facing classroom suffered glare and solar gain from the unobstructed east facing windows; insulated shutters improved situation and security.

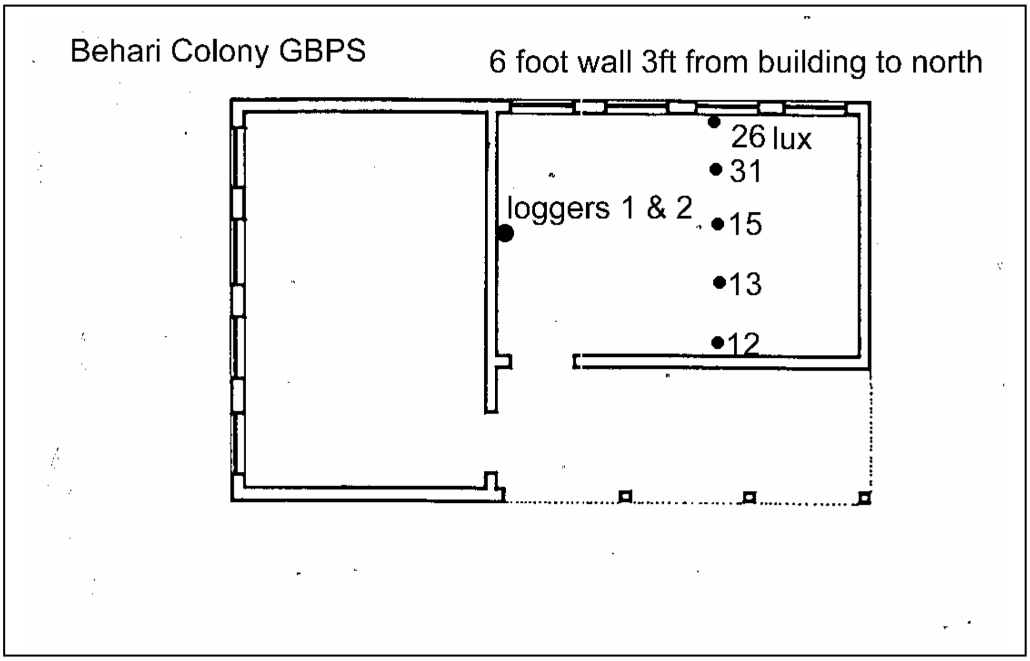


Figure 44 Behari Colony GBPS

The main intervention at Behari Colony was an awning that spread across both the roof of the classroom with north facing windows and also across the yard on the south side, creating a shaded area where the children sat for their lessons.

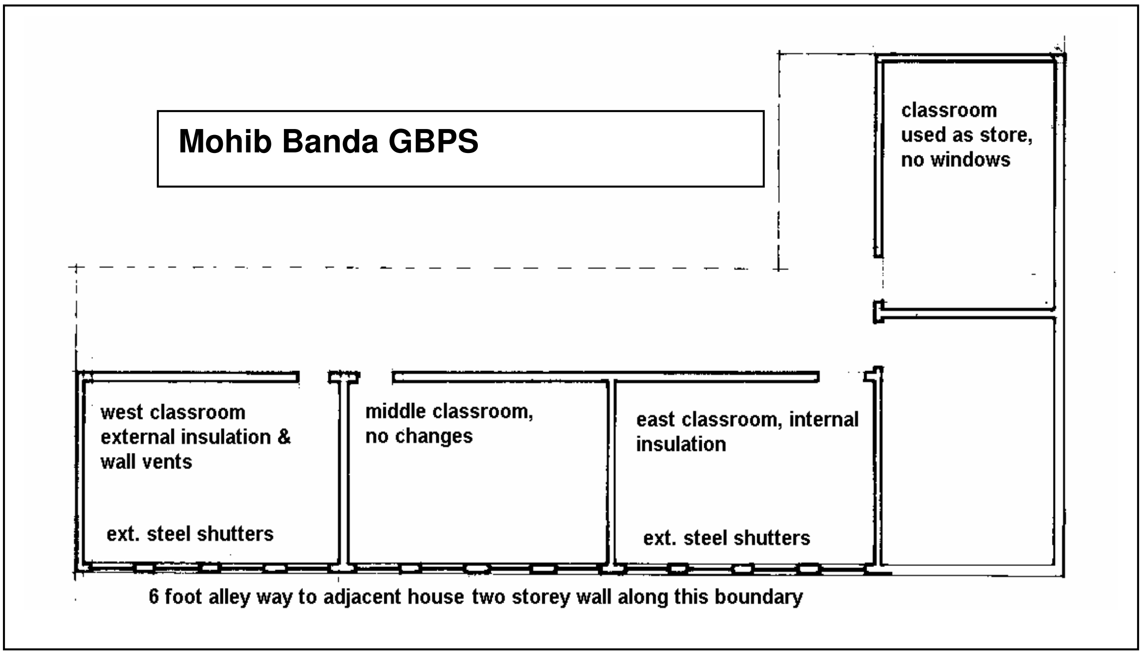


Figure 45 Mohib Banda GBPS This was the biggest school so a range of strategies were investigated in the three south facing classrooms. The wall described as south facing is in fact orientated south west.

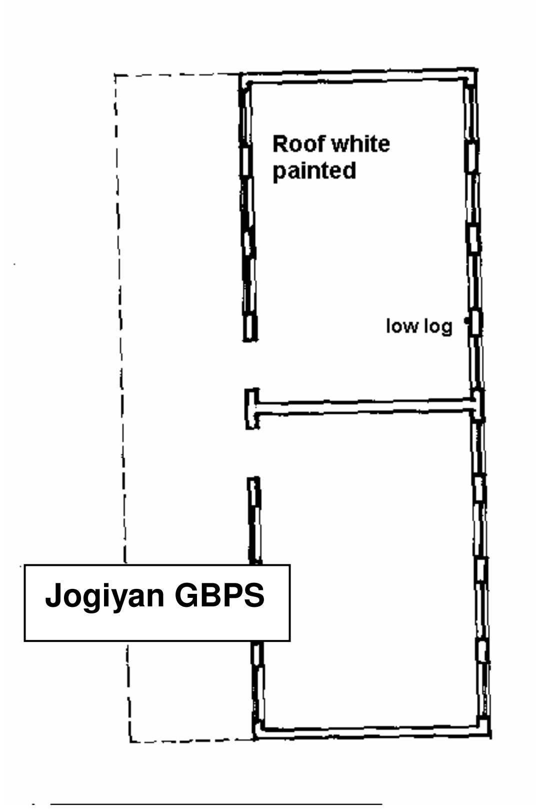


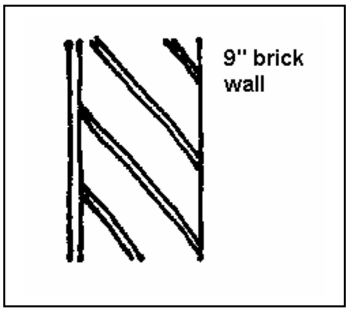
Figure 46 Jogiyan GBPS The school at Jogiyan is in excellent condition, the best in the project. It is in good decorative condition with well glazed timber frame windows It is the only primary school in the project that had cross ventilation.

Appendix 3 Construction details

Standard school construction:

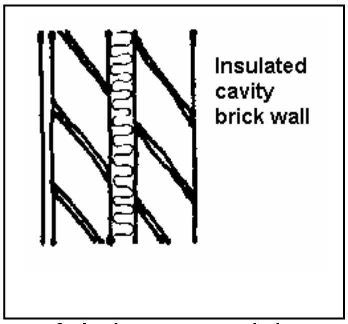
Walls

External Walls: 9" (225mm) brickwork, plastered internally



Changes to wall construction considered

cavity brick construction
plastered internally



Advantages:

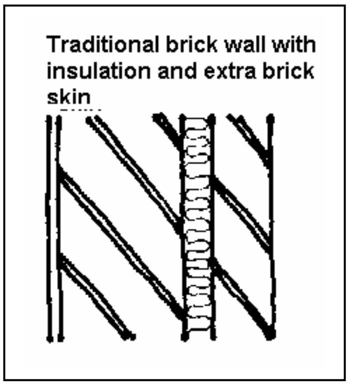
- enhanced thermal performance
- tried and tested in UK
- insulation protected in cavity

Disadvantages:

- Construction method dependent on careful site supervision and meticulous use of wall ties.
- Implies considerable change to building strategies including foundation, window details etc
- Difficult to resolve ring beam for earthquake protection

External walls:

9"(225mm) brick, plastered internally
insulation
extra brick skin to protect insulation



Advantages:

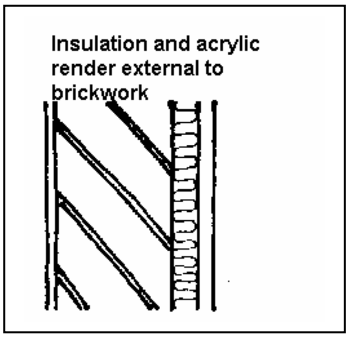
- Sometimes used in Peshawar

Disadvantages:

- Extra cost
- Increased foundation size etc

External walls:

9"(225mm) brick
Insulation bonded to brickwork
Reinforced acrylic render to protect insulation



Advantages:

- Less material increase than other options

Disadvantages:

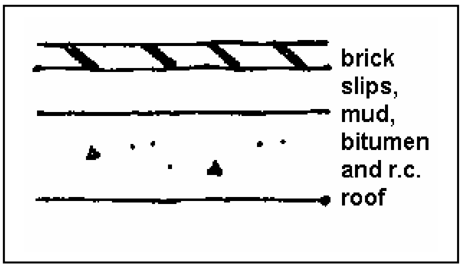
- Acrylic render is not easily available

Changes to wall construction were not pursued because simulation indicated that this was less effective and more expensive than improving roof construction and also because of the substantial additional cost of modifying wall construction. For summer conditions shading exposed east or west facing walls with planting would be desirable.

Standard roof construction

Roof:

50mm brick slips
and/or 75 mm mud
6"(125- 150mm) r.c. slab

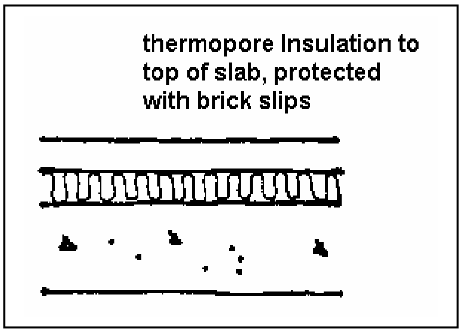


Advantages:
- familiar

Disadvantage:
- poor thermal performance

Changes to roof construction considered:

2"(50mm) brick slips
2"(50mm) thermopore insulation
125-150 mm r.c. slab

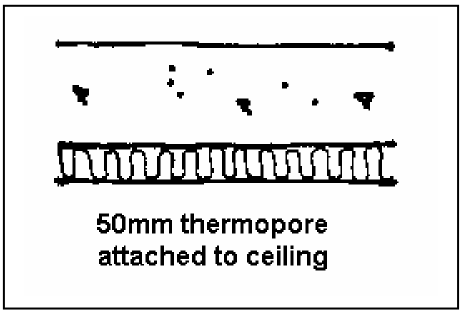


Advantages:
- better thermal performance anticipated

Disadvantages:
- thermopore is believed to make roofs leak.
- heavy, expensive if screed under insulation is laid to falls

Changes to roof construction considered:

r.c. slab, finished externally as existing
2"(50mm) thermopore insulation
fastened internally

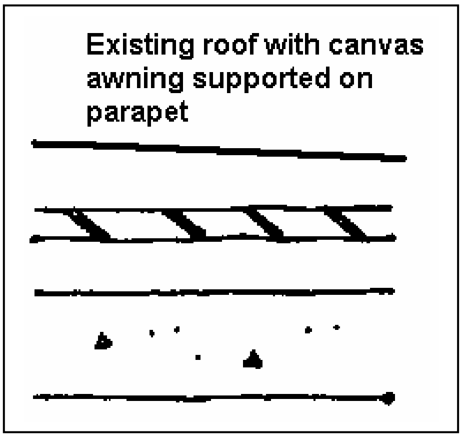


Advantages:
- Cheap to execute
- minimal extra loading on roof

Disadvantages:
- Prevents visual inspection of slab

Changes to roof construction considered:

Awning over existing roof construction



Advantages:
- Cheap, easy
- Minimum disruption

Disadvantages:
- Not long lasting
- No help in winter conditions

Appendix 4 Field trip diary

Field Trip number 1 from August 1996

Thursday 22nd August Flight to Karachi.

Saturday 24th August 1996 arrived in Peshawar

Sunday 25th August Day trip to inspect schools. Evening meeting with Gul Najam Jamy. Trip to bazaar to investigate ways of attaching loggers to the walls. We purchase cake tins to hold the loggers, hinges, and hasps and padlocks. A local man will join the hasps and hinges to the cake tins.

Monday 26th August Day trip to Charsadda schools. Late afternoon trip to Mohib Banda Schools

Tuesday 27th Meeting with Ms Stella Jafrai, Director, IUCN, Karchi. Day spent selecting schools, arranging notes and correspondance, preparing for detailed meeting with Fazil-I-Manan. Down to bazaar to pick up cake tins, etc. Send driver to purchase bamboo ladder.

Wednesday 28th August . Meeting with Deputy Director, Primary Education Department who kindly supports our proposals, signs letters giving access.etc. Driver and mason spray paint the tins black. Out to Charsadda GGPS to attach loggers. Chokidar is waiting for us along with a few village men who are interested to help with fixing. (these men would not be here on a school day)Three logger fixed. Wall fixing is difficult and a lot of the fixings get broken. On to Mohib Banda to attach loggers. Chokidar absent. Difficult to get into school- use bamboo ladder to climb into school yard. Teacher, Shah Jahan, is very helpful and arranges access. Three loggers attached. Back to Jogiyan in Nowsherra for first visit to driver Sham's school. School is in fine condition, only disadvantaged by east - west orientation of windows.

Back to the office and meeting with Mr Rafiq, IUCN local director.

Thursday 29th August Out to Sarband School to fix loggers. Chokidar present, enthusiastic. Back to Behari school to fix loggers. Teachers present. They discourage fixing of external logger as there is no school wall. Back to IUCN where we fix an external logger in the garden area. Meeting with Mr Himayatullah, Additional Secretary for the Environment.

Friday 30th August Discussions with Mr Rafiq and Gul Najam Jamy about dissemination of project information, project workshop. Afternoon off and trip to Marakand.

Saturday 31st August Train to Islamabad. Meeting with Mr Arif Alueddin, Managing Director ENERCON, Islamabad.

Sunday 1st September. Meeting with Arif Alueddin, Mohammad Afzal Haq, Secretary for Education, Mr Sheikh, Treasury Department. Discussion about ways to use information, proposal to include schools information in model school. NESPAK are reshaping the model design and Arif agrees to produce a copy of their design for comment as soon as he receives it. Working with ENERCON, it is intended that these comments become government recommendations, guide lines for model practice. Different model specifications would be applicable to the different climatic areas, hope for a pilot project. Mr Sheikh draws attention to proposal to build Basic Health Units adjoining Primary Schools (previous work on Basic Health Units for British Council confirms that units are under used because of problems staffing, equipment, and lack of familiarity of local population with the units.) He also feels that any model school proposal should include latrines. (of the schools included in the Thermal Comfort project, only one has latrines)

Arif is keen to organise publication of research material through ENERCON.

Monday 2nd September Flight home via Karachi, meet Prof Bashir of Dawood School of Architecture.

Tuesday 3rd September arrive home

Field trip Diary second field trip
31st December 1996 flight Heathrow- Karachi

Thursday 2nd January 97 Meeting with Gul Najam Jamy to discuss proposals, set up meetings for following week.

Sunday 4th January
Meeting with Mr Alam Gin Gandapor, local deputy director of IUCN and particularly interested in Forestry and planting. He sets up a meeting with the Divisional Forestry Department in Nowsherra who can supply trees.
Later time spent searching for materials, particularly thermopore sheets(polystyrene) or other insulating materials. Discover Asia Enterprises in the Commercial Complex, near PDA/PMU offices provide a guaranteed glasswool insulating coat for the top of a flat roof (see advertisement in Appendix) which is intended to be topped with 19 mm of concrete screed. This seems like an unsatisfactory specification as the concrete would surely crack and unfortunately the vendors are unable to show us any installed examples. Asia Enterprises also install an insulated ceiling with an aluminium frame to support the square sheets of thermopore but this is quite expensive.

Visit Mr S Khan to agree price and specification for insulated window shutters for Sarband School.

Order clay pots to insulate roof at Sheikh Kali and request that the potter makes square pots. Subsequently he is uncertain about this as it is outside his normal product range so we agree a price of 35R/s per round bowl, 100 bowls needed for one classroom roof.
Clay bowls have the advantage that they are locally made from a natural material and will hold an insulating cushion of air against the roof. The rows of upturned bowls will be staggered on the roof to minimise the gaps between the bowls. It is agreed that mud (traditionally used as an insulating material on flat roofs) will be applied between the bowls. There is some concern about the wieght of the bowls which are usually intended for laundry and are of unnecessarily robust construction for the purpose of insulation. To reduce the weight on the roof the existing layer of mud on top of the concrete slab will be removed. Contact Mason to agree price for insulated granolithic floor at Sheikh Kali (where the classroom floor is uneven and very damp.) Mason is unfamiliar with using thermopore under a floor slab and does not use visquene plastic vapour barrier. He agrees to visit site to price.

Monday 5th January
Visit to Forestry District Office, Nowsherra. A varity of trees are recommended for shading. Forestry will liase with the schools and hope to arrange planting for 7/8 February, National Plantation day. It is hoped that planting can be carried out and children involved in the planting of the trees. Trees will come to site barerooted, approximately 4 foot high (a good height for successful transplanting) and will require one half gallon of water per week per tree when first planted. Trees recommended for shade include simel, sheshum and jacorenda Trees are proposed for Mohib Banda, Behari Colony and Sheikh Kali.

Visit Mohib Banda school. The lower logger has been stolen. So far, with problems on two consecutive downloadings, we have no low level data from Mohib Banda. We fit three more loggers at low level on the internal walls, one in each of the three classrooms. It is much easier attaching the logger boxes using a small hand drill brought from England. The teachers and the chokidar are much troubled by vandalism at the school and we agree that it would be desirable to fit shutters on the windows and also additional windows for cross ventilation. The teachers expect to get the adjacent land owner to paint his house wall white to improve the reflected light in the classrooms.

Visit Jogiyan school and down load loggers. White painting of roof is agreed. Logger information is unexpected- temperatures in the buildings are highest around midnight towards the end of the year.(1996) It appears that perhaps the chokidar uses the building at night and warms it up with some additional heating- probably a smouldering metal tray of charcoal or coals brought in from an outside fire.

Tuesday 6th January
Visit Behari School. In summer air movement is a problem as the air is so still. The school are concerned about knocking substantial holes in the building so we investigate the use of fans. I calculate the fan speed required and am disappointed that fan ratings are not given on the fans available in the Saddar Bazaar- they come plastic or metal, the metal noisier but more purposeful looking and cheaper. I had intended to provide an awning to the roof of Behari School but the teachers are not impressed with this idea because the awning would seem more useful over the yard so that the children were cooler. We agree to provide two awnings- one for the roof and one for the yard. The things the teachers most want are a wall to enclose their school, and latrines.(it is a city school and the lack of latrines must be inconvenient- children needing to relieve themselves ask to go home and then disappear for hours!) Children at the school seem busy and well organised. There are six teachers or assistants. The children wear dark shalwa camise and a blue beret with a badge as uniform. The teachers are not keen on trees or planting unless there is a wall- in the past they have tried to plant trees and they just get trampled on and eaten by the oxen which eat anything growing. The mason wants 35,000R/s to build the boundary wall, not including gates, but the teachers think they could find someone for around 20,000R/s I agree the design of the gates The classroom is still piled high with desks- heaps of desks stretching nearly to the ceiling over about half of the room- poorly balanced and very dirty and dusty. It is apparently a punishable offence to sell Government property so although they do not need the desks they cannot get rid of them. I ring Mr Manan, Deputy director of Schools in Peshawar, to complain about this and am surprised on my next visit to find that the furniture has been moved out to the alley way at the back of the school 'because it was ruining my study' It will come back in to the classroom when I go away.

Wednesday 7th January Site visits with Jamy and Mason. First to Behari. Teachers are keen to get enclosing wall and latrines. Wall is justified in thermal research budget as it will support awning shading both pupils and incoming air to building. Mason prices for wall:. 35,000Rs for 97 foot wall. Jamy hopes to provide latrines on environmental budget. Still on the track of thermopore, visit a few other markets and addresses. Out to Charsadda with Mason and engineer. Mason prices 3300 RS for floor. He has problem of travelling from Peshawar to do the work. We are uncertain about accepting this price. Return to office. Air conditioning tile manufacturer agrees to provide tiles at the reduced rate of 12R/s per square foot. A mason will have to bed them on the roof and grout them in with white cement grout.

Thursday 9th January.
Rounding up materials. First of all trip to street of tent makers to choose awning for Behari.
Later meeting on Behari site with Mr Khan to agree details of school gates, fixings for awnings and fly screen replacements. (Fly screens are subsequently fitted and it is disappointing to note on a subsequent trip that the old fly screens have been refitted over the new ones making a screen that has sharply reduced ventilation opportunities.)
Work on schedules for work. Late (at dusk though the driver is concerned to go to the tribal area as darkness falls) we go out to Sarband to look at the fitting of the first insulated shutter. It seems to fit well though the stay need adjustment..

Friday 10th January Down to Lahore, meeting with Bishop of Lahore, Sammy Azariah and Felicity Hill (VSO teacher trainer from Oxford)

Saturday 11th January visit missionary schools in Bishop of Lahore's project. Visit city schools, and two village schools (Shah di Khoi and Sawar Road) with Felicity Hill (Children are taught outside in small groups at both schools. The classrooms are very cold at this time of year. These missionary schools have children both male and female. Shah di Khoi has not yet got any classrooms but they are working hard to organise the project.

Sunday 12th January Visit Aitchson College, Lahore for meeting with Headmaster, Shameem Khan. School is interesting in that it demonstrates standards that can be achieved in terms of comfort. Classrooms are heated in winter but not cooled in summer. Good air movement is achieved by siting the classrooms to catch the breeze(not tight against the boundary wall as is usual in government or missionary schools where getting the most classrooms on a site is one of the goals) Good daylighting is achieved by open location and helped by high ceilings in classrooms with good decorative condition and very clean fly screens.
Fly back to England and arrive on 13th January.
Sarband data was lost for several months because of a problem in this tribal area.
Data was not downloaded at this time. It was decided that one of our students from the Northern areas of Pakistan, Saleem Akhter, might go up to Peshawar to encourage progress, carry out thermal comfort survey, soothe the situation and to carry out specific measuring studies. He was pleased to travel back to Peshawar as he intended to make his MSc thesis a study on 'Ventilation for Cooling in Peshawar.'

Field trip Diary March 1998 Fourth field trip
Monday 30th March

Visit to Sarband. Our shutters look good. No sign of teachers or children (I never have seen the teachers at this school) The chokidar is summoned by the local children and we are pleased to see him. The shutters are closed when we arrive and the room reasonably cool. Apparently the shutters are not used in the way I had intended- opening them on a casement stay to let in daylight but to exclude the east sun- because the neighbourhood children who cannot afford the 5RS month to attend school come and poke things through the fly screens. The chokidar would like a wall. I am not keen about a wall because it will reduce daylight and air movement and will be very expensive. I offer a hedge. A nice lemon tree hedge but the chokidar feels the plants will immediately be stolen. He lives some distance from the school (though it was his site) Discovered that the loggers were not in the logger boxes. Initially concerned that they have been stolen but the Chokidar accurately remembers that they were taken form the site in the previous year. (later disappointed to discover we have no monitoring on Sarband since January 1997)
The air conditioning tiles are being applied to the roof of the north facing classroom.

Visit to Behari School.
Behari looks like a success story. The school microclimate is quite transformed by the new wall. Local efforts have levelled out the school yard behind the new wall and obtained a tube well. With the wall and the new water supply, all sorts of things are growing and transforming the site. Trees are growing and will soon provide some shade, tomatoes, vegetables and flowers are growing round the edges of the site. The awning has been very successful. It is left up all the time except when there is a storm. The windows still have two layers of wire fly screen but the classroom generally looks much cleaner and the furniture store has disappeared.

Tuesday 31st March 98
Sit visit to Mohib Banda . The school looks good -it now has both water and electricity supply and there are lots of plants and trees. The tungsten light fittings are extremely poor and would benefit from replacement with fluorescent tube fittings. The west classroom is dark and stuffy because the child with the shutter keys is not in school today. Apparently the ventilators work well. Roofs at Mohib Banda leak. We hope this will be cured by our external work.
Visit Jogiyan school .One logger has been stolen(low level)so we install a new logger. And talk to Assistant head of School. Roof paintwork looks in need of another coat- it has not lasted very well.
Back to IUCN office to work on detailed proposals for week. Surveyor in IUCN tells me of excellent Japanese primary school built in Hyathabad. Mr Manan will arrange trip to visit.
Out to 'Guls Garden' Nursery to price hedging materials for Sarband. Lemon trees can be obtained for 8r/s each, delivered to site.
Supper with Jamy planning Autumn workshop.

Wednesday 1st April
Site visit first of all to the Janus school in Hyathabad. It is a Japanese aid school. The school is very nice looking, well constructed and clean. The main problems are the lack of fly screens and the east-west orientation of the windows so the rooms get very hot. Good lighting is achieved by four fluorescent tubes in each classroom. Children's pour flush latrines are filthy.
Site visit to Sheikh Kali in Charsadda.
The headmistress and staff are very welcoming. The clay pot story is extraordinary. Apparently the clay pots were put on the roof in March. Teachers thought they improved comfort in the buildings in the early part of the summer. School stopped mid-June and a Government building contractor came and removed them from the roof to replace them with the normal brick tiles. It is not clear where the bowls had gone. Any reject building materials tend to lie about round the edge of the building - and there were no fragments to bowl- so it might be presumed that a new home had been found for these washing up bowls. I took down the loggers as there seemed to be no point in continuing with the monitoring.

Lunch in Peshawar then a bit more searching for materials (pricing visqueen, bituminous paint, cement and bricks for our new insulated roof at Mohib Banda.

Visit to Parks Community Development- Zakaullah Khan and Shafiq Durrani. They think they could do pour flush latrines for Behari for 8000-9000 R/s and will come on site on Friday morning .

Appoint labouring staff to carry out insulation work at Mohib Banda. Sheeran will fix thermopore internally with the assistance of a day labourer (300 R/s day for Sheeran and 80 R/s day for labourer. Working party to Mohib Banda will be van plus driver, Mason plus labourer, Sheeran .plus labourer, Masoot, me and IUCN driver.

Thursday 2nd April

Long day at Mohib Banda.

The van brought the thermopore. The pupils from the school gather round and help unload it. Sheeran and his labourer fasten it very neatly to the underside of the slab in the east classroom using screws into rawl plugs and large washers. Sheeran is a very neat workman. We are pleased to find that overnight the teachers have removed the mud (traditionally used as insulation on top of a concrete slab) from the roof, clearing down to the concrete slab. Masoot and the labourers go off to purchase sand and aggregate locally so that we can cast a screed to give a fall on the roof towards the drain holes.(it is no wonder that the roof leaked- the drain holes are constructed a bit like a swimming pool - about 3 inches higher than the roof area- so the roof would not drain until the water was at least three inches deep on the roof. The mason puts on a screed with falls to the drain holes which are cut deeper. The screed is a minimum of about 30 mm on the thin edge (probably a bit thin but I am concerned about the weight) and about 100mm on the top edge.

The mother of one of the teachers, Shah Jahan, sends a very nice lunch for the 10 assembled workers.

After lunch a large number of village men turn up to help work. They are pleased that the project involves some physical action and are getting fed up with the LUPUS project because 'nothing ever happens except talk'

After lunch I go to the nearest town(about 5 miles away to buy glue that will stick the polystyrene and sweets for everyone, a traditional celebration of the start of a building project. Lots of the school children have turned up and are pleased to get involved in tasks such as handing materials on to the roof or wetting the bricks. Every one keeps working until about 5.00 p.m. It is hard work because the concrete is all mixed by hand and passed up onto the roof in a small dish that sits on the head (it is not easy keeping the mason to the 1:3:6 mix that we previously agreed- generally the cement powder is going a long way!) when the mason finishes the slab- we cover it with the polythene sheet and bits of damp sacking to prevent too much water evaporation - the mason will return on Saturday when the slab has cured a bit.

Everyone is paid off at the end of the day, although we are expecting Sheeran and his labourer to work on Friday, finishing the internal thermopore layer in the east classroom.

The labourers prefer to take the bus than travel with us (they are not at ease with contact with a woman outside their own family)

Later discuss two other projects that Jamy and IUCN would like to see - a model sustainable hotel in the mountains and a model latrine installation at the central bus station- I believe there are no lavatories there at all at present. Need to investigate how many buses come into Peshawar City bus station per hour.

Friday 3rd April

Meeting with Shafiq Durrani and site visit to Behari Colony school where we agree that an installation of a three hole latrine might be about right (one for the teachers and two for the children.) Three chamber septic tank proposed . I enquire about smaller sized latrines for smaller children but this is not something that people ever do - I think they might be less dirty if the ergonomics of the children were more carefully considered. Shafiq would like to make the installation with a very small window- I would rather make provision for more light and ventilation and propose roof lifted up above the walls but this is not welcomed.

Masoot and I then went to investigate the Ethnology Museum on the Peshawar University Campus as a venue for our Autumn workshop. It is a nice building with nice grounds but there is very little in the way of small rooms for seminar groups and it is a very long way from the centre of Peshawar and the general bustle- could be almost anywhere! We will discuss price with Jamy.
Buy screws to fix more loggers and head out to Sarband late morning. We are disappointed to find the teachers have already dispersed their classes and gone home. We fix the three new logging devices in the north facing room. The chokidar appears after a while- he has been down to the bazaar in Peshawar. We are unable to agree on the hedging- he wants a wall and I am not keen because of the cost- and the visual intrusion. A hedge would make the incoming air cooler,
Our driver, who comes from Sarband wants to attend the mosque for Friday prayers so Masoot and I sit about outside the GBP School. A Mr Khan comes along and introduces himself- he has given the site for the GGPS and GGMS (Government Girls Middle School) mostly, as I understand it, because he wants his six girls to get into school without being observed by men outside his family. He is keen to show us his school and his hoojera so we go off for a look round. He has a large house with huge gun turrets and a spacious, well orientated school adjacent to his house. There is a strong team of women teachers who are pleased to talk to a visiting woman. We measure up Mr Aunarngzeli Khan's school as a possible replacement for the Sheikh Kali school and fit up some loggers in the classrooms. (In due course the clay washing bowls were fitted onto this roof. It is disappointing to report that the logger in the room with the bowls was mislaid and so we did not get any data from this venture.)
Next to the Meteorological office on the Khyber Road near the Pearl Continental. There is lots of equipment for measuring earthquakes and nuclear fallout but nothing for temperatures. That is recorded at the Airforce base- not easily available to civilians. He will ask his boss if we can have a pass and someone to accompany us on Saturday afternoon.
Finally up University Road looking for Brick tiles for the top of the roof at Mohib Banda- find something suitable at the top of Jamrud Road: 2600R/s for 1000 bricks delivered to Mohib Banda.

Saturday 4th April 1998
Out early and up to the brick works at 7.30 a.m. Finally we are all assembled and the van to carry the bricks appears. Khansheeran is detailed to travel with the bricks and off we go picking up black bitumen paint en route. The concrete slab looks quite good- a bit crumbly in places where there was too little cement. The mason hacks out the drainage holes a bit and then paint the top surface with the bitumen. We run out of bitumen paint and the car is despatched to the nearest town to buy more paint. The bricks are very slow to appear. Finally after lunch the bricks, a huge lorry and Khan Sheeran arrive hot and tired. The lorry had broken down en route. The ceiling with the internal insulation is finished.
Back to the Meteorological office and then to the Airforce base seeking temperature data but no joy. Nearly Eid and everyone has animals tethered up on the verges and attached to their car bumpers for the feast. I wonder if people get injured by these animals tethered in unsuitable places and with unsuitable materials (bulls led on bits of string) but Masoot feels the main trouble is that lots of them 'runs away!'

Sunday 5th April
Up early to leave for Mohib Banda at 7.00 a.m. Jamshek the driver has slept in the office so that we can make an early start. We buy sand at a merchant in the small town close to Mohib Banda. Having bought the sand we then have to hire a van to transport it out to the school. When we get to the school there has been a tragedy. The kitchen roof of one of the teachers, Iqbul, collapsed last night while they were eating their supper, killed their baby and injured two of their other children. The baby's funeral will be at 9.00 this morning so things are pretty quiet until later in the day. The mason is very late to arrive on the bus from Peshawar. Finally members of the NGO arrive, the kids wet the bricks in the new tube well and pass the bricks onto the roof. It is agreed that the brick tile topping will be just mortar jointed- not another screed though the mason feels this would be a better construction- clearly the brick work will crack a bit with the compressible surface underneath- I am worried about the weight.

We finish in time to drop me at the airport for the late afternoon flight to Islamabad. Masoot will carry on working for a few weeks to finish the various bits of work. If he hasn't got a better job by September, we will employ him for a few weeks to tidy things up and get a coat of paint on the schools before the workshop. We are interested to compare the wearing characteristics of various types of paint- Government usually supplies white wash- it very quickly starts to flake. It will be difficult to apply a better quality paint, emulsion for instance, without scraping off all the lime wash.

Monday 6th April 1998
Visit to the Meteorological Office in Islamabad where I am very lucky to meet the Director- General of the Metorological Iffice in Pakistan, Dr Qumur uz Zaman Chaudrey. He promises to send me the hourly temperature data.
Later. Meeting with Arif Alueddin at ENERCON. Arif is keen that we carry on the refurbishment work through an NGO. Discuss Autumn workshop and suitable Chief guests.
Back to VIP (the guesthouse where I am staying) for a meeting with Gul Najam Jamy, planning out the details of the workshop. Jamy hopes to get University Vice-Chancellor as Chief guest for the workshop - there is a hope that a school of Architecture could be started in Peshawar and so a link with building research would be desirable. Green's Banqueting suite seems more desirable than the University as a venue- more central, easier for rail transport etc. We will organise a student design competition with a cash prize and for each school of Architecture a couple of free student places and one for staff in the workshop as well as free travel and accommodation.

Tuesday 7th April
Fly home.

Field trip Diary Workshop field trip

Saturday 24th October. Flew into Lahore and transferred up to Peshawar on the morning flight.
Sunday 25th October. Day off (and trip up the Kyber!)
Monday 26th October. Last minute planning for workshop, photocopy papers, make arrangements for school tour and Heritage trail tour to the Sethi Houses.
Meet Mr Zahoor Durrani of Sethi Travel who will arrange our heritage tour visit- he will give us a guided tour of buildings in the old city and then is arranging tea in the Sethi House.
Tuesday 27th October. Around 40 people assemble for the workshop, including lecturers from both Lahore and Karachi, two site agent types from Gilgit- working for the Aga Khan foundation.. Seem keen, interested, well informed. Four students, in two pairs have produced a competition design for a low energy school. Last minute panic with both overhead machine and slide projector.
Presentations through the morning, lunch, discussion, out at 3.00 p.m. on Old City tour.
Wednesday 28th October. Day out touring the refurbished school buildings. Start at Behari Colony, then Mohib Banda where we have lunch (taken with us in boxes as there was rather too many of us to descend on Shahjahan's Mum) and then onto Sarband for tea. The Workshop dinner is arranged for the Shiraz in Jamrud Road. Nearly everyone turns up- about 40 people including some of the people who have worked on the project- Khan Sheeran and his dad, and Masoot who now has a permanent job, etc.
Thursday 29th October. Last day of the workshop. Mostly taken with discussion sessions focussing on strategies to reduce energy use and to discuss common environmental problems that need to be addressed. One of the problems is that the house type is evolving. In the city people cannot afford a plot big enough for the traditional courtyard house. Houses are designed for 5 people but 10 people or more are usually housed in that unit. So many plans are submitted for approval by people not qualified to design houses- the way they get round the regulations is to pay an architect to sign their drawings. Architects felt this illegal practice should be more strongly discouraged. The group felt that most people wanted airconditioning in some part of their dwelling. People in my discussion group felt that better use of the media and television would enhance interest in strategies to reduce energy use/ improve comfort. People felt that there was quite a lot of cheating in payments for energy use and this made it not worth getting involved in energy efficiency issues. There was interest in a simple code that could be strictly implemented. The group of architects and lecturers(all Pakistani except me) felt that wider discussion of television, raising peoples awareness of what could be achieved - and more publication of case studies circulated to architects. Architects felt that a 'model building' in different climate types would be very influential.
One of the most interesting developments from the workshop was a group of Pakistani Architects formed who would keep in contact to share information particularly on environmental issues. It was hoped that case studies could be published of buildings that are performing well so that people would have increasing confidence in using these strategies.
We were grateful to Mr Asif Khan, Secretary, Education for taking time out to come and close the final session. He presented the certificates of attendance(Oxford Brookes short course certificates) and the workshop concluded with lunch.
Javaid Malik (Sunbelt Architecture) has been carrying out some interesting low energy buildings in Peshawar. He has built a couple of houses with wind catchers including one in the Old City for his cousin. It uses wind catchers and evaporative coolers. It is apparently performing well. A group of people from the workshop were interested to visit this on our last afternoon in Peshawar.
Later debriefing session with Jamy.
Friday 30th Down to Islamabad to meet Arif Aalueddin who had been unable to get up to the workshop. We discuss strategies for implimenting the proposals for increased public awareness. Arif is publishing a quarterly magazine about activities relating to ENERCON. He will be pleased to set aside a page in each publication for notes about environmental building. (Our first page in this magazine was an account of the workshop and a brief resume of the general work supported by DFID)

Saturday 31st October Flight home from Lahore.

Appendix 5 Monitored data

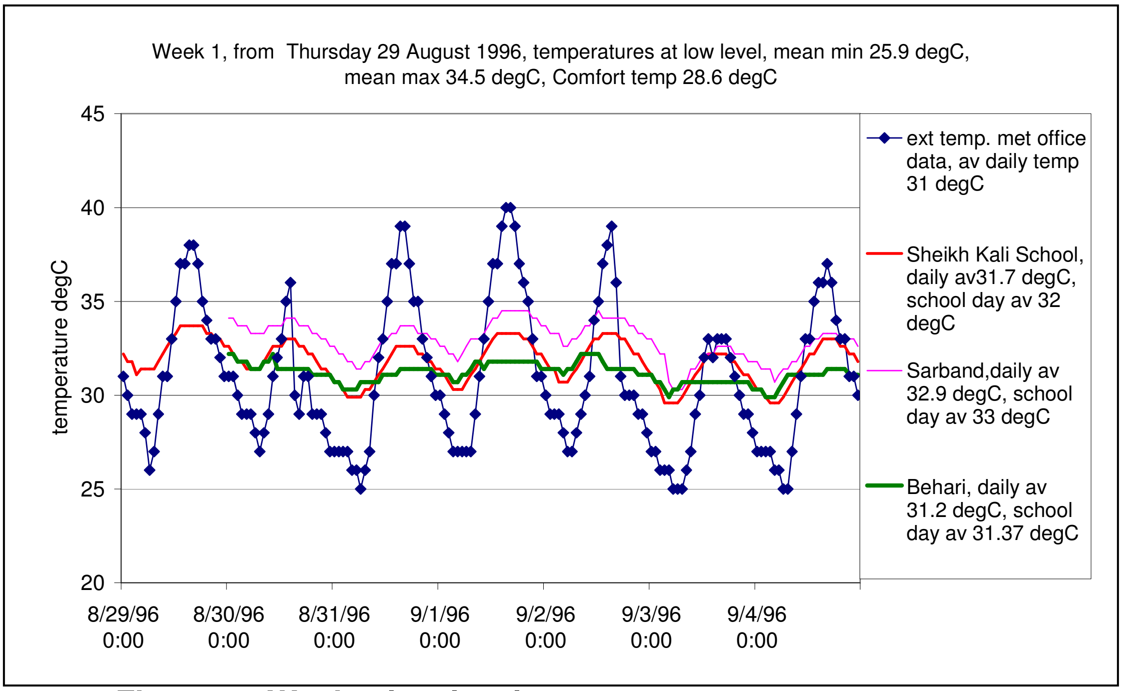


Figure 47 Week 1 low level temperatures

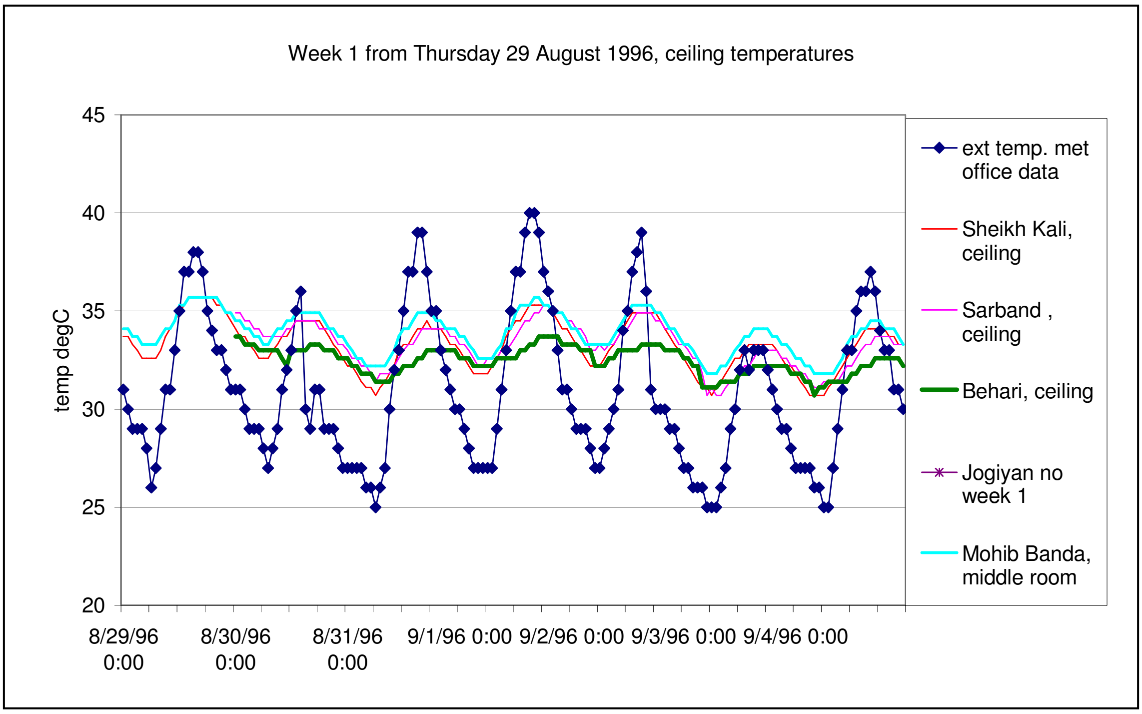


Figure 48 Week 1 Ceiling temperatures

Temperatures at ceiling level are much less variable than the classroom temperatures: three of the schools have very similar temperature profiles at ceiling level. Roof construction is similar – concrete slab topped with mud (Mohib Banda and Sheikh Kali) or brick slips (Sarband and Behari) Variation at low level in the classroom is influenced by window orientation, ventilation and use of classroom.

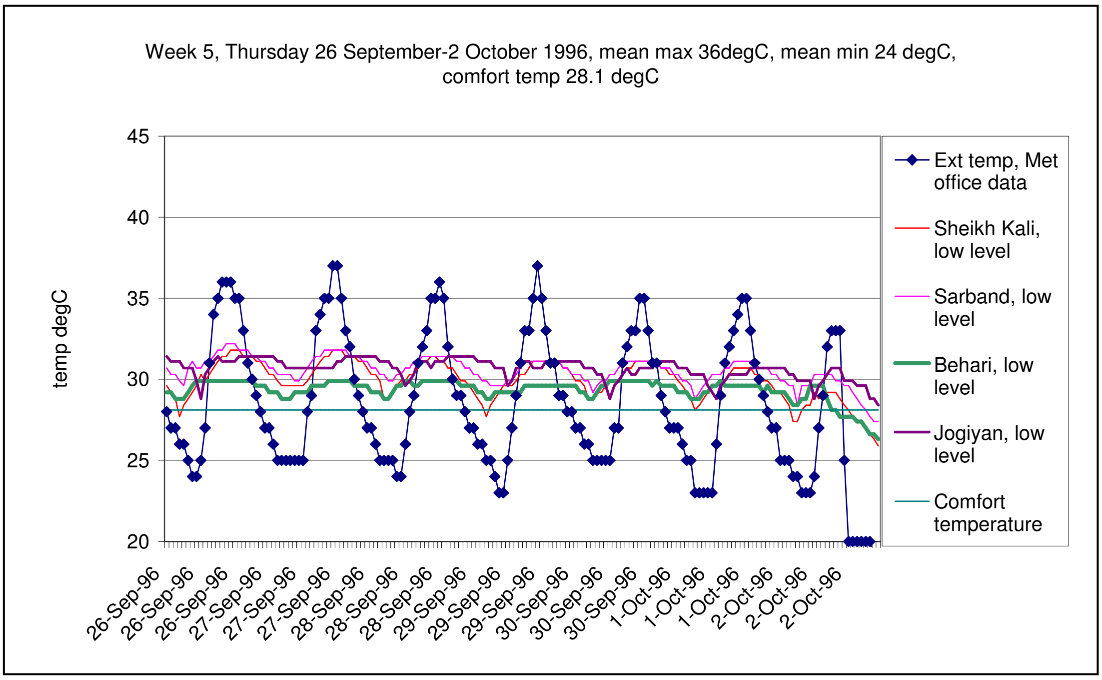


Figure 49 Week 5 temperatures at low level

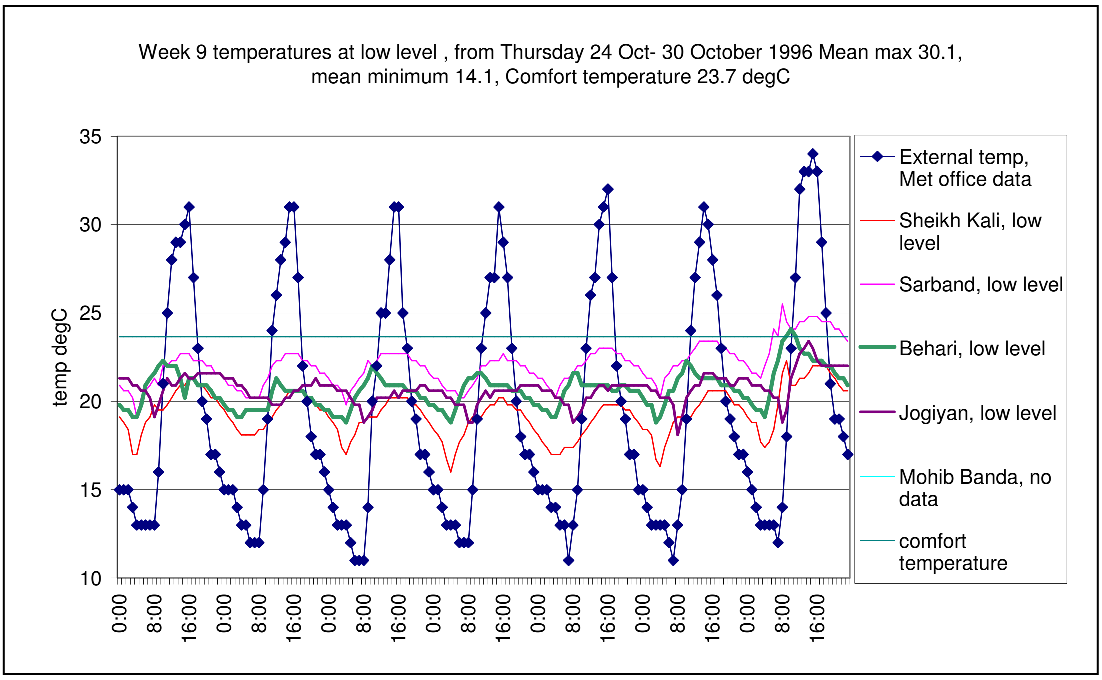


Figure 50 Week 9 low level temperatures

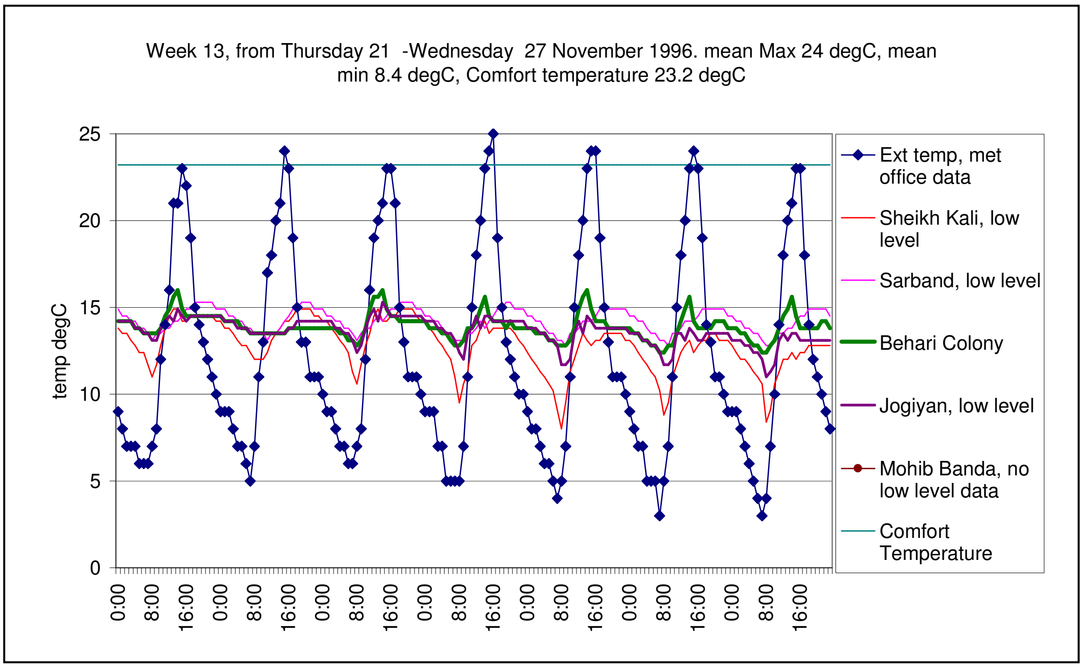


Figure 51 Week 13 low level temperatures

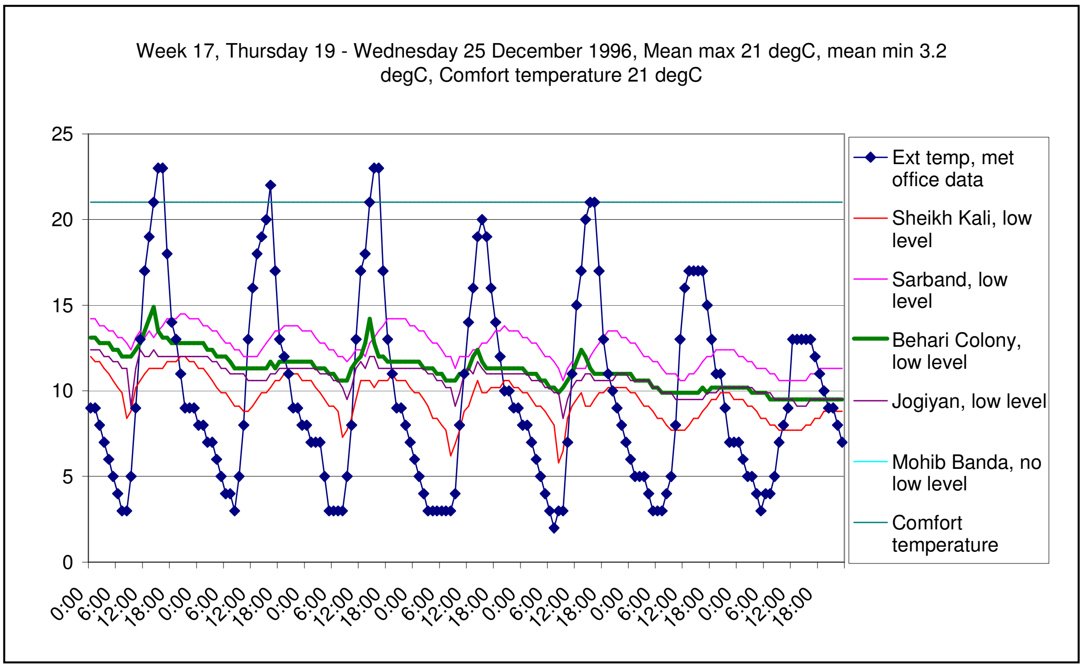


Figure 52 Week 17 Low level temperatures

Peaks in the Behari temperatures are attributed to an open south facing door catching the low winter sun; the sun was probably shining directly onto the logger (see logging position from school information in appendix. It is interesting to note that unexpectedly the classroom with south facing windows, Sheikh Kali, is coldest- this could possibly by attributed to the damp floor- see improvement by February with new terrazzo floor

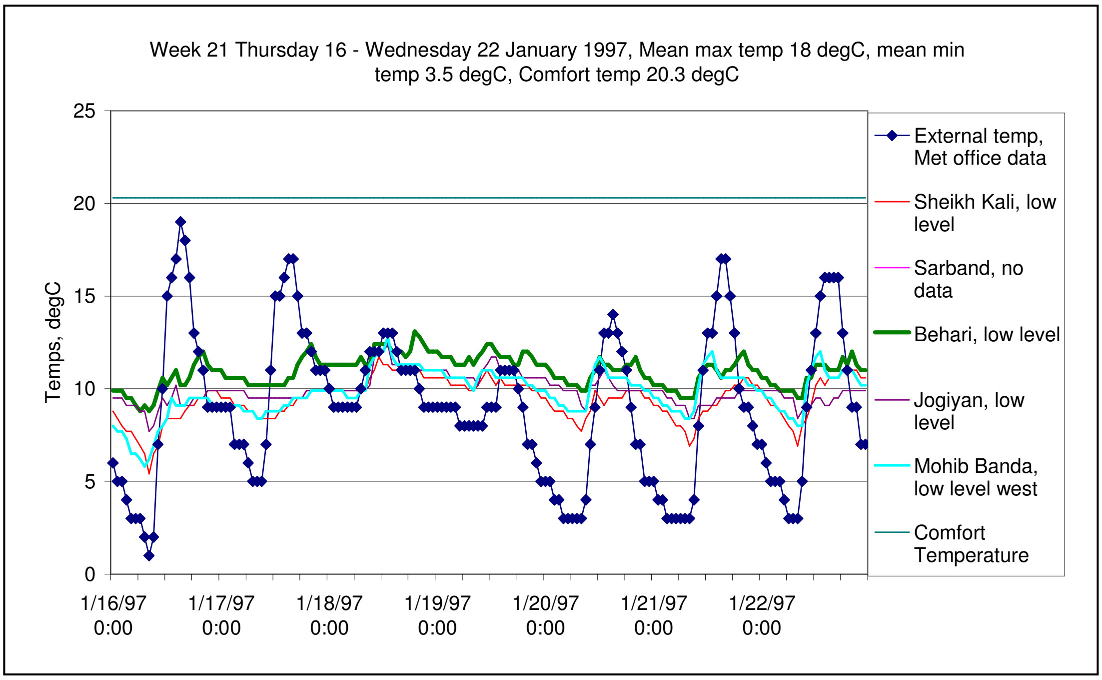


Figure 53 Week 21 low level temperatures

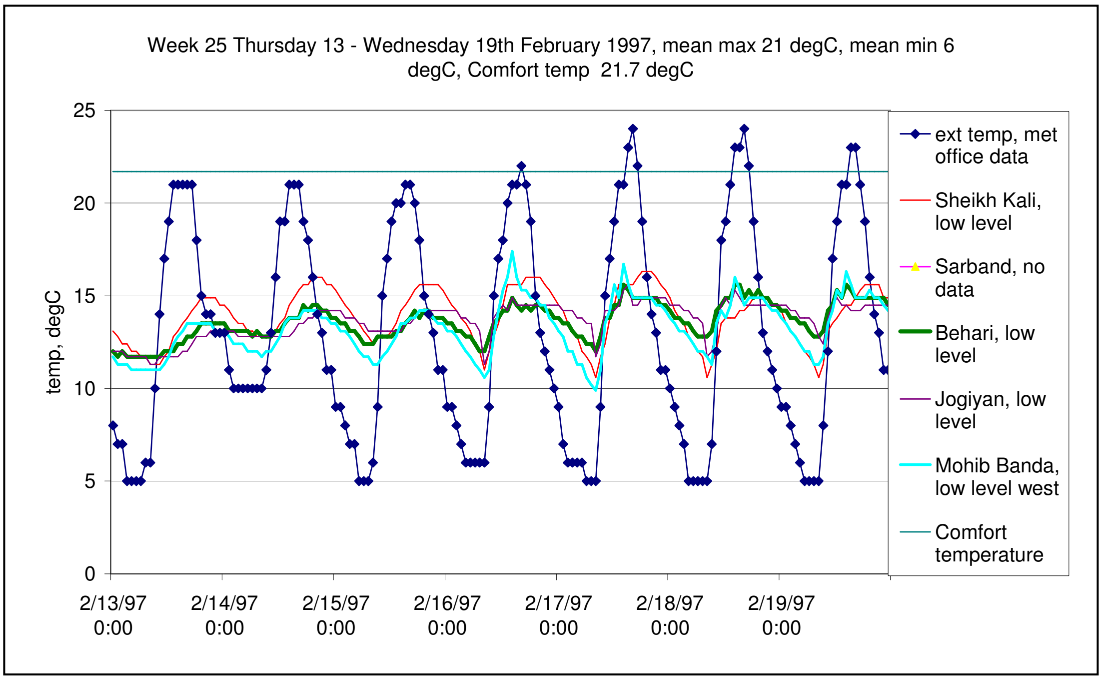


Figure 54 Week 25 low level temperatures

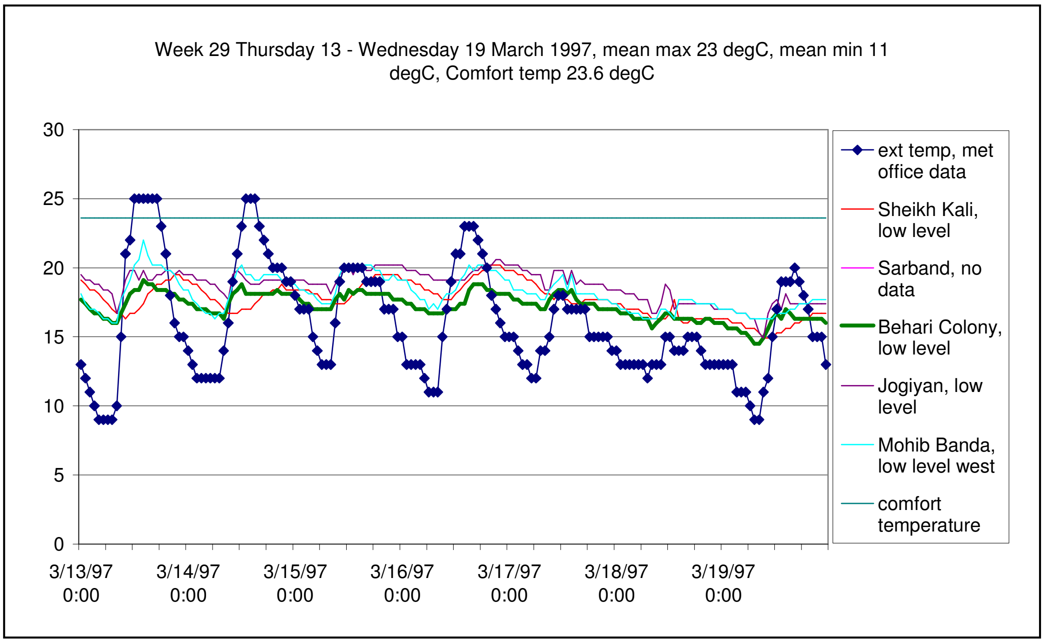


Figure 55 Week 29 low level temperatures

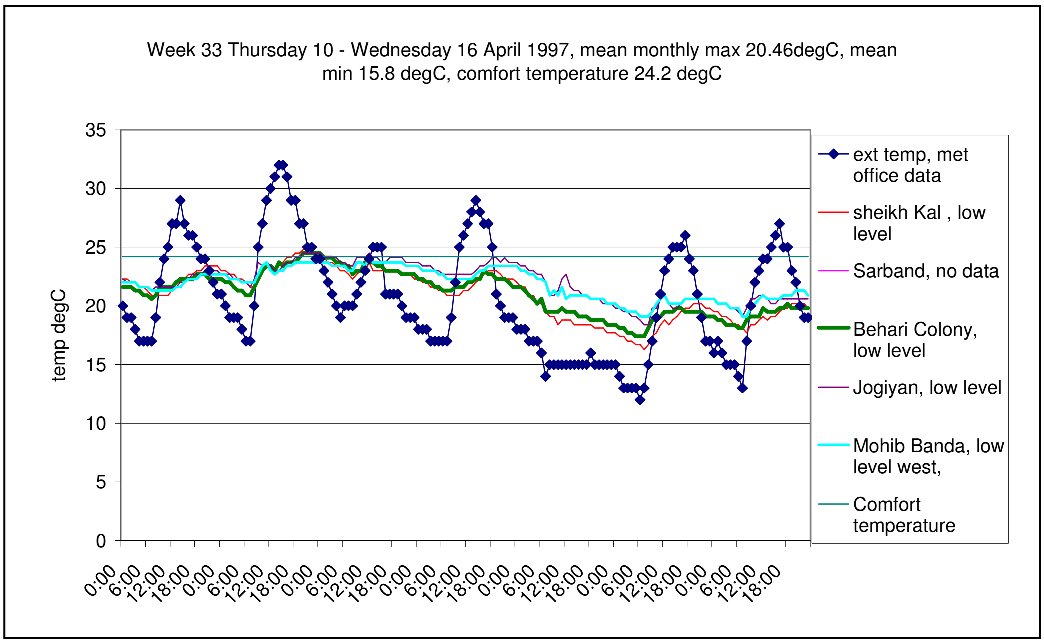


Figure 56 Week 33 low level temperatures

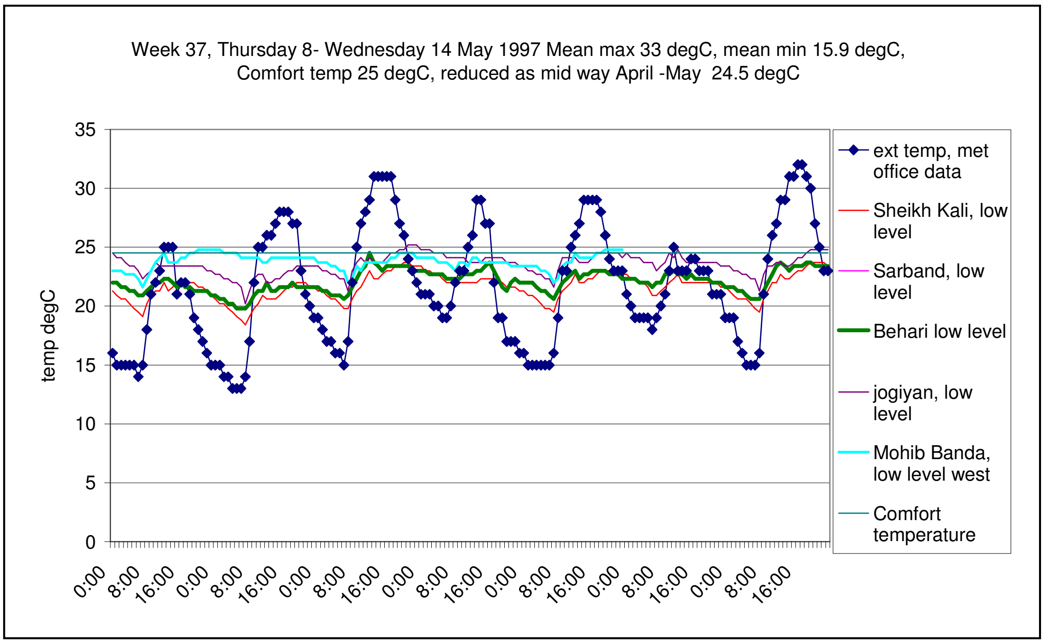


Figure 57 Week 37 Low level temperatures

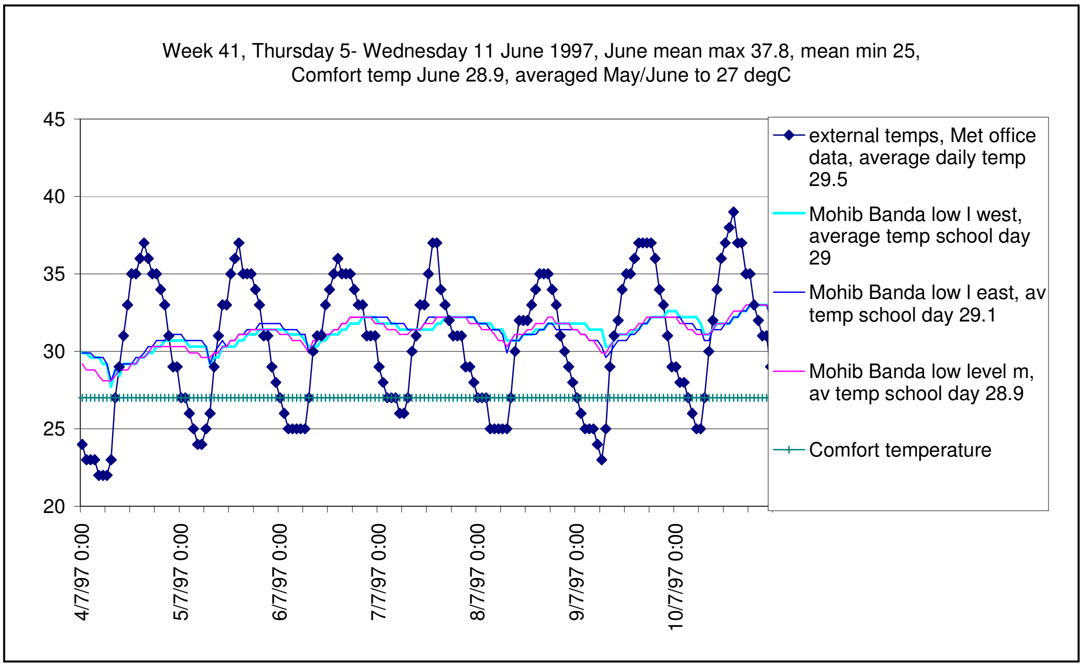


Figure 58 Week 41 Low level temperatures at Mohib Banda

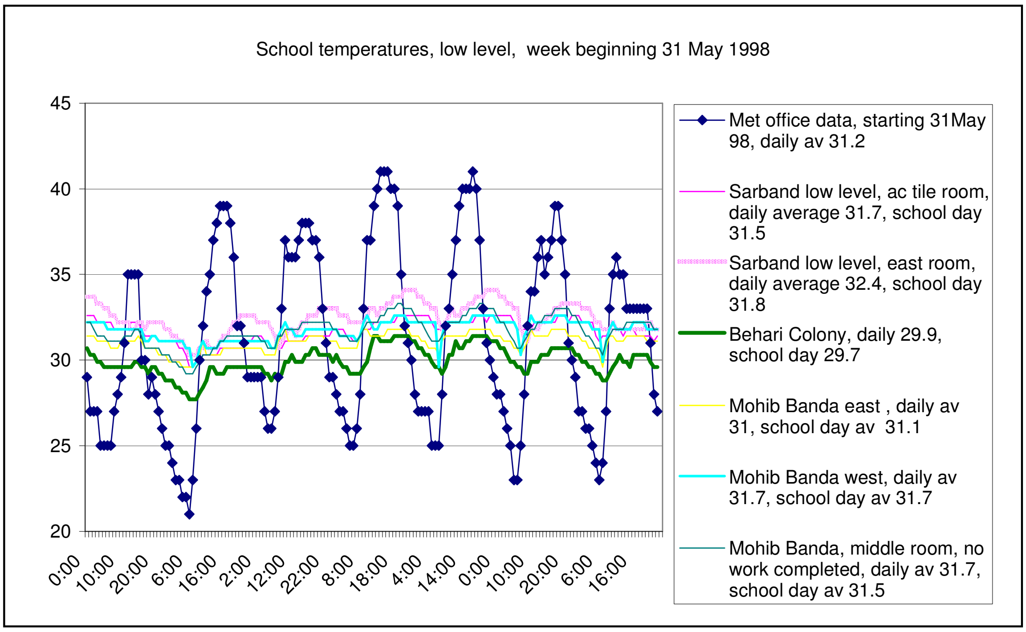


Figure 59 Week beginning 31 May 1998, low level temperatures

Appendix 6: choosing the data presentation

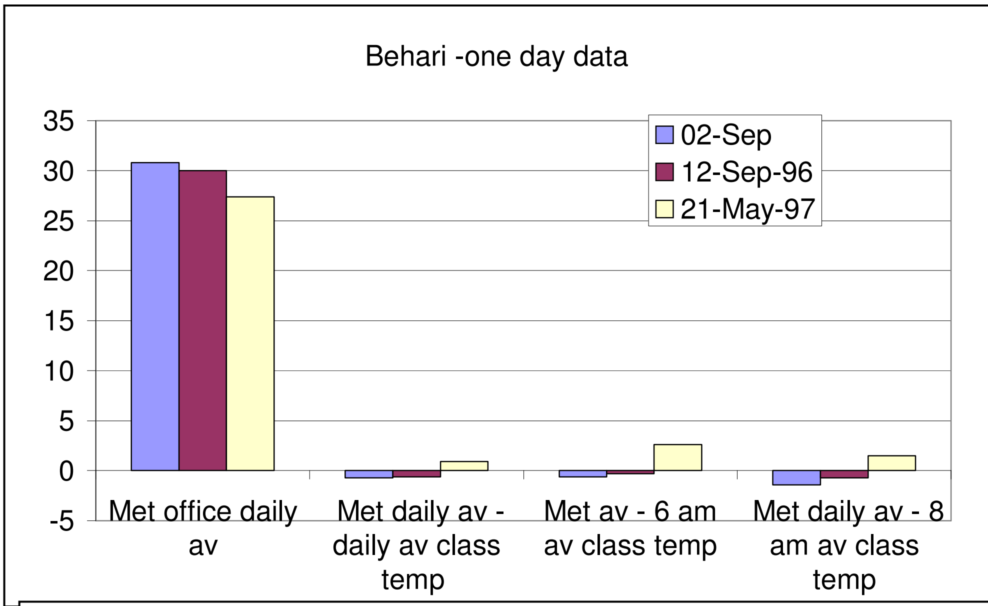


Figure 60 Comparing data for one day
It can be seen that comparison of single days suggests a varying performance: temperatures are influenced by preceding days.

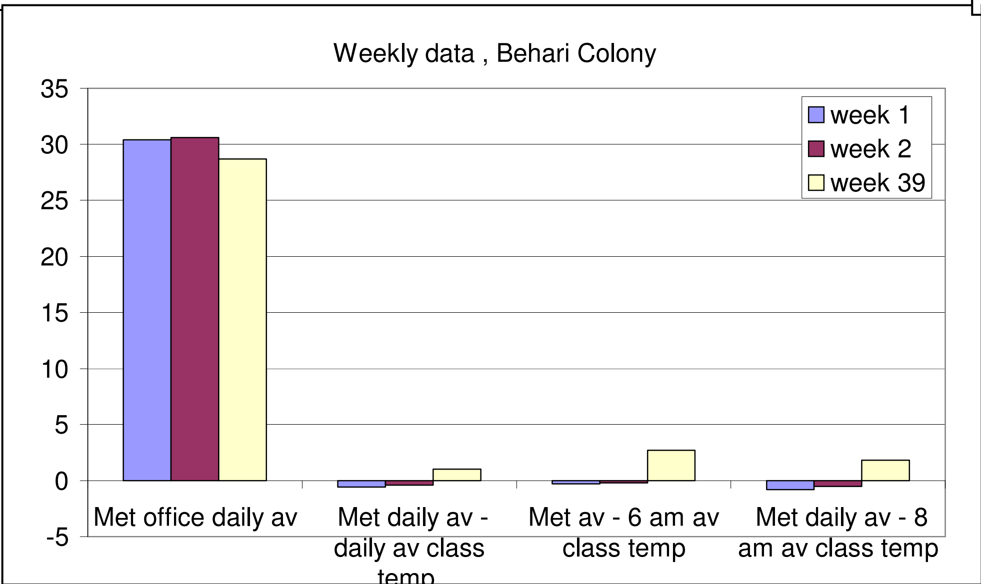


Figure 61 Weekly data. Average daily, 6 am av and 8 am av give similar results. Weeks 1 and2 are before intervention, week 39 after installing awning over roof

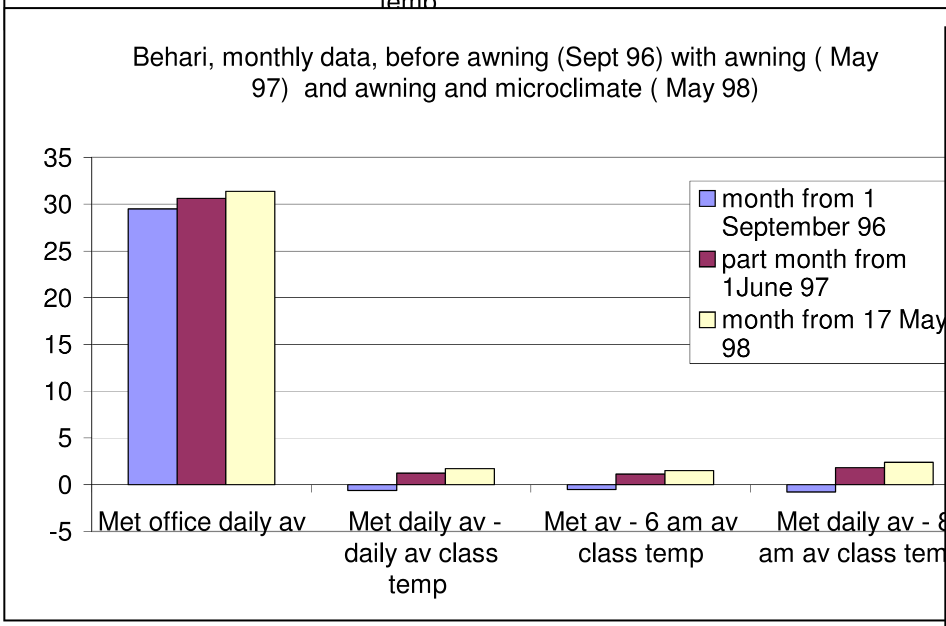
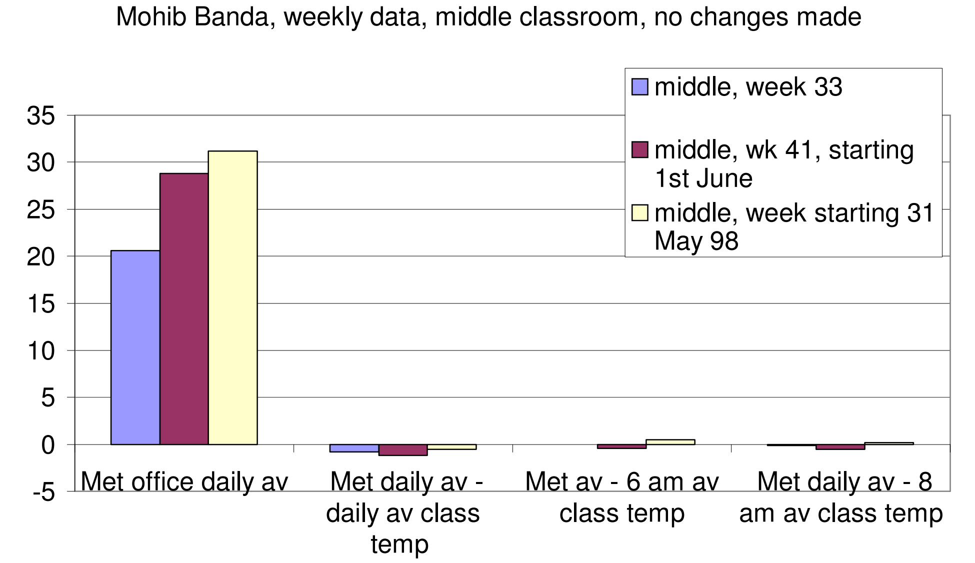
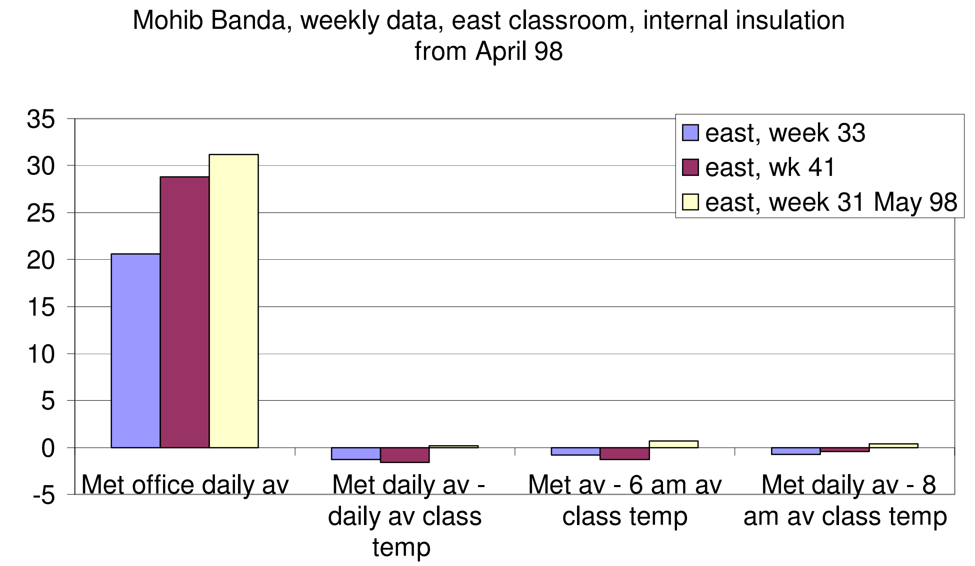


Figure 62 Behari Monthly data: information is similar to weekly data





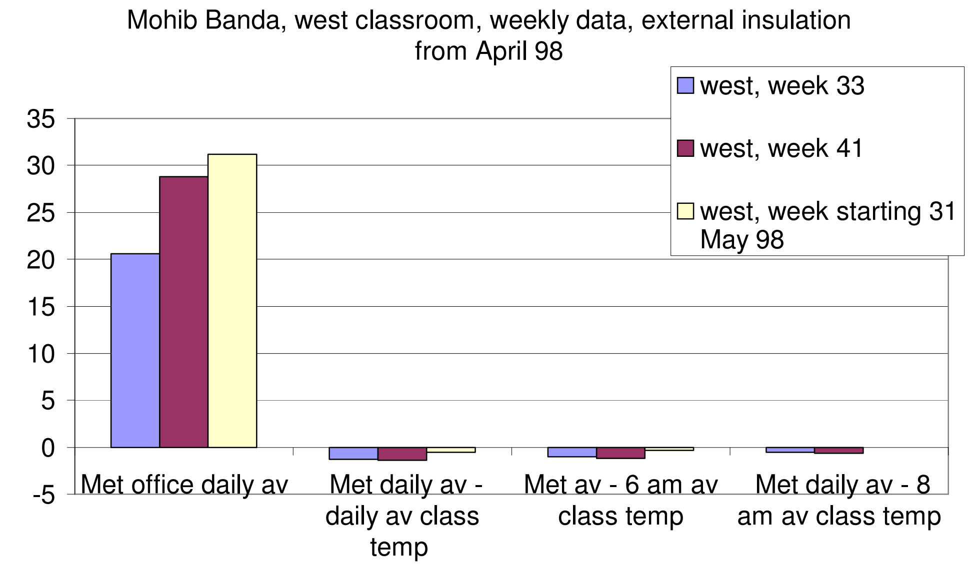
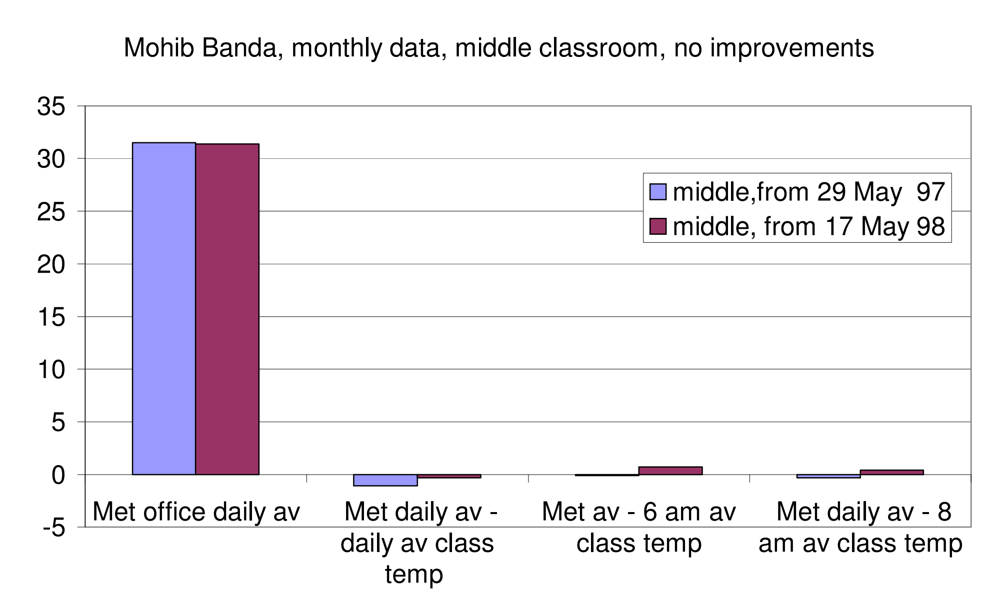
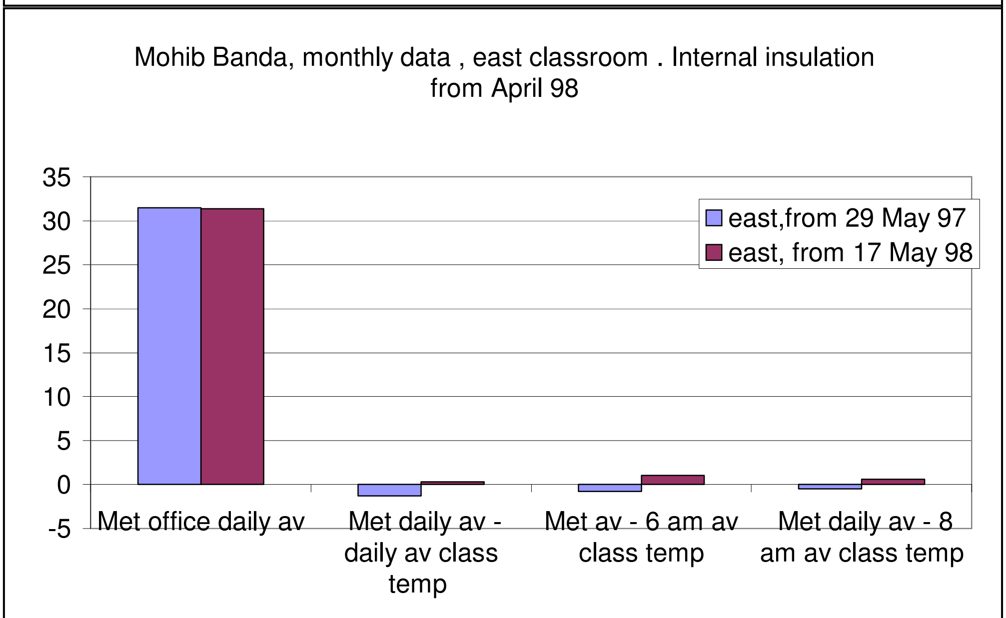


Figure 63 Three graphs of three classroom s at Mohib Banda A very similar story is told by these figures comparing average external temperature with average temperatures at 6 a.m. and 8 a.m. over one week





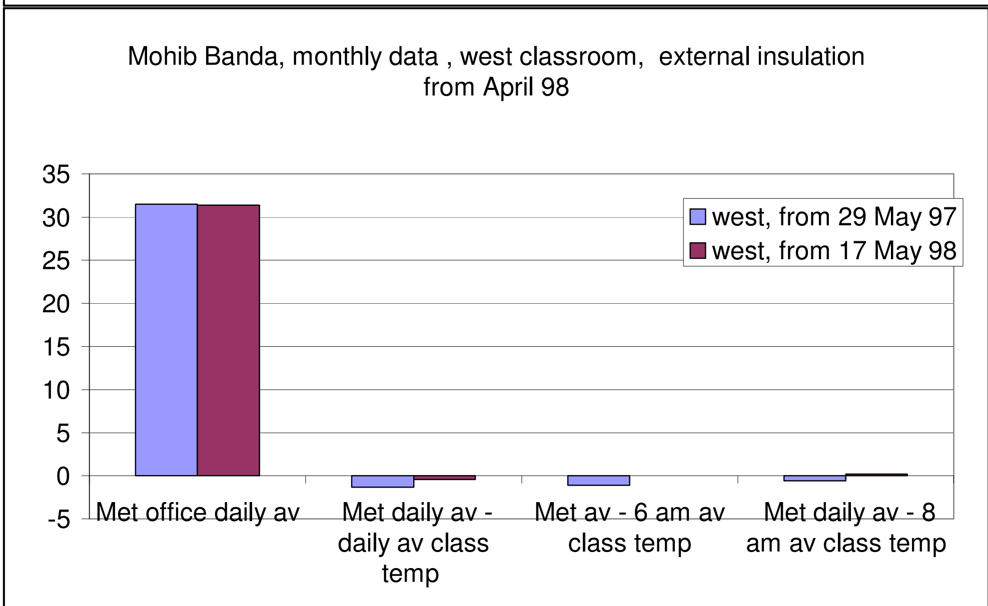


Figure 64 Mohib Banda one month data. comparing average classroom temperature 6 a.m. average and 8 a.m. average with weekly data, figure 49, it can be seen that monthly data does not improve accuracy.