Energy Efficient Housing

Improvement of Thermal Performance of RC Slab Roofs

November 2010




ENERCON

Government of Pakistan
CAPITAL DEVELOPMENT AUTHORITY
Islamabad

UN-HABITAT
FOR A BETTER URBAN FUTURE

United Nations
Pakistan
Improving lives and helping people

EXECUTIVE SUMMARY

Pakistan is amongst the most rapidly urbanizing countries in Asia. Over 40 million additional people are expected to live in towns and cities in Pakistan by 2025. This represents a large scale and fast moving change from rural to urban settlements, from rural to urban housing and from traditional construction to new technologies. The majority of the country experiences extremely hot summers with temperatures over 40 degrees for several months. The northern half of the country has cold winters with freezing temperatures at night. In previous rural lifestyles people would often sleep outside their homes during the hot summer nights. Urban life is not as conducive to this option and it is more important that buildings are comfortable during day and night time as people spend more time indoors.

Most residential buildings in Pakistani towns and cities are 1-2 storeys with flat roofs. The traditional rural mud roof is being increasingly replaced with RC slab roofs. In case of closely spaced/adjacent houses, the roof becomes the most exposed part of the building to the sun during maximum daylight hours, RC slabs absorb a great deal of heat which continues to be emitted through the night time affecting the comfort of residents. Densely populated cities with congested living spaces have worsened the situation particularly for low-income groups who have limited access to outdoor space and who cannot afford to have electrical solutions (fans and air conditioning) to maintain thermal comfort level.

Pakistan has been challenged with problems in electricity generation, increasing demand, outpacing supply and thus resulting in extended load shedding especially in the summer. The price of electricity has increased dramatically, making life difficult for those on low and average incomes. Building improvements that reduce reliance on electricity are most important to reduce costs and improve comfort for low income families and to reduce the electricity consumption. While roofs pose a major problem in terms of heat gain (and heat loss in the winter), they are also easier to retrofit with improvement measures than other parts of the building.

UN-HABITAT in partnership with the Ministry of the Environment, ENERCON and the Capital Development Authority Islamabad, under the flag of Delivering as One UN Pakistan Joint Programme for the Environment, Outcome 5: Green Building initiated a Project to demonstrate and test measures to improve the thermal performance of housing, specifically to improve Reinforced Cement Concrete (RC) flat roofing.

The project has two phases: 1. Research, testing and analysis, 2. Promotion and awareness. This report documents the work carried out under phase 1, and information materials developed for promotion under phase 2.

The applications have been carried out on single storey Government houses in Street 31 of Sector G-6/1 Islamabad in partnership with the Capital Development Authority. All houses of the same specification and condition were selected so as to compare the results.

Moreover, UN-HABITAT carried out desk reviews of best local and international practices, market surveys and meetings with manufacturers. 19 different improvement products and techniques specifically were selected and installed on the roofs in coordination with manufacturers. Techniques applied on the roofs are of three type's insulative, reflective and radiant barrier (false ceiling). Costs ranged from 3 to 80 PKR per square foot. Commonly available materials with specialized materials and newly developed products have been compared by involving manufacturers to participate on a public-private partnership basis ensuring cost effectiveness. Further solutions can be added to expand the menu on a continued basis.

Project development work initiated in April 2010. Site work completed in June 2010 and the performance of roofs was monitored during July 2010 when outdoor temperatures were frequently above 40 degrees. Community members were trained in the recording of thermal data and comfort levels, temperatures were recorded at specific times during the day.

All of the solutions improved the indoor temperature in comparison to an unimproved control house, but 9 of the 19 roofs reduced the indoor temperature to below 34 degrees (selected threshold for comfort without use of AC) decreasing 4 degree on average. This is a remarkable success and proves that passive building measures alone can help significantly reduce electricity consumption.

All the solutions have been documented step by step for correct application. The costs, performance, weight and durability has also been analyzed and presented in a simple format, so technical people and households can make informed decisions about better option which suits their home and circumstances.

All steps in the process and the outcomes of the project will be shared with stakeholders for further dissemination, promotion and increased awareness.

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Appendices

1. INTRODUCTION

1.1 Pakistan Energy Context

Pakistan has been facing the worst energy crisis of its history, especially in the shape of huge shortfalls in electric power production, exacerbated by an infrastructure deficit. Demand is rising rapidly, driven in part by the trend of urbanization along with numerous other factors. Moreover, 65% of overall electricity is being generated through thermal power plants (run either by gas or oil). It contributes largely in emission of Green House gases causing environmental hazards. A significant amount of electricity is being used in cooling and maintaining thermal comfort in residential buildings in the summers. Mud houses and traditional roofs are being replaced by RC slab roofs as people are aligned towards urbanization. RC structures absorb and emit more heat thereby increasing the heat island effect of built up areas and cities.

Electricity bills have gone up to 20% of an average household income apart from the high initial cost of installation of electrical appliances (Air Conditions, fans, and room coolers) which majority of population hardly affords. Frequent load-shedding and fluctuating supply depicts that many households invest in uninterrupted (UPS) power supplies or generators, especially if livelihood activities rely on electricity. Recent measures taken by the government to overcome the power crisis are reducing working days in a week in government offices and early closure of markets at night have adverse effects on the overall economy of the country on macro level and simultaneously livelihood of common man on micro level.

1.2 Pakistan Urban Development and Housing Construction

People tend to move towards cities for better livelihood opportunities and living standards in terms of better facilities and services. While their economic circumstances may improve, they are also likely to find themselves living in much different housing conditions, with smaller living space, less private outdoor space, less mobility for women and children, and more time spent inside buildings particularly for women, young children and the elderly. High density results in poor levels of indoor daylight and poor ventilation. Higher numbers of people in small space means increased needs for ventilation. People live in very congested spaces in cities with little to no open space or verandahs compared to what they used to have in villages, where most families live in joint family compounds with shared large open spaces, usually with shaded areas. In villages many household tasks are done outside including cooking and laundry and the compound is used by members of the family for sleeping at nights in the summers. In cities, outdoor spaces are less open even if available, and do not have the same level of privacy.

Apart from traditional patterns of space and living, traditional construction materials and technologies are also replaced increasingly in urban areas with conventional materials including cement concrete block walls, fire bricks and reinforced cement concrete roofs. The RC slab roof is particularly prevalent in those areas where people plan to build an additional storey in future. The majority of residential buildings in urban areas in Pakistan are 1-2 storey's, especially in the rapidly growing secondary cities and in informal settlements of larger cities. When houses are built closely together or adjoining, the roof is the most exposed part of the building to the sun. The heat gained from the roof has a significant impact on the rooms directly beneath. When many buildings are still limited to 1-2 storeys, this means the roofs are affecting most of the accommodation. Unlike lightweight CGI roofs which get heated quickly and cool down quickly, RC slab roofs retain the heat gained during the daytime and continue to emit heat for several hours, making rooms

uncomfortable during night time when almost all the family members gather inside. Combined with poor ventilation, this makes sleeping difficult, affecting people's health and comfort. Rooms are extremely uncomfortable during peak summers when there is no fan due to load-shedding, apart from the expense.

Discomfort in buildings can be mitigated not only by active (electrical) cooling and heating but also by better landscaping, better building design, construction and passive control. Knowledge of thermal performance and control in buildings has a long history of local practices and recent scientific and construction advancements. Both can contribute directly and through interpretation to improved solutions.

Improving thermal comfort in buildings can contribute to the following:

- Reduction in overall demand for energy, benefiting the wider economy
- Reduction in household spending on energy, saving finances for other needs
- Improve quality of life significantly, especially for women, children, elderly and sick persons who spend more time in the house

There are numerous sources of information and solutions for improved thermal performance available in engineering circles, but the level of knowledge and good practice among building designers, the construction sector and awareness among house owners is very low. Developing simple and accessible public information and creating a much increased level of awareness is vital to create demand for improved buildings.

1.3 The UN Joint Programme for the Environment

One UN is the result of a UN Reform process that brings together the strengths of all UN agencies to increase efficiency and efficacy in a transparent and accountable manner for better service delivery to the people of Pakistan for crises management and human development. It will enhance coordination and support to the government, donors and development partners to further align UN activities with national priorities and procedures in line with the Paris Declaration on Aid Effectiveness. Within the One Programme, there are five thematic areas that the UN is concentrating on along with cross cutting themes of gender, human rights, civil society and refugees. The thematic areas are:

- Health and Population
- Agriculture, Rural Development and Poverty Reduction
- Education
- Disaster Risk Management
- Environment

The One UN Joint Programme for the Environment focuses on sustainable environment and pro-poor sustainable development programmes. The programme includes the promotion of public-private partnerships, supporting sustainable energy technology development and application, learning from best practice, capacity building of institutions and the involvement of communities towards long term solutions.

The One UN Programme for the Environment has a number of areas of activity. The energy efficient housing project is developed under sub-component of Green Industries, Energy and Jobs. This project also contributes to the objectives of Sustainable Urbanization. This has tried to optimize the agreed roles of the UN as convener of stakeholders, advocacy, technical advisory and cost effective pilot and demonstration implementation.

1.4 UN-HABITAT in Pakistan

The United Nations Human Settlements Programme, UN-HABITAT, is the participating agency in the Joint Programmes for the Environment and Disaster Risk Management. It has been working since 2005 supporting the Government of Pakistan Earthquake Reconstruction and Rehabilitation Authority (ERRA), in the successful owner driven reconstruction of over 600,000 houses destroyed in the Kashmir earthquake. This programme included the identification and promotion of both indigenous knowledge and the introduction of modern innovation and best practice to ensure reconstructed houses were not only hazard resistant but also to improve environmental performance.

In the field of urban environment, Sustainable Urban Development Network (SUD-Net) is an innovative network of global partners promoting a multilateral and inter-disciplinary approach to sustainable urban development. UN-HABITAT supports local and national governments through SUD-Net and its component, the Cities in Climate Change initiative to address key urban environmental issues related Climate Change.

UN-HABITAT technical team has developed significant capacity in the development and promotion of housing improvement measures, training and working closely with communities in large scale public awareness. This programme shows the progress which can be made in the development of standards, educating the technical professionals and achieving field implementation to improve housing. The progress made since 2005 laid a foundation for ongoing work with NDMA and Provincial Governments, Academia and Partner Organisations.

UN-HABITAT recognizes that post disaster reconstruction provides an opportunity to introduce not only hazard resistant reconstruction through technical advice but it also provides a platform for additional improvements to housing construction standards as well.

Pakistan is one of the fastest growing populations and has one of the fastest rates of urbanization in the world. This growth will mean a massive increase in existing housing stock particularly urban and low income housing. Efforts are being made now to introduce efficiencies that can potentially become mainstreamed in time to improve housing conditions, urban life and ameliorate the environmental impact.

In line with UN-HABITAT's mandate and the approach of the Delivering as One UN Pakistan Joint Programme for the Environment, the priority is to engage with authorities and institutions, develop public-private partnerships and maximize outreach to communities to deliver better housing, and contribute to more socially and environmentally sustainable cities.

2. OBJECTIVES

Objectives of Energy Efficient Housing Project are:

- Compilation, testing and comparison of different energy efficiency measures to improve the thermal performance of RC slab roofs.
- Development of user-friendly information for guidance and public awareness.

3. METHODOLOGY

3.1 Identification of partners

UN-HABITAT developed the project design and implementation strategy in cooperation with the following partners.

- **Ministry of Environment**: Being a lead agency working on environment and addressing environmental issues in the country.
- **Capital Development Authority (CDA):** Being responsible for development of Capital city and for the maintenance works in the housing schemes under its jurisdiction.
- **ENERCON National Energy Conservation Centre (ENERCON):** is an attached department of the Ministry of Environment, Government of Pakistan. Serves as the national focal point for energy conservation/energy efficiency activities in all sectors of the economy, namely industry, agriculture, transport, building and also mandated for the development of energy code in Pakistan.
- **UN-HABITAT**: The United Nations Human Settlements Programme is the United Nations agency for human settlements. UN-HABITAT's mission is to promote socially and environmentally sustainable urban development with the goal of providing adequate shelter for all.
- **Manufacturers and Suppliers**: Different private companies dealing with materials for thermal efficiency.

3.2 Market survey:

UN-HABITAT team comprised of five engineers lead by a technical advisor carried out a desk review of best local and international practices, and afterwards the team visited the markets and held meetings with manufacturers of different insulative, radiant barrier and reflective technologies through Pakistan. Manufacturers were invited to participate at their own cost under public private partnership. Samples were collected and studies were carried out to understand product's efficiency, cost effectiveness and environmental impacts. This included products still under development. Meetings were also held with academia and engineering experts to ensure the widest range of options properly considered.

3.3 Selection of houses

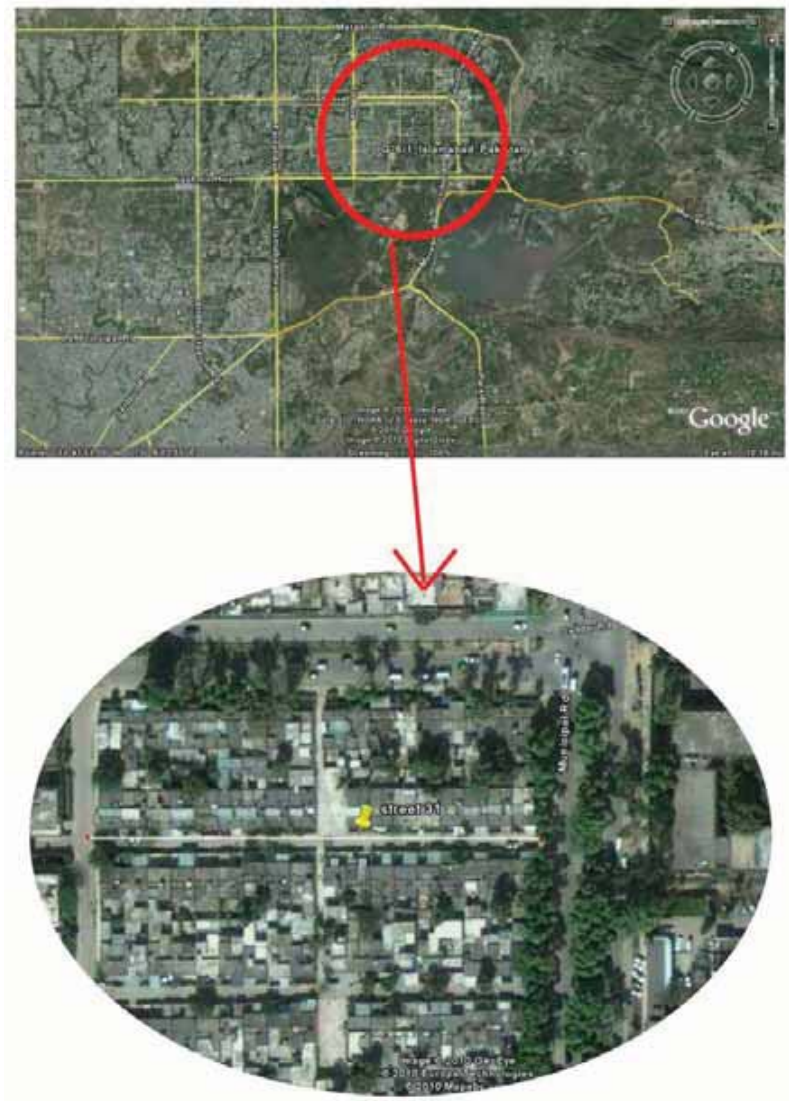
This project was planned to be implemented on existing houses where the improvement in interior conditions could be measured by residents.

The selection of houses was based on the following criteria:

- Single storey houses having a roof slab area less than 600sft to reduce the cost of each option and ensure maximum number could be included. All houses need to be at the same location and of the same type and construction specifications for application of better comparison of solutions.
- Single storey housing was practically easier to work on, easier to lift materials and with less disruption to households during and after construction for site visits.

- In single storey houses, all rooms were directly affected by the roofs condition. The project was designed to see if a measurable difference could be made to the inside environment and thermal comfort.
- Government housing schemes were the best option as all houses have been constructed in the same way and were owned by only one authority, which helped to have a single agreement for application of solutions to all houses.

Different government housing schemes were visited to find houses in accordance with the criteria. CDA housing scheme, constructed in the 1960s, located in Street 31, Sector G-6/1, has been selected and finalized for testing and demonstration of improvement measures because of structural and architectural similarities amongst the buildings, separation in the roof slabs (no continuous slab), close to the CDA maintenance office, high density housing with roof as the most exposed surface to sun light.



A total of 19 roofs were selected for testing and demonstration of different energy efficient techniques to improve their thermal performance. Eleven houses were identified on the right hand side of the street and 8 houses were identified on the left hand side of the street. West facing rooms of all houses have been selected for thermal data collection to ensure greater consistency in condition and comparison of results according to time of day.

Houses on the left lane of the street have a roof project area of 570 sft each.

Houses on the right lane of the street have a roof project area of 370 sft each.

View of roof top with 570 sft

View of roof top with 370 sft

Plot size on both sides of the street is almost the same but there is a slight difference in the house plan. On the right hand side the continuous slab was found to be 370 sft.

Total plot area for these houses is (25ft x 50ft) house area is 750 sft. Front and back courtyards are narrow, ranging from a 6 ft to 10 ft wide space. Average number of people in a house are seven. Small size kitchens are common and are built on the front side of the house. Each house has more than one washroom with one built in the back or front courtyard within the boundary wall. Piped water is being supplied in these houses; some houses have underground water tanks in the front courtyards for storage of water while others use portable storage tanks placed on their roofs. Boundary wall of 6ft height encloses the compound (25 ft x 50 ft). There are small size trees in both front and back courtyards which are rapidly being cut down to find more space for building extra rooms as families are growing.

3.4 Construction Specification

9 inch brick masonry walls with cement sand mortar. Wall height is 10 ft. Walls are plastered and painted externally and internally. Average room size is 12ft x 15ft, each room usually has two doors and a window. Windows are made of steel frame with single glazing; size of the window is 3ft x 5ft. Wooden doors are of size 3ft x 7ft. Rooms are being used for sleeping, living, study and dinning etc due to non availability separate space for all these purposes.

Thickness of RC slab is 5 inch. All roofs are old and have bituminous coating over slab. Bitumen is replaced after every 3 to 4 years. Roofs contains slope of 1:100 for drainage. 3 inch diameter RC pipes are being used as spouts for drainage of rain water from the roof.

3.5 Agreements

An agreement between Ministry of Environment, UN-HABITAT and CDA was signed on May 13, 2010 to start the work on site. In this agreement CDA agreed with UN-HABITAT to provide access to the houses. CDA designated their official for coordination between UN-HABITAT staff and the community and permitted to provide space in their maintenance office nearby for temporary storage of materials.

A second agreement was signed on May 24, 2010 between Ministry of Environment and manufacturers of energy efficient construction materials where a number of manufacturers agreed to provide their products free of cost under public-private partnership.

4. SITE WORK

4.1 Community participation

All the residents of the project houses are tenants of the Capital Development Authority. They are government officials (with an average salary of PKR 15,000 /month), have long-term tenancies and many have invested in upgrading their houses by interior decorations and extensions. Before starting the project activities, the entire community was invited for discussions about the living conditions of their houses, use of fans and ACs, fuel use and bills, and briefings on the improvement measures and the documentation process.

All residents of Street 31 CDA housing scheme were trained by UN-HABITAT staff for thermal data collection as part of first activity on the site. Devices for thermal data collection (thermo hydrometer) along with data collection sheets (forms) were delivered to the people after training was done.

Thermo hydrometers to take inside temperatures were installed in all houses and sensors were exposed outside to take outside temperature readings. Households were supposed to record temperature after every 3 hours in a day and observe thermal comfort levels at different times of the day.

After analysis of one week's data recorded by the people, it was found that there were many shortcomings and irregularities in the data recorded by the people, particularly in night hours. To tackle this fundamental issue, a community focal person was assigned to ensure proper regular data collection, by reminding people of the set times for reading. Data collection was found to be more accurate and regular later on. UN-HABITAT team regularly monitored the placement and working condition of the thermometers.

4.2 Roof preparation

4.2.1 Leakage problems in roofs

The CDA housing scheme selected for the application of retrofitting measures was constructed in 1960, and the roof slabs were deteriorated. CDA is the responsible agency for routine maintenance of these houses and slabs in case of leakage. Local residents expressed their concerns that improvement activities on their roofs might damage their roofs by building work and worsen the problems of leakage and they might have to wait until the next fiscal year for CDA to get maintenance budget approved. Many roofs which had already been waterproofed with bituminous coating by CDA were found to be leaking. A detailed inspection of the roofs was done and marks from leakage were found inside several rooms. Water proofing of the slabs was therefore found necessary before the application of thermal solutions, not only to address the concerns of households but also to facilitate the proper application of some measures such as reflective paint finishes.

4.2.2 Water proofing of roofs

Water proofing/surface treatment on RC roof slabs was done in two ways, i.e. Bituminous coating or PCC (1:2:4) 2 inches thick topping, depending upon type of thermal solution to be applied on the surface.

4.2.3 Bituminous coating

All roofs with insulative techniques or false ceiling underneath the slab were treated with bituminous water proofing before the application of solution because it is cost effective and it takes less time in its application. Life of bituminous coating is 3 to 4 years.

4.2.4 Plain Cement Concrete (1:2:4) topping

Roofs which were planned to have new reflective surfaces applied on top were treated with 2" thick PCC (1:2:4) for water proofing because paint could not be applied on normal bitumen.

4.3 Thermal improvements

The application of different solutions to improve thermal performance of RC slab roofs is divided in to three categories:

- Insulative techniques
- Reflective surface techniques
- Radiant barrier techniques

4.3.1 Insulative techniques

Insulative techniques are applied on the top surface of the roof slab. These techniques slow down the heat transfer from the top by slowing down the conduction of heat. Following are the different insulative techniques applied on roofs.

- Stabilized mud (cement stabilization)
- Mud with High density Styrofoam (thermo pole)
- Brick tiles with stabilized mud
- Polystyrene (Jumbolon) with plain concrete screed.
- Concrete wizard insulating tiles
- Sachal CLC (cellular light weight concrete) tiles

- Smart concrete tiles (aerated concrete with thermo pole used as sandwich between concrete layers)
- Munawar AC Tiles (Terrazzo mixed with white apoxy with thermo pole sheet)
- Fired clay extruded hollow tiles
- Green netting

Insulative techniques are effective in both ways by keeping the heat out of the house in the summers and retaining the heat to escape from the house in the winters. Most insulative techniques are durable and have a life more than 10 years. Insulative solutions in most cases increase a considerable load on the roof slab. Slab needs to be structurally examined before the application of heavy insulative techniques. Mud needs to be renewed after every 3 years to avoid any vegetation and growth of insects. Insulative techniques in combination with reflective surfaces can further improve the efficiency of slab.

4.3.2 Reflective techniques

Through these techniques sun radiations (infrared rays) are reflected and thus it helps reduce the absorption of heat into the roof. Reflection depends upon the colour of the slab; the lighter the colour (white), the more it will reflect. Reflective techniques applied are as under:

- Lime wash
- White Enamel paint
- Weather shield white paint
- OCEVA-MOL chemical
- Aerosol Heat reflective paint.

Surfaces need to be cleaned frequently in order to attain maximum efficiency especially where there is considerable dust. Reflective surfaces vary in durability; some need to be replaced after every 3 months or after the passage of rainy seasons. The durability also depends on whether the roof is in regular use or not.

4.3.3 Radiant barrier techniques (false ceiling)

Radiant barrier techniques work by reflecting heat absorbed by the slab or by reflecting direct sun radiations. In the standard house when the roof slab gets hot, it radiates heat directly into the room below. A radiant barrier is an additional layer, usually a false ceiling provided underneath the slab to stop the heat from radiating into the room. The false ceiling, may work by absorbing the heat, (insulative) or reflecting the heat (reflective). There should be an adequate and ventilated air gap between the slab and the radiant barrier to be most effective. Radiant barriers applied are as follows:

- Gypsum board false ceiling
- Gypsum board with aluminum foil on the back
- Paper board false ceiling
- Thermo pole false ceiling

These techniques are durable if proper care is taken. These techniques can be used as a decorative finish as well. These solutions are more appropriate if the room height is adequate.

4.4 Thermal data collection

Thermal data was collected and analyzed before and after the application of solutions. Thermal data collection started by the end of May 2010 and the majority of solutions completed by the end of June and fully completed by the start of August, 2010. There has been a significant difference in temperature and humidity in May and August which made the comparison of different solutions complicated. To mitigate these problems and to get more accurate data comparison, a control house was identified in the same street with similar environment and with no treatment on the roof. Thermal data of all houses has been collected on the same day and analyzed to make conclusions.

S/No.	Solution	Temperature	
		3:00pm	12:00am
	Outside Temperature	**41.0**	**32.0**
	Control house (no improvements) Inside temperature	**36.2**	**36.7**
1.	Stabilized mud	35.3	35.4
2.	Mud with thermo pole	33.6	34.1
3.	Brick tiles with stabilized mud	33.1	33.9
4.	Extruded Polystyrene (Jumbolon)	32.2	32.0
5.	Concrete wizard tiles	34.7	35.6
6.	Sachal CLC tiles	34.0	34.0
7.	Smart concrete tiles	33.7	32.0
8.	Munawar AC tiles	33.0	33.4
9.	Alnoor tile	34.1	33.8
10.	Green netting	35.1	33.7
11.	Lime wash	33.1	32.6
12.	Weather shield paint (white)	33.7	32.6
13.	White enamel paint	33.1	32.9
14.	Aerosol heat reflecting paint	34.2	33.4
15.	OCEVA-MOL chemical	34.7	33.6
16.	Gypsum board false ceiling	34.6	34.9
17.	Gypsum board with aluminum foil	34.9	34.5
18.	Paper board false ceiling	32.2	31.7
19.	Thermo pole false ceiling	34.4	33.6

Highly efficient (very good) Good Average

Note: This data has been collected after completion of all roofs from 1 to 31 July 2010.
Data collected is initial and will be consistently monitored for comprehensive analysis.

4.5 Weight, Skill and Cost

4.5.1 Weight and Skill

Weight of applied solution and skills are given in the below table.

No.	Solution	Weight, lbs/sft Approx.	Skills
1.	Stabilized Mud	28	No special skills required
2.	Mud with thermo pole	40	No skill required
3.	Brick tiles with stabilized mud	30	No skill required
4.	Extruded polystyrene (Jumbolon)	26	Basic concreting and masonry
5.	Concrete wizard tile	30	Basic concreting and masonry
6.	Sachal CLC tiles	16	No skill required
7.	Smart concrete tiles	16	No skill required
8.	Munawar AC tiles	15	No skill required
9.	Alnoor tiles	18	No skill required
10.	Green netting	NA	Steel fixing skills required
11.	Lime wash	NA	No skill required
12.	Weather shield paint	NA	No skill required
13.	White enamel paint	NA	No skill required
14.	Aerosol heat reflecting paint	NA	No skill required
15.	OCEVA-MOL chemical	NA	Skills required, specialist
16.	Gypsum board false ceiling	NA	Skills to fix frame required
17.	Gypsum board with aluminum foil false ceiling.	NA	Skills to fix frame required
18.	Paper board false ceiling	NA	Skills to fix frame required
19.	Thermo pole false ceiling	NA	Skills to fix frame required

Note: Solutions having weight more than 20 lbs/sft should only be applied if there is adequate strength in slab to sustain these loads. While applying mud solutions extra load should be considered in case of water absorption of the soil, careful treatment over mud should be done to avoid water absorption.

4.5.2 Cost of solution

Cost for each solution is presented in the below table.

No.	Solution	Initial cost Rate/ sft (PKR)	10 years cost Rate/ sft (PKR)
1.	Stabilized Mud	32	32
2.	Mud with thermo pole	52	52
3.	Brick tiles with stabilized mud	39	39
4.	Extruded polystyrene (Jumbolon)	76	76
5.	Concrete wizard tile	78	78
6.	Sachal CLC tiles	80	80
7.	Smart concrete tiles	70	70
8.	Munawar AC tiles	80	80
9.	Alnoor tiles	81	81
10.	Green netting	60	60
11.	Lime wash	3	30
12.	Weather shield paint	8	80
13.	White enamel paint	8	80
14.	Aerosol heat reflecting paint	39	390
15.	OCEVA-MOL chemical	35	350
16.	Gypsum board false ceiling	44	44
17.	Gypsum board with aluminum foil false ceiling.	45	45
18.	Paper board false ceiling	22	22
19.	Thermo pole false ceiling	30	30

Note: Costs calculated for 10 years do not cater for the inflation.

5. INFORMATION AND PROMOTION

5.1 Model preparation

Mini models (1 ft x 1 ft) for each solution applied on the roof prepared to assist with photographs of the actual section or specification, and for demonstration, since after finishing the roof surfaces, visitors will not be able to see what has been done under the finished surface. Mini models can easily be transported for technical training and information campaigns.

Green Netting

Stabilized Mud

Mud with thermo pole

Jumbolon

Concrete Wizard

Sachal tile

Smart Concrete

Munawar AC tile

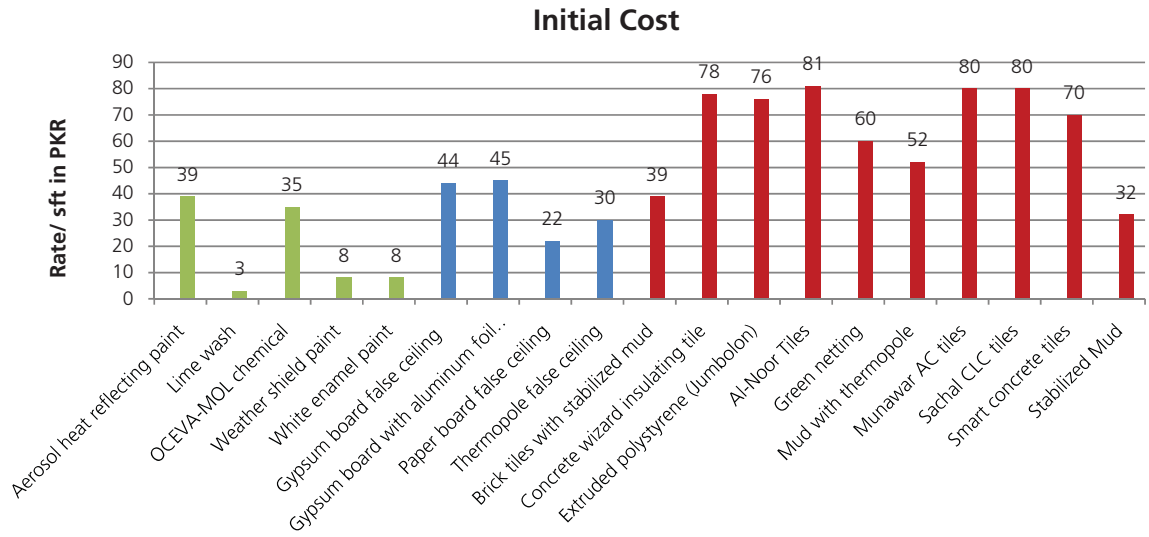
Hollow Clay tile

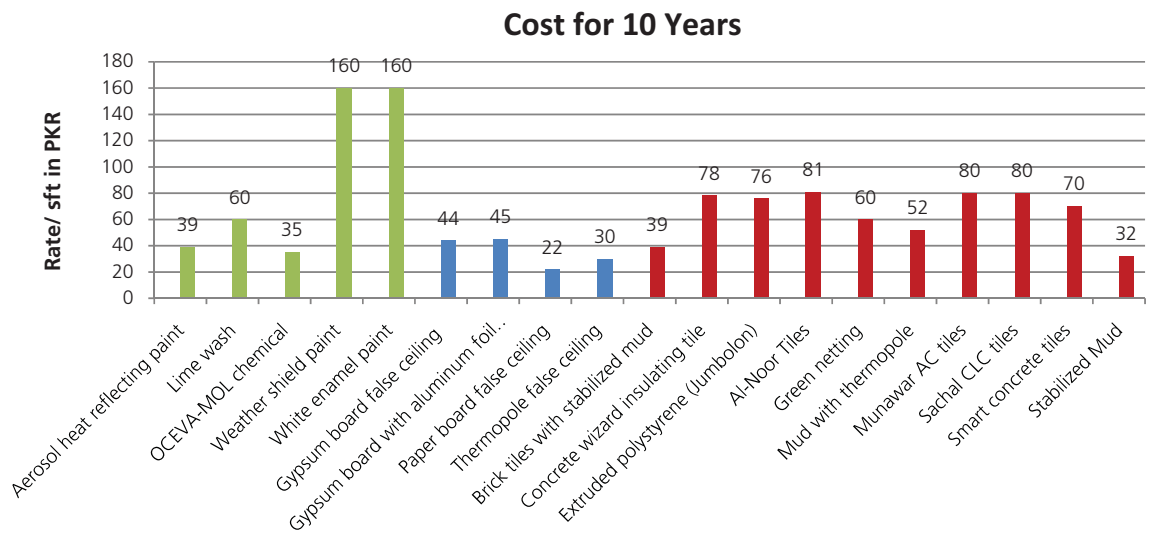
5.2 Information flyers

The step by step information of how to apply each improvement measure option / solution was documented in an individual one page flyer, using onsite photographs to provide technical guidance on correct application. Simple outline information of the materials, tools and skills required and estimated cost was included. These flyers can provide technical people, masons and households with adequate information in an accessible format. The set of information forms the basis for training and resource material for those interested in an overview of the sector. See these useful flyers at **Appendix I**.

6. CONCLUSIONS/FINDINGS

6.1 Cost benefit





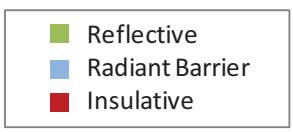


Chart 1 gives initial cost of solution. Apparently low cost solutions need to be replaced often so the cost over a longer time adds up to a higher cost as given in Chart 2. Investing in some of the more expensive but more durable solutions represent better value for money.

6.2 Performance

Thermal comfort level recorded by the people and observed by the team working in the field was set as below 34 degree Celsius. This temperature level (34 degree Celsius) was set as a target to reduce the temperature below, temperatures observed above this limit are considered as uncomfortable and need electrical solutions to bring it down. Solutions applied/ tested on the roofs have shown satisfactory results which have been described already in the report.

6.2.1 Traditional and new techniques:

Traditional solutions to maintain thermal comfort levels inside the houses which are based on old knowledge of traditional construction are brick tiles with stabilized mud (stabilized with wheat straw), lime wash and hollow tiles. These solutions are easily available and no great skill is required to apply such solutions. Brick tiles with stabilized mud is being extensively used throughout the country as a separate roofing option in combination with girders to improve the inside house environment. Reluctance amongst the people was observed in using mud on RC slab roofs due to the issues of vegetation, growth of insects in decaying soil and from an aesthetical perspective.

New materials specifically made for insulation purposes include Jumbolon (polystyrene), insulating paper board, smart concrete tiles, and Munawar AC Tiles are more durable and efficient in maintaining comfortable temperatures inside the houses. These solutions add to the aesthetical appearance of the roof. Some new solutions like insulating paper board and smart concrete tiles have only one manufacturer in the country and hence are not available easily. The paper board product is based on recycled material and is therefore more environmentally sustainable. Considering the good performance of this and other new materials solutions, it is hoped that better promotion can increase the range of products available for commercial, public and residential applications.

Traditional materials are low energy consuming in terms of their production and are more environment friendly. Solutions like brick tiles with stabilized mud, cement stabilized mud, mud with thermo pole, tile insulations of all kinds can be combined with reflective techniques to achieve better results.

The results show that traditional and environmentally friendly materials perform comparably with specialized new industrially produced materials and are more likely to be affordable and available. Therefore there is a technically feasible solution available for a range of income groups that will also address other criteria such as appearance and durability.

6.2.2 Skill and feasibility

All false ceiling/ radiant barrier techniques requires skill to fix the frame. Lime wash and paints can be applied by the owner himself. Masons are required to apply tile solutions, Jumbolon (polystyrene) with concrete screed. Mud solutions do not require any special skills and can be applied by ordinary labourers and people themselves. Green net would require more intensive work and skills for fixing the frame.

6.2.3 Winter

Some measures are more useful in areas which experience cold winters, where insulation from heat loss is equally important to consider. Such solutions include Jumbolon (polystyrene), brick tiles with stabilized mud, insulating paper board, stabilized mud, mud with thermo pole and thermo pole false ceiling. The reflective paint finishes make little contribution to winter insulation.

6.2.4 Use of the roof

If the roof has a lot of use, by people walking around, or taking any other load, then some solutions are less appropriate as the surface wears off quickly, or might be damaged. Amongst such solutions are all reflective surface finishes.

6.2.5 Time lag

Solutions with reflective surfaces take less time to cool down because of same slab thickness and no increased mass, but slabs having no solutions take more time because it absorbs more heat during the day time. Slabs with more weight like stabilized mud, mud with thermo pole, brick tiles with stabilized mud takes more time to cool down during the night because of more thermal mass being provided on the roof. This also makes them more useful in winter as the building mass holds heat for longer.

7. NOTES

During the course of this project UN-HABITAT found considerable interest among house owners, engineers and architects to have greater access to information about the range of options available, suitable for different conditions and applications and particular interest in the cost. It is important that this information reaches a wider public audience for discussion as many households can find an easy and cost effective solution to the serious challenge of making their homes more comfortable and reducing their bills.

The demonstration value of the roofing is useful during construction but limited when the building is finished in some cases. Therefore future projects to demonstrate in more cities should consider learning lessons from feedback to the pilot case.

The development of information material has focused on very practical guidance for all solutions tested and the simple information on the cost, not withstanding the fact that costs will vary depending on labour costs, inflation and market availability.

UN-HABITAT noted that the current engineering and architectural curricula do not deal with the topic of energy efficient design or construction. This means that the next generation of technical professionals do not have a good foundation in energy efficient design. It is therefore important to have continuing opportunities for technical people to access information through professional institutes and through other channels including training, guidance materials and public information. The range of specialized training within Pakistan appears to be relying heavily on resource material from cold weather climates rather than climate regions and construction economies more closely resembling Pakistan.

This project has been based on bringing existing solutions together and raising awareness among first the technical professionals and then the wider public, in a practical, accessible way. This should be considered as a first step in improving housing. Options for further development may include for example:

- Energy efficient building design training,
- Energy audit training for technical professionals and house owners,
- Improvement measures for girder and tile roofs,
- Improvement measures for walls.
- Improved water proofing, energy efficiency and hazard resistant roofing.

Over 1.5 million roofs will be constructed or repaired in the flood affected areas of Pakistan. This is an excellent opportunity to ensure the roofs are of better performance, through providing engineers, masons and the community with simple to understand information.

UN-HABITAT would like to thank the participating manufacturers for their cooperation and support, NUST, UET Peshawar, Ministry Of Environment and CDA.

APPENDIX I: INFORMATION FLYERS

Improve your roof

ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

FOAM INSULATION (Jumbolon)

1

Remove the loose particles, pebbles and dust from the roof surface

2

Cover the roof with plastic sheet (1/2 mm polythene). The plastic sheet should cover the entire roof and edges.

3

Lay the 2 Inch thick foam (extruded polystyrene sheets) on the plastic sheet. Do not damage the foam. Provide 1 inch overlaps where there are joints to avoid gaps.

4

Cover the foam (extruded polystyrene) with another plastic sheet in order to protect its surface from fresh concrete and water. Cut 1 ft diameter semicircles in the foam to allow drainage at spouts.

5

Maintain the same slope for the concrete for drainage as per slope of roof slab.

6

Cover the whole roof with 2 inch thick concrete 1: 2: 4 (cement:sand:aggregate) and level the concrete surface with float. The concrete will provide a wearing coat and protect the foam.

TAKE NOTE

- *Use aggregate of 3/ 8 inch for the concrete mix.*
- *Water for mixing and curing concrete should be clean enough.*
- *Do not apply a heavy load on the roof until after the initial curing time. Cure the roof for at least 7 days.*

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INSULATIVE FOAM INSULATION (Jumbolon)

FOAM INSULATION (Jumbolon)

Concrete Topping	2 inches thick 1:2:4 cement concrete
Plastic sheeting	1/2 mm polythene sheet
Polystyrene Foam	2 inches thick extruded foam as mat.
Plastic sheeting	1/2 mm polythene sheet

ADVANTAGES / DISADVANTAGES

- Foam insulation, plastic sheeting and concrete are all easily available and easy to install without special skills or tools.
- The foam insulation is protected by the concrete top coat and should last for at least 10 years.
- The cost is higher than other solutions, but will last longer and gives better results.

MATERIALS (for 15 x 15 ft room)

Cement	7 bags ordinary Portland cement
Sand	20 cft
Aggregate	35 cft, 3/8"size
Water	210 liters
Foam	2" thick. 255 square ft extruded polystyrene Jumbolon or other
Plastic	1/2 mm sheet. 512 square ft laid in two layers.

APPROXIMATE COST:
76 PKR per square feet
AUGUST 2010

TOOLS

1 Steel Pan, 2 Shovels for concrete mixing.
1 Square pipe (3 inch x 1 inch)
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float, 1 Aluminium float for concrete finishing.
1 Knife for trimming plastic and foam.

LABOUR

1 Skilled Mason
2 Labourers

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Foam Insulation (Jumbolon)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.0	31.1	31.9	32.2	32.8	32.6	32.0

NOTES

- Temperature difference made by the solution is high and thermal comfort level is maintained for the whole day. Foam insulation is equally good for both seasons not only it maintains thermal comfort level keeping cool in summer but also keeps the house warm in winter.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
DIAMOND FOAM
M-952,Amer Pura Chowk,
Rawalpindi Pakistan
Phone : +92 51 5501010
E-mail : jumbolon@diamondfoam.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

THE UN-HABITAT BETTER ROOFING PROJECT

The Ministry of the Environment, ENERCON, CDA and UN-HABITAT in cooperation with private sector manufacturers installed 19 different roofing improvement measures on 19 RC roofs in G/ 6-1 Islamabad in Summer 2010.

The objective is to test and compare the effectiveness of different solutions to improve the thermal performance of roofs, and to develop simple technical guidance for public information and awareness.

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Improve your roof

ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

TILE INSULATION (MUNAWER AC TILE)

1

Clean the surface and remove all loose particles and pebbles from the roof .

2

Mix the ingredients of cement sand mortar (1:4) in the required proportion. Sand should be free from mud and other impurities.

3

Lay the tiles in 1 inch thick cement sand mortar. Start laying from the edges. Use trowel to spread and set the mortar in required thickness.

4

Fix and level the tiles. Do not strike tiles hard with the hammer as this may cause damage. Use rubber hammer if possible, if not strike gently.

5

Carefully handle the tiles to avoid marks of cement sand mortar on the surface of tiles.

6

Use white cement slurry to fill the joints. Cure the surface for at least three days. Surface should be kept clean for better performance.

TAKE NOTE

- *Work should be avoided in extreme hot weather conditions and if the rains are expected.*
- *Maintain the roof slab for while laying tiles to ensure drainage.*
- *Use mortar within 45 minutes of addition of water so that cement might not set.*

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INSULATIVE TILE INSULATION (MUNAWER AC TILE)

TILE INSULATION (MAT)

Cement Sand Mortar	1 inch thick (1:4)
MAT Tile	12"x12"x1.25"(LxWxH)
Appoxi With white cement	1 Coat

ADVANTAGES / DISADVANTAGES

- Munawer AC Tile easily available and easy to install without special skills or tools.
- MAT Tile insulation is protected by the appoxi top coat and normally lasts for at least 30 years.
- The cost is higher, but will last longer and gives better results.
- Additional water proofing is not required.
- Top surface needs to be cleaned frequently.

MATERIALS (for 15 x 15ft room)

Cement	4 bags ordinary Portland cement
Sand	20 cft
White Cement	1/2 bag
Water	200 liters
Tiles	225 Sft
Appoxi	2 KG

APPROXIMATE COST:
80 PKR per square feet
AUGUST 2010

TOOLS

2 Steel Pan, 2 Shovels for mortar mixing.
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float,
1 Rubber Hammer
1 Concrete cutter
1 Measuring Tape

LABOUR

1 Skilled Mason
2 Labourers

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (MAT)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.7	31.9	32.8	33.0	33.2	33.7	33.4

NOTES

- Temperature difference made by Munawar AC tiles is significant.Works initially by reflecting sun radiations and later on works by slowing down the heat penetration.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
TIC NUST, House # 31, Street 111, G-11/3, Islamabad
Phone : +92 51 9267642
E-mail : msnetpk@yahoo.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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FALSE CEILING (Gypsum Board With foil)

1

Use a level to draw a line completely around the room indicating where the wall angle will be applied. Do not assume that original roof slab is level. Fasten the wall angle at all points with nails.

2

Do not drill holes to the full thickness of slab. Use safety glasses while drilling in the slab.

3

Use screw drivers to drive the screws. Never use hammer to drive screws. Cut suspension wire in required size usually double than distance between ceiling and slab which is 8 inch.

4

Suspension wires should be closely spaced to hold the frame firmly. Stretch each wire to remove any kinks and make a 90 degree band where the suspension wire crosses the level line.

5

Drop the ceiling panels into position by tilting them slightly, lifting them above the framework and letting them fall into the place.

6

Make sure all panels are fixed and set properly A suitable distance between fan wings and ceiling should be there.

TAKE NOTE

- *Roof should be made water proof before the installation of false ceiling otherwise water penetration may spoil the ceiling.*
- *Make sure all the suspenders are tightly fixed in the roof and screws are not loose.*
- *Do not use damaged pieces of gypsum board or aluminum frame.*

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RADIENT BARRIER INSULATION (Gypsum Board with Aluminum Foil)

FALSE CEILING (Gypsum Board F0IL PAPER)

8 mm thick gypsum board false ceiling with aluminum foil on back,
Fixed 8" below the slab,
suspended using aluminum frame.

ADVANTAGES / DISADVANTAGES

- Easy to install without special skills or tools.
- The Gypsum board is durable should last for at least 15-20 years.
- The solution is economical, for better performance there should be adequate space between slab and ceiling.
- In case of damage replacement of material is very easy.

MATERIALS (for 15 x 15 ft room)

Cross Tee Strip	2"x1" 240 Rft
Raval Plug (rubber)	65 Nos
Silver Wire	20 Rft (4mm)
Hanger	20 Nos
Gypsum Board Sheet (2'x2')	60 Nos (8mm)
Angle 1"x1"	60 Rft
Screw 2" long	60 Nos
Thread	50 Rft

APPROXIMATE COST:
45 PKR per square feet
AUGUST 2010

TOOLS

1 Drill machine,1 Hand claw ,
1 Screw drive
1 Water level (pipe),
1 Hack saw blade

LABOUR

1 Skilled carpenter.
1 Labourer

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with False ceiling Insulation (Gypsum Board with aluminum foil)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	33.6	34.0	34.7	34.9	35.1	35.0	34.5

NOTES

- Difference in temperature is very small and comfort level is low, Efficiency of this technique can be enhanced by providing ventilation in attic space.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Zaidi Brothers
Office#1 Block No#35
Chugtai Plaza Blue Area
Phone:+92 51 2878193-94
E-mail:zadibrothers@hotmail.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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Improve your roof

PAINT INSULATION (AEROSOL Paint)

Thoroughly clean the surface and remove all the dust particles. Wash the surface if necessary or in case of any oily and sticking objects are present on the surface.

Apply base coat of heat reflective paint. Before application of base coat make sure that the surface is dry.

Give three hours setting time after the application of base coat.

Keep the paint stirred during painting to maintain its consistency. Painting should be even everywhere .

Apply reflective paint thoroughly on edges and corners to avoid heat gain from all parts of the roof. Use brush for painting especially in corners.

Freshly painted surface needs to be protected and avoid walking on the roof so that it may not get damaged. Surface needs frequent cleaning for better performance.

TAKE NOTE

- *Surface should be dust free before application of reflective paint*
- *A setting/drying time of minimum 3 hours should be given after application of base coat.*
- *Avoid painting if weather is not clear or there are chances of rain during the day, wet surface should be avoided for painting.*

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REFLECTIVE INSULATION (Aerosol Paint)

PAINT INSULATION (Aerosol paint)

2 coats of aerosol reflective paint on the surface including one base coat.

ADVANTAGES / DISADVANTAGES

- Product is not easily available but easy to apply without special skills or tools.
- The cost is higher than other reflective solutions, and performance is satisfactory.
- It is not durable, requires replacement after 3 months (depends upon weather conditions).
- It doesn't increase weight on slab.

MATERIALS (for 15 x 15ft room)

Reflective paint for base coat 15 liters
Retro heat insulator paint 7 liters
Kerosene oil 5 liters

TOOLS

2 Paint Brushes, 2 Buckets
1 Roller

LABOUR

1 Skilled Painter

APPROXIMATE COST:
39 PKR per per square feet
AUGUST 2010

TIME

1 Day

PERFORMANCE

House with No Improvement							
Time	**06:00**	**09:00**	**12:00**	**15:00**	**18:00**	**21:00**	**24:00**
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Aerosol Paint)							
Time	**06:00**	**09:00**	**12:00**	**15:00**	**18:00**	**21:00**	**24:00**
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.3	30.3	32.5	34.2	34.9	35.0	33.4

NOTES

- Temperature difference observed after the application of solution is moderate. Comfort level is low. Surface appearance becomes dull after few days and efficiency is seen to be considerably reduced.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
TAMZ E-29/27 Shaheen
Colony Walton road
Lahore Pakistan
Phone:+92 42 6668218
E-mail:mehdi@tamz5.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
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Improve your roof

PAINT INSULATION (Enamel Paint)

1

Use coconut brush for proper cleaning and removal of dust from the roof.

2

Apply first coat of enamel paint with the help of paint roller if the roof area is larger, brush can be used for smaller roofs.

3

Corners and edges are painted in the end to provide ease in work. Use brush for painting in corners and edges.

4

Let the surface dry for minimum two hours after the application of first coat. Do not allow anyone to walk on freshly painted surface.

5

Apply second coat by moving backward from the front. Shoes or bare feet should be clean and it should not left a mark on the surface.

6

Avoid walking on freshly painted surface. Cover the surface in case of any possibility of rain splashes or storm winds.

TAKE NOTE

- *For application of paint, surface should be smooth and it should be cleaned and washed by using soap/detergent if possible.*
- *Avoid painting in extremely hot weather. Heat will make the paint blister, also avoid painting if rain is expected.*
- *Oil based enamel paint takes 24 hours to get completely dry, it can easily get damaged during this time so proper care should be taken during this time.*

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REFLECTIVE INSULATION (Enamel)

PAINT INSULATION (Enamel paint)

2 coats of white enamel paint on the surface

ADVANTAGES / DISADVANTAGES

- Easily available and easy to apply without special skills or tools.
- It reflects sun light and does not allow slab to gain heat. Slab cools down rapidly during night.
- The cost is low than other solutions, and gives good results.
- Not durable and requires to be renewed after every 3 months period.

MATERIALS (for 15 x 15ft room)

Enamel Paint (White Color)	5 liter
Kerosene Oil	2 liter

TOOLS

2 Paint Brushes, 2 Buckets
1 Roller

LABOUR

1 Skilled Painter

APPROXIMATE COST:
8 PKR per per square feet
AUGUST 2010

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Enamel Paint)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.0	30.1	32.0	33.1	33.6	33.8	32.9

NOTES

- Significant improvement in temperature is observed after the application of white enamel paint. Comfort level is maintained for maximum period during 24 hours.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Easily available in local market.

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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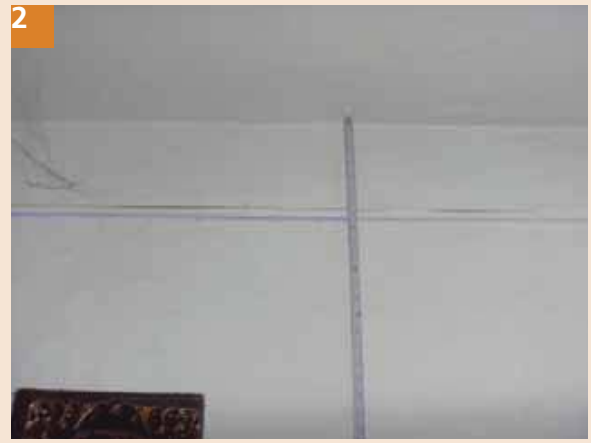
Improve your roof

FALSE CEILING INSULATION (Thermopole)

1

Mark points on walls below the slab with the help of tube water level. Tube water level should be free from bubbles for accurate measurement.

2



Position the wall angle so that the bottom flange rests on level line which has already been drawn on the wall.

3

If wall angles are not square, position the cross tee slots accordingly. Install the main tees so that they are level with wall angle already mounted, use a long level for this purpose.

4

Install the cross tee by inserting the ends of cross tees into the slots of main tee. Determine the position of cross tees by the size of panel (2 feet apart). Check right angle

5

Drop the ceiling panels into position by tilting them slightly, lifting them above the framework and letting them fall into place.

6

Fan should not be fixed closer to the ceiling as it makes noise when moves because of lighter weight of thermopole sheets.

TAKE NOTE

- *Use lighter frame to optimize the cost as thermopole sheets do not have much weight.*
- *Main tees are generally available in 12 ft length, for rooms wider than 12' main tees can be spliced be sure to align the splice so that*
- *Suspension wires are correctly positioned. Splice carefully otherwise all the main tees will be thrown off.*

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RADIENT BARRIER INSULATION (Thermopole)

CEILING INSULATION(Thermopole)

1" thick thermopole (expanded polystyrene)
False ceiling suspended 8" below the slab with aluminum framing (2'x2') panels.

ADVANTAGES / DISADVANTAGES

- Easy to install without special skills or tools.
- The thermopole (polystyrene) is susceptible to fire and not durable.
- It is light in weight, if not fixed properly creates noise when fan moves.
- In case of damage replacement of material is very easy.

MATERIALS (for 15 x 15ft room)

Cross Tee Strip	2"x1" 240 Rft
Raval Plug (rubber)	65 Nos
Silver Wire	20 Rft (4mm)
Hanger	20 Nos
Thermopole Sheet (2'x2')	60 Nos (8mm)
Angle 1"x1"	60 Rft
Screw 2" long	60 Nos
Thread	50 Rft

APPROXIMATE COST:
30 PKR per per square feet
AUGUST 2010

TOOLS

1 Drill machine,1 Hand claw ,
1 Screw drive
1 Water level (pipe),
1 Hack saw blade

LABOUR

1 Skilled Mason
1 Labourer

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with False Ceiling insulation (Thermo pole)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	29.5	31.9	33.1	34.4	34.7	34.9	33.6

NOTES

- Improvement in thermal comfort level is moderate. Temperature difference is lower than a normal house.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Available in local market

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

THE UN-HABITAT BETTER ROOFING PROJECT

The Ministry of the Environment, ENERCON, CDA and UN-HABITAT in cooperation with private sector manufacturers installed 19 different roofing improvement measures on 19 RC roofs in G/ 6-1 Islamabad in Summer 2010.

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STEP BY STEP HOW TO DO IT

PAINT INSULATION (Weather Shield Paint)

1

Clean the roof surface and remove all the dust particles. Wash surface if necessary with water, marks of oil, grease should be removed.

2

Apply base coat of weather sheet paint using brush or roller. Make sure the surface is completely dry before the application of first coat.

3

Use brush for painting in corners and on edges for thorough painting.

4

Make sure all the surface is painted evenly and thoroughly. Let the first coat dry for 3 to 4 hours depending upon the weather before the application of second coat.

5

Apply second coat using either brush or roller. Use roller if surface area is more.

6

Freshly painted surface needs to be protected from rains or wind storms. Surface needs frequent cleaning for better performance..

TAKE NOTE

- *Avoid painting in extreme hot weathers, it would cause the paint to blister. Also do not paint when it is raining.*
- *Use safety gloves while dealing with the paint and wash your hands thoroughly before eating.*
- *Do not touch your eyes with hand during or after painting without proper hand washing..*

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REFLECTIVE INSULATION (Weather shield paint)

PAINT INSULATION (Weather Shield Paint)

Two coats of weather sheet paint (white colored) on surface.

ADVANTAGES / DISADVANTAGES

- Easily available and easy to install without special skills or tools.
- It reflects sun radiations and doesn't allow slab to absorb much heat. Slab cools down quickly during the night.
- The cost is lower than other solutions, and gives good results.
- Not durable, needs to be renewed after 3 months.

MATERIALS (for 15 x 15ft room)

Weather Shield Paint (White)	5 Liter
Kerosene Oil	1 Liter

TOOLS

2 Paint Brush, 2 Buckets
1 Roller (Optional)

LABOUR

1 Skilled Painter

APPROXIMATE COST:

8 PKR per square feet
AUGUST 2010

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with PAINT Insulation (Weather Shield Paint)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.8	31.0	33.4	33.7	33.9	33.9	32.6

NOTES

- Temperature difference made by reflective surfaces is almost the same. Roof cools down rapidly during the night because no heavy thermal mass provided to it.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Easily available in local market.

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

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ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

PAINT INSULATION (Slaked Lime)

1

Remove dust and other particles from the roof surface with the help of brush. Wash the surface with water to remove oily deposits if any.

2

While working with lime wash it is important to keep the material stirred on regular basis in order to keep the lime in suspension.

3

Apply first coat of lime wash using brush. Application should be vigorour to ensure even application everywhere on the surface.

4

Let the surface dry for at least 3 hours depending upon the weather conditions.

5

Apply second coat of lime wash after 3 hours drying of first coat with the help of a brush. Lime wash should be done from center to the corners.

6

Give 24 hours time for setting of lime. Do not allow anyone to walk on the roof during this time. Cover the surface if rains or wind storms are expected.

TAKE NOTE

- *Lime wash should be kept stirred during application so that lime remains suspended*
- *Dry surface needs to be dampened before application of lime wash as to avoid suction of moisture from it but do not apply lime wash immediately after wetting the surface.*
- *Do not use rollers to apply lime wash on the surfaces. Use gloves during the work and avoid contact with eyes.*

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REFLECTIVE INSULATION (Slaked Lime)

PAINT INSULATION (SLAKED LIME)

2 coats of lime wash on the roof

ADVANTAGES / DISADVANTAGES

- Easily available and easy to install without special skills or tools.
- Surface is required to be kept clean for better performance.
- The cost is lower than other solutions, and gives good results.
- It is not durable and requires to be renewed after every 3 months period.

MATERIALS (for 15 x 15ft room)

Slaked Lime	5 Kg
Water	30 Liter

TOOLS

2 Paint Brushes, 2 Buckets
1 Roller
I Cotton cloth 2 meters

LABOUR

1 Skilled Painter

APPROXIMATE COST:
3 PKR per square feet
AUGUST 2010

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Paint Insulation (Slaked lime)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.0	31.1	32.0	33.1	33.6	32.9	32.6

NOTES

- Lime washed surface has shown good results with a temperature difference of 4 °C as compared to an untreated roof.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Easily available in local market.

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

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Ministry of Environment,
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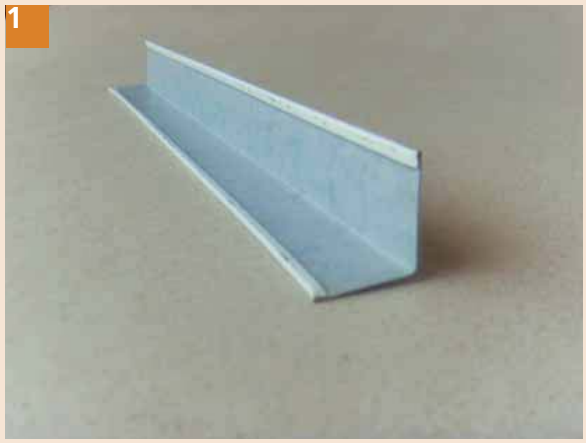
ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

FALSE CEILING INSULATION (Paper Board)

1



Ensure all aluminum framing (wall angles and tee sections) are straight and intact before using them for framing.

2

Fix L-shaped (wall angle) strip 8 inch below the slab on walls, make sure wall angle is not loose, insert nails at regular intervals. overlap the wall angle on inside corner and miter on outside corner.

3

T-shaped strip is used on internal side, ensure tees are strong and straightened with intact slots.

4

Fix the frame properly using hanging wires drilled into the roof, make sure frame is properly fixed and not loose.

5

Avoid contact of water with paper board sheets, should be stored in a dry place.

6

Fix paper board sheets in the frame, make an opening hole for fan rod, it should not be of bigger size.

TAKE NOTE

- *Use hanging wires closely to make the frame stronger.*
- *Ensure all screws are tightly fixed.*
- *Use safety glasses while drilling in the roof.*
- *Roof should be properly treated for water proofing before using paperboard false ceiling.*

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RADIENT BARRIER INSULATION (Paper Board)

FALSE CEILING (Paper board)

1" thick paper board false ceiling fixed in panels of (2'x1') 8" below the roof slab suspended with aluminum frame.

ADVANTAGES / DISADVANTAGES

- Easy to install without special skills or tools.
- The Paper board is durable, light weight, should last for at least 15 years.
- Very economical, gives very good results.
- In case of damage it's replacement is very easy, available in multiple design.
- Highly susceptible to damage when comes in contact with water.

MATERIALS (for 15 x 15ft room)

Cross Tee Strip	2"x1" 315 Rft
Raval Plug (rubber)	65 Nos
Silver Wire	20 Rft (4mm)
Hanger	20 Nos
Paper Board Sheet (2'x1')	115 Nos (8mm)
Angle 1"x1"	60 Rft
Screw 2" long	60 Nos
Thread	50 Rft

APPROXIMATE COST:
15 PKR per square feet
AUGUST 2010

TOOLS

1 Drill machine,1 Hand claw ,
1 Screw drive
1 Water level (pipe),
1 Hack saw blade

LABOUR

1 Skilled Mason
1 Labourer

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with False Ceiling Insulation (Paper Board)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.2	30.8	32.1	32.2	32.4	32.4	31.0

NOTES

- Temperature difference is very high as compared to an untreated roof. Solution has shown good results in keeping the thermal comfort level high.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
GHONSLA Innovative Insulation
Packages Ltd Waltan road Lahore
Phone: +92 321 4243583
E-mail:zehrahyderali@gmail.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

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Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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PAINT INSULATION (OCEVA-MOL)

1

Clear the surface, use grinder to remove all marks and sticking material from the pours of concrete.

2

Apply 1st coat of AC cleaner to remove existing chemicals and dust from the surface. AC cleaner is used to remove chemical impurities particularly.

3

Let the surface dry after using AC cleaner for minimum 6 hours. Provide first coat of OCEVA-MOL liquid rubber.

4

Rubber paint should be thoroughly applied in all corners and wall junctions to avoid leakages from all parts of the slab and let the surface dry for one day.

5

Mix OCEVA-MOL chemical with white cement in required proportion i.e. one part of chemical and two parts of white cement.

6

Apply final coat of Rubber appoxi of OCEVA-MOL mixed with white cement and let the surface dry for two days.

TAKE NOTE

- *Avoid contact of chemical with eyes and body.*
- *All chemical impurities oily deposits and bitumen must be removed before the application OCEVA-MOL*
- *Surface needs frequent cleaning for better performance.*

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REFLECTIVE INSULATION (OCEVA-MOL)

PAINT INSULATION (OCEVA-MOL)

2 coats of rubber appoxi mixed with white cement and one coat of liquid rubber underneath for water proofing.

ADVANTAGES / DISADVANTAGES

- Easily available and easy to install without special skills or tools.
- It does not require any additional water proofing or curing.
- Cost is higher than other reflective surfaces but it lasts longer up to 20 years
- Surface is required to kept clean for better performance.

MATERIALS (for 15 x 15ft room)

White Cement	1/2 Bag
AC Cleaner	5.5 liter
OCEVA-MOL	18 Liter
Water	50 liters

TOOLS

2 Paint Brush,
2 Bucket (35 liters)

LABOUR

1 Skilled Painter
1 Labourer

APPROXIMATE COST:
35 PKR per square feet
AUGUST 2010

TIME

2 Days

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with PAINT Insulation (OCEVA-MOL)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	30.8	31.8	33.9	34.7	35.6	35.0	33.6

NOTES

- Temperature difference made by the solution is smaller, and thermal comfort level is low.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
IWBC Protection Founders
452-B, Saddar Bazar
Ghulam Muhammad Abad, Faisalabad
Phone:+92 41 2681468
E-mail: iwbc_pf@yahoo.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

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Ministry of Environment,
Government of Pakistan,
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TILE INSULATION (Brick Tile)

1

Apply water to the mud and it should be kept soaked for one day. Mud to be used should be free from vegetation and other organic impurities.

2

Add wheat straw to the mud and prepare the mud, mixing it bare footed thoroughly until the mix gets a uniform shape.

3

Provide mud plaster to the surface 3 inch thick. Make the surface smooth by hands. Let the mud dry for three days.

4

Provide polythence sheet 1/2 mm thick over mud plaster. Cover every inch of roof by polythene sheet to avoid any water penetration from the top

5

Lay fire clay brick tiles over polythene sheet by using some suitable pattern. Polythene sheet should not be damaged while laying tiles.

6

Provide cement slurry on the top. Use trowel to properly fill all the joints to avoid water penetration.

TAKE NOTE

- *Fill all the cracks appeared in the mud after drying with mud slurry.*
- *Surface should be cured for at least 3 days for proper setting of cement.*
- *Top surface can be lime washed to further improve its performance.*

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TILE INSULATION (Flat Brick Tile)

TILE INSULATION (Flat brick tile)

3" thick mud compacted + 1/2 mm polythene sheet above and laying 1.75" thick flat brick tiles with cement slurry grouting at top.

ADVANTAGES / DISADVANTAGES

- Materials are easily available and technique is already in practice.
- It is cost effective, easy to install and no special skill required
- Mud needs to be replaced after every 5 years to prevent any vegetation and insect growth.
- Its efficiency can be improved by applying reflective finish on the top.

MATERIALS (for 15 x 15 ft room)

Cement	1 bags ordinary Portland cement
Sand	5 cft
Water	600 liters
Mud	75 Cft
Brick Tile	460 Nos (12"x6"x1.75")
Straw	5 Kg
Plastic	1/2 mm sheet. 260 square ft laid in 1 layers.

TOOLS

2 Steel Pan, 2 Shovels for mixing.
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float,
1 hammer

LABOUR

1 Skilled Mason
2 Labourers

TIME

3 Days

APPROXIMATE COST:
39 PKR per square feet
AUGUST 2010

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (Flat Brick Tile)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.9	32.5	32.7	33.1	33.7	33.8	33.9

NOTES

- Temperature difference is high as compared to an untreated roof. Roof takes more time to transfer heat inside and cools down slowly because of more mass. Efficiency can further be improved by providing reflective finishes on top.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Available at brick kiln

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
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STEP BY STEP HOW TO DO IT

FALSE CEILING INSULATION (Gypsum Board)

1

Use a level to draw a line completely around the room indicating where the wall angle will be applied. Do not assume that roof slab is already level.

2

Position the wall angle so that the bottom flange rests on level line which have been drawn on the wall already. Fasten wall angles securely with nails.

3

Do not drill holes to the entire thickness of slab. Locate the position of holes to be drilled by the position of main cross tees with the help of long level.

4

Stretch each wire to remove any kinks and make a 90 degree band where the suspension wire crosses the level line.

5

Drop the ceiling panels into position by tilting them slightly, lifting them above the framework and letting them fall into place.

6

Keep a safer distance between fan wings and ceiling.

TAKE NOTE

- *Roof should be made water proof before the installation of false ceiling otherwise water penetration may spoil the ceiling.*
- *Make sure all the suspenders are tightly fixed in the roof and screws are not loose.*
- *Do not use damaged pieces of gypsum board or aluminum frame.*

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RADIENT BARRIER INSULATION (Gypsum Board)

CEILING INSULATION (Gypsum Board)

8 mm gypsum board ceiling fixed in panels of 2'x2', 8"
Below the roof slab suspended with the help of aluminum framing.

ADVANTAGES / DISADVANTAGES

- Easy to install without special skills or tools.
- The Gypsum board is durable, light weight should last for at least 20 years.
- Cost is moderate, efficiency can be improved by providing ventilation in space between slab and ceiling.
- In case of damage it's replacement is very easy, available in multiple design.

MATERIALS (for 15 x 15ft room)

Cross Tee Strip	2"x1" 240 Rft
Raval Plug (rubber)	65 Nos
Silver Wire	20 Rft (4mm)
Hanger	20 Nos
Gypsum Board Sheet (2'x2')	60 Nos (8mm)
Angle 1"x1"	60 Rft
Screw 2" long	60 Nos
Thread	50 Rft

APPROXIMATE COST:
43 PKR per square feet
AUGUST 2010

TOOLS

1 Drill machine,1 Hand claw ,
1 Screw drive
1 Water level (pipe), 1
Hack saw blade

LABOUR

1 Skilled Mason
1 Labourer

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with False Ceiling Insulation (Gypsum Board)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.2	32.2	33.0	34.6	34.8	35.0	34.9

NOTES

- Temperature difference made by this solution is relatively smaller, roof takes more time to cool down gives a decorate finish to slab, commonly used.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Zaidi Brothers
Office#1 Block No#35
Chugtai Plaza Blue Area
Phone:+92 51 2878193-94
E-mail:zadibrothers@hotmail.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
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ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

MUD INSULATION (Stabilized Mud)

1

Thoroughly mix cement and mud until it gets uniform color. Mud used for the purpose should be free from lumps and bubbles. Mud should be dry enough to avoid pre-hardening of cement.

2

Add water to the mix and prepare stabilized mud. Cement and mud ratio in the mix is (1:12).

3

Lay stabilized mud and smooth the surface with the help of iron float. Use stabilized mud with in 45 minutes of adding water to it,otherwise cement might get set.

4

Required slope for drainage should be maintained and it is done along as the work proceeds before material starts setting.

5

Lay cement slurry on top to provide smooth finish and to protect water penetration from the top.

6

Top surface should be kept moist for a minimum period of three days. 2 coats of lime wash can be used on the top to make the surface reflective and improve the performance of solution.

TAKE NOTE

- *Slope of the slab should be carried to the top.*
- *Mud used should be free from grass roots and other materials ratio for the mix should be 1:12 with 1 part of cement and 12 parts of mud.*
- *Work should not be done in bad weather conditions.*

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INSULATIVE INSULATION (Stabilized Mud)

INSULATIVE INSULATION (Stabilized Mud)

4" thick stabilized mud having one part of cement and 12 parts of mud and cement slurry on the top surface.

ADVANTAGES / DISADVANTAGES

- Easy to install without any special skills, cost effective.
- Good for mud roofs in rural areas.
- With a lime wash finish on the top surface its efficiency can be improved.
- It deteriorates with rain splashes and needs frequent maintenance.

MATERIALS (for 15 x 15 ft room)

Cement	7 bags ordinary Portland cement
Sandy soil	75 cft
Water	500 liters

TOOLS

2 Steel Pans, 2 Shovels for mixing.
1 Hand level
1 Trowel, 1 Wooden float,
1 Aluminium float for finishing.

LABOUR

1 Skilled Mason
2 Labourers

TIME

2 Days

APPROXIMATE COST:
32 PKR per square feet
AUGUST 2010

PERFORMANCE

House with No Improvement							
Time	**06:00**	**09:00**	**12:00**	**15:00**	**18:00**	**21:00**	**24:00**
Temperature OUTSIDE	**29.1**	**34.3**	**39.7**	**41.0**	**39.2**	**34.1**	**32.0**
Temperature INSIDE	**32.6**	**33.3**	**34.9**	**36.2**	**37.6**	**37.1**	**36.7**

House with Insulative Insulation (Stabilized Mud							
Time	**06:00**	**09:00**	**12:00**	**15:00**	**18:00**	**21:00**	**24:00**
Temperature OUTSIDE	**29.1**	**34.3**	**39.7**	**41.0**	**39.2**	**34.1**	**32.0**
Temperature INSIDE	**32.6**	**33.3**	**33.9**	**34.8**	**35.4**	**35.5**	**35.4**

NOTES

- Difference in temperature is smaller and roof takes much time to cool down because of heavy mass being provided on the top surface.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Available in building material hubs

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

THE UN-HABITAT BETTER ROOFING PROJECT

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FOAM INSULATION (Mud With Thermopole)

1

Lay 4 inch thick mud on the surface and compact it with the help of hammer to 2 inch thickness. Water can be sprinkled to attain required thickness.

2

Lay 2 inch thick thermopole (expand polystyrene) sheet over mud with 1/2 mm polythene sheet above it to protect against water penetration from the top.

3

Add water in the mud and keep it soaked for a period of one day. Add wheat straw in the mud and mix it thoroughly until it turns into uniform blend.

4

Lay 2 inch thick mud plaster over polythene sheet and finish the surface with iron float. Let mud plaster dry for 2 days.

5

Lay 1 inch thick layer of cement concrete (1:2:4) over mud layer. Concrete layer will provide a wearing surface and protect the mud from weather effects.

6

Cure the surface for a minimum period of seven days. Two coats of lime wash can be used on the top for more improved thermal performance.

TAKE NOTE

- *Use aggregate of 2/ 8 inch for the concrete mix.*
- *Provide polythene sheet between mud layer and cement concrete so that mud may not absorb water from the concrete..*
- *Cracks in mud layer should be repaired and filled with slurry before providing concrete layer on the top.*

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INSULATIVE INSULATION (Mud With Thermopole)

THERMOPOLE WITH MUD

2"mud+2" thick thermopole (styro foam) + polythene sheet 1/2 mm thick(transparent)+ 2" mud layer with 1" PCC (1:2:4) topping.

ADVANTAGES / DISADVANTAGES

- Easy to install, cost effective and gives good result.
- Good for mud roofs in rural areas..
- It adds significant weight on the slab so it can't be used on structurally weak slabs.
- Efficiency can be improved by applying reflective coats of lime wash on the surface.

MATERIALS (for 15 x 15 ft room)

Cement	3 bags ordinary Portland cement
Sand	210 cft
Aggregate	20 cft, 2/8"
Water	500 liters
Mud	85 Cft
Plastic	1/2 mm sheet. 512 square ft laid in two layers.
Thermopole	225 Sft

APPROXIMATE COST:
52 PKR per square feet
AUGUST 2010

TOOLS

1 Steel Pan, 2 Shovels for mixing.
1 Hand level, 1 Trowel, 1 Wooden float,
1 Aluminium float for concrete finishing.
1 Hack saw blade
1 Knife for trimming plastic and foam.

LABOUR

1 Skilled Mason
2 Labourers

TIME

2 Days

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Insulative Insulation (Mud With Thermopole)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.0	33.0	33.2	33.6	34.6	34.2	34.1

NOTES

- Temperature difference is satisfactory after the application of mud, roof needs much time to get heated and to get cooled down.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Easily Available in Local Market

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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STEP BY STEP HOW TO DO IT

TILE INSULATION (Concrete Wizard Tile)

1

Clean the surface by removing all the dust and other particles.

2

Mix the ingredients of cement sand mortar in required proportion (1:4). Do not prepare mortar for the whole roof as cement will get set after 45 minutes.

3

Lay cement sand mortar 1 inch thick and fix the tiles in mortar. Maintain the required slope.

4

Use electric tile cutter to avoid damages to the tiles and save extra time required to cut the tiles manually. Tiles should be laid in such a way that minimum cutting is to be done.

5

Use trowel or plain steel bar (2/8") dia bar to fill the joints properly with cement slurry.

6

Finished surface should be cured for a minimum period of three days.

TAKE NOTE

- *Sand used for mortar should be free from clay and organic materials. Water used for preparation of mortar should be clean enough to drink.*
- *Provide Proper slope for efficient drainage. Maintain the slope given on the roof to the top surface.*
- *Lay tiles from corner to the center to avoid walking on freshly laid tiles.*

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INSULATIVE INSULATION (Concrete Wizard Tile)

TILE INSULATION (Concrete Wizard)

2" thick concrete wizard tile (light weight) placed and fixed in 1" thick cement sand mortar, cement grouting in joints.

ADVANTAGES / DISADVANTAGES

- Easy to install, in case of damage tiles can be replaced.
- Comparatively lighter in weight, can also be used on old roofs.
- Reduces the water absorption as compared to ordinary concrete.
- It is durable against wear and tear.

MATERIALS (for 15 x 15 ft room)

Cement	4 bags ordinary Portland cement
Sand	20 cft
Water	250 liters
Tile (12"x12"x2")	225 Nos

TOOLS

2 Steel Pans, 2 Shovels for concrete mixing.
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float,
1 Aluminium float for concrete finishing.
1 Concrete cutter, 1 Rubber hammer,
1 Paint Brush

APPROXIMATE COST:
78 PKR per square feet
AUGUST 2010

LABOUR

1 Skilled Mason
2 Labourers

TIME

2 Days

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Insulative Insulation (Concrete Wizard Tile)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.8	33.1	33.8	34.7	35.4	35.9	35.6

NOTES

- Temperature difference being made by the solution is smaller and roof slab takes more time to cool down because of increased thermal mass.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Concrete Wizard
Plot#31-A, Main road, I-9/2
Industrial Area Islamabad
Phone: +92 51 14448065
E-mail: info@conwiz.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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ENERGY EFFICIENT HOUSING
STEP BY STEP HOW TO DO IT

TILE INSULATION (Smart Concrete Tile)

1

Clean the surface and prepare cement sand mortar (1:4). Sand should be free from mud, water should be clean and free from impurities.

2

Lay the tiles starting from the edges in cement sand mortar (1:4). Use rubber hammer to set the tiles to avoid any damages. Mortar prepared should be used within 45 minutes of addition of water.

3

Use hand saw to cut the tiles if electric tile cutter is not available. Cover the entire roof with tiles and leave no space empty.

4

Cure the tiles before providing cement slurry on the top so that tiles may not absorb water from the slurry.

5

Use two coats of white appoxi on top surface to improve performance of slab by reflection and to enhance water proofing properties.

6

Surface needs to be cleaned frequently to maintain good reflective shine.

TAKE NOTE

- *Avoid walking on freshly laid tiles so that tiles may not be displaced.*
- *Maintain required slope while laying tiles for efficient drainage.*
- *While using white appoxi on the top surface make sure that feet are not dirty or use clean jute bag under feet.*

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INSULATIVE INSULATION (Smart Concrete Tile)

TILE INSULATION (Smart Concrete)

2-3/4" thick smart concrete tiles, laid in 1" thick cement sand mortar with cement grouting in joints and 2 coats of white appoxi.

ADVANTAGES / DISADVANTAGES

- Easy to install, found efficient, lighter in weight.
- Ease of handling, can be nailed, planed and sawn.
- Water resistant, excellent insulation against heat, cold and sound.
- Durable, cost is lower as compared to other tile insulation, life is more than 25 years.

MATERIALS (for 15 x 15ft room)

Cement	5 bags ordinary Portland cement
Sand	20 cft
Water	250 liters
Tile (15"x8"3")	275 Nos
White Cement	1/2 Bag
Plugger Powder (Rubber)	1Kg

APPROXIMATE COST:
65 PKR per square feet
AUGUST 2010

TOOLS

2 Steel Pans, 2 Shovels for concrete mixing.
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float, 1 Aluminium float for concrete finishing.
1 Hand Saw, 1 Rubber hammer, 1 Paint Brush

LABOUR

1 Skilled Mason
2 Labourers

TIME

2 Days

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Insulative Insulation (Smart Concrete Tile)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.5	32.3	33.0	33.7	33.8	33.6	33.0

NOTES

- Significant temperature difference was observed after the application as compared to an untreated house. Works primarily by reflection and then slows down the heat transfer.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Al-Taiba Associates
93-H,Commercial 1st floor
DHA, Phase-1, Lahore Cantt
Phone: +92 42 5742822
E-mail:ourarshad@hotmail.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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STEP BY STEP HOW TO DO IT

TILE INSULATION (Sachal)

1

Clean the roof and remove dust,pebbles,leaves etc from the surface.

2

Fix tiles in cement sand mortar (1:4), mortar thickness is 1 inch, use mortar with in 45 minutes of addition of water to it. Thickness of mortar should be kept constant throughout the slab.

3

Lay and fix the tiles starting from the edges. Use rubber hammer to avoid damage to the tiles and to ensure tiles are properly set and fixed in mortar.

4

Lay tiles in level with a gap of 1/2 inch in between for grouting. Remove surplus mortar around the tiles.

5

Use cement slurry for grouting. Use trowel to properly seal the gaps between tiles so that water may not penetrate from the joints.

6

Cure the surface for a minimum 3 days period. Lime wash can be used above to make it reflective and improve the performance of tiles.

TAKE NOTE

- *Sand used for mortar should be free from clay and organic materials. Water used for preparation of mortar should be clean enough to drink.*
- *Provide Proper slope for efficient drainage. Maintain the slope given on the roof to the top surface.*
- *Lay tiles from corner to the center to avoid walking on freshly laid tiles.*

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INSULATIVE INSULATION (Sachal Tile)

TILE INSULATION (Sachal Tile)

Sachal cellular light weight concrete tiles laid 1" thick cement sand mortar (1:4) with cement grouting.

ADVANTAGES / DISADVANTAGES

- Easy to install,gives better performance and efficiency.
- Ease of handling, affordable price range
- Immaculate and ever lasting finish, maintenance free elegant look.
- Available in multiple colors and sizes.

MATERIALS (for 15 x 15ft room)

Cement	4 bags ordinary Portland cement
Sand	20 cft
Water	200 liters
Tile	130 Nos (16"x16"x2")

TOOLS

2 Steel Pans, 2 Shovels for concrete mixing.
1 Hand level and 100 ft thread for setting out
1 Trowel, 1 Wooden float, 1 Aluminium float for concrete finishing.
1 Concrete cutter, 1 Rubber hammer

LABOUR

1 Skilled Mason
2 Labourers

TIME

2 Days

APPROXIMATE COST:
80 PKR per square feet
AUGUST 2010

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (Sachal Tile)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.1	32.4	33.8	34.0	34.2	34.3	34.0

NOTES

- Temperature difference is moderate and thermal comfort level is not much high. Roof slab cools down slowly once get heated. It retards heat transmission by conduction.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Sachal Engineering Works
59-E, Street: 7,I-10/3
Islamabad Pakistan
Phone: +92 51 4446873-74
email:jimmy@sachal.com.pk

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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STEP BY STEP HOW TO DO IT

TILE INSULATION (Al-Noor Tiles)

1

Clean the roof surface. Remove dust, pebbles, scratch bitumen or concrete humps if any to make the surface even and smooth.

2

Lay Fire clay hollow tiles with out any mortar. Make sure fire clay tiles are laid and set properly.

3

Always use tile or marble cutters to cut the tiles where smaller pieces are required. Using chisel for cutting may cause tiles to be broken and wastage of tiles.

4

Tiles should be laid in order to allow ventilation through them for better performance. For this purpose at least 4 inch gap should be provided between open ends of hollow tiles and edge of roof.

5

Fix the tiles from sides/edges with the help of cement sand mortar (1:4) so that tiles could not be displaced easily.

6

Cement sand mortar should be cured for at least three days to ensure proper setting of cement.

TAKE NOTE

- *Corner from the closed side of tiles should be made tapered with cement sand mortar to avoid any water penetration from the corners.*
- *Mortar should be cured for at least 3 days.*
- *Water proofing of the roof should be done before laying tiles if there is any leakage problem because no further treatment is done on the roof.*

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INSULATIVE INSULATION (Al-Noor Tile)

TILE INSULATION (Al-Noor Tile)

Al Noor fire clay tiles laid on the roof with provision of drainage at corners, no mortar is used.

ADVANTAGES / DISADVANTAGES

- Very easy to install no skilled labour required.
- Saving in consumption of mortar and it's performance is better.
- The cost is affordable, it lasts longer and gives better results,easily removable and work can be done quickly.

MATERIALS (for 15 x 15ft room)

Tile (8"x8"x3") 525 Nos
Thread 100 Rft

TOOLS

1 Concrete Cutter
1 Hammer

LABOUR

1 Skilled Mason
2 Labourers

APPROXIMATE COST:
80 PKR per square feet
AUGUST 2010

TIME

1 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Tile Insulation (Al-Noor Tile)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	31.3	32.1	33.2	34.1	34.2	34.1	33.8

NOTES

- Temperature difference is moderate and thermal comfort level is not high. It works by reducing heat conduction through cavity.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
AL-NOOR Refractries
(Pvt) Ltd, 108 Street 110
Westridge 1 Rawalpindi
Cantt Pakistan
Phone: +92 51 5479381
Email:info@alnoor-refactries.com

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

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INSULATIVE INSULATION (Green Net)

1

Drill holes in slab on corners to fix MS bed plate. Care should be taken while working near the corners to avoid falling down. Manual drill can also be used if electric drill is not available.

2

Fix MS plate by tightening screws. Do not use hammer to drive the screws.

3

Weld MS square conduit pipe of 1-1/4 inch size vertically for framing. Use safety lenses during welding. Provide proper and continuous welding layer for strength and durability.

4

After fixing the frame, fix green net. Remove wrinkles by tightening. Use copper wire to fix the net, care should be taken to avoid torning of net.

5

Keep suitable size for framing panels to avoid sagging incase of external loads being imposed by falling leaves.

6

Make the frame and fix net in such a way that access would be possible on the roof, openings on both sides will help cross ventilation

TAKE NOTE

- *Frame should be strong enough to withstand all wind pressures. Diagonal bracing should be done to improve the stiffness.*
- *MS conduit pipes should be painted to avoid rusting.*
- *Corners of framing should be smooth to avoid any damages to the net.*

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INSULATIVE INSULATION (Green Net)

INSULATIVE INSULATION (Gr. Net)

Green net fixed with 1-1/4" square conduit pipe framing with provision of access to the roof.

ADVANTAGES / DISADVANTAGES

- Green net insulation, easily available and easy to install environment friendly.
- It can also be used for growing vegetable and plants four seasonal on roof top.
- It is not durable, life is up to 3 years and susceptible to fire.
- The cost is higher than other solutions and gives better results.

MATERIALS (for 15 x 15 ft room)

MS Square pipe	130 Rft (1.25"x1.25")
Raval Plug concrete	#3 Three inch 16 Nos
MSBed Plate	4"X4" (6mm) 6 Nos
Welding Stick	1 packet
Green Net	325 Sft
Copper Wire	250 Grams

APPROXIMATE COST:
60 PKR per SFT
AUGUST 2010

TOOLS

1 Nut bolt Key, 1 Welding plant,
1 Steel cutter, 1 Hand level,
1 Drill machine
1 hammer

LABOUR

1 Welder
1 Net fixer
2 Labourers

TIME

2 Day

PERFORMANCE

House with No Improvement

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.6	33.3	34.9	36.2	37.6	37.1	36.7

House with Insulative Insulation (Green Net)

Time	06:00	09:00	12:00	15:00	18:00	21:00	24:00
Temperature OUTSIDE	29.1	34.3	39.7	41.0	39.2	34.1	32.0
Temperature INSIDE	32.5	31.1	34.7	35.1	35.4	35.0	33.7

NOTES

- Temperature difference being made is small and comfort level remains low. It provides shade to the roof and stops direct sun rays to the roof.
- The temperatures above are based on average readings over 20 days during 1-31 July 2010.

FOR MORE INFORMATION

Manufacturer
Available in Plant Nursery / hardware store

UN-HABITAT
GPO Box 1980 Islamabad
Phone : +92-51-8357358
Fax: +92-51-8357359
E-mail:mailbox@unhabitat.org.pk
Website: www.unhabitat.org.pk

Government
Ministry of Environment,
Government of Pakistan,
G-5/2, Islamabad

THE UN-HABITAT BETTER ROOFING PROJECT

The Ministry of the Environment, ENERCON, CDA and UN-HABITAT in cooperation with private sector manufacturers installed 19 different roofing improvement measures on 19 RC roofs in G/ 6-1 Islamabad in Summer 2010.

The objective is to test and compare the effectiveness of different solutions to improve the thermal performance of roofs, and to develop simple technical guidance for public information and awareness.

UN-HABITAT promotes socially and environmentally sustainable housing and cities for all

Developed by UN-HABITAT under the Joint Programme for the Environment DELIVERING AS ONE UN PAKISTAN

ENERCON
Government of Pakistan
CAPITAL DEVELOPMENT AUTHORITY
Islamabad
UN-HABITAT
FOR A BETTER URBAN FUTURE
United Nations Pakistan
Improving lives and helping people

APPENDIX II: OVERALL TEMPERATURE COMPARISON

Solution	Temperature Inside/Outside	Time							Result
		06:00 am	09:00 am	12:00 pm	03:00 pm	06:00 pm	09:00 pm	12:00 am	
Control House: Slab thickness is 5 inch. It does not have much thermal mass to hold heat inside but still it takes more time to cool down because of more absorbed heat.	Inside	32.6	33.3	34.9	36.2	37.6	37.1	36.7	RC slab gains too much heat during the day time slab radiates this heat during the night and takes more time to cool down.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Munawar AC Tiles: Fixed with 1 inch thick cement, sand mortar (1:4) as base and grouting with white cement slurry at top.	Inside	31.7	31.9	32.8	33.0	33.2	33.7	33.4	Temperature difference is high and thermal comfort level is maintained, works both ways by reflection and by slowing down the heat penetration by conduction.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Gypsum with Aluminum Foil Ceiling: 8mm thick gypsum board false ceiling with aluminum foil on back, fixed 8" below the slab, suspended using aluminum frame.	Inside	33.6	34.0	34.7	34.9	35.1	35.0	34.5	Temperature difference is high and thermal comfort level is low, requires ventilation in attic space for better slowing down the heat penetration by conduction.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Aerosol Reflective Paint: 2 coats of aerosol reflective paint on the surface including one base coat.	Inside	30.3	30.3	32.5	34.2	34.9	35.0	33.4	Temperature difference observed after the application of solution is moderate. Comfort level is low.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
White Enamel Paint: 2 coats of white enamel paint on the surface	Inside	30.0	30.1	32.0	33.1	33.6	33.8	32.9	Significant improvement in temperature is observed after the application of white enamel paint. Comfort level is maintained for maximum period during 24 hrs.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Thermo pole false ceiling: 1 inch thick thermo pole (expanded polystyrene) false ceiling suspended 8" below the slab with aluminum framing (2'x2') panels.	Inside	29.5	31.9	33.1	34.4	34.7	34.9	33.6	Improvement in thermal comfort level is moderate. Temperature difference is small, ventilation in space between slab and ceiling can improve results.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Weather Sheet Paint: Two coats of weather sheet paint (white coloured) on surface.	Inside	30.8	31.0	33.4	33.7	33.9	33.9	32.6	Temperature difference made by all reflective surfaces is almost the same. Roof cools down rapidly during the night because no heavy thermal mass provided to it.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Lime Wash: 2 coats of lime wash on the roof	Inside	31.0	31.1	32.0	33.1	33.6	32.9	32.6	Lime washed surface has shown good results with a Significant temperature difference, surface needs to be frequently cleaned, roof cools down quickly at night.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Paper board false ceiling: 1 inch thick paper board false ceiling fixed in panels of (2'x1') 8" below the roof slab suspended with aluminum	Inside	30.2	30.8	32.1	32.2	32.4	32.4	31.7	Solution has shown very good results by maintaining thermal comfort level during whole day and night, same temperature is maintained throughout the day
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	

Solution	Temperature Inside/Outside	Time							Result
		06:00 am	09:00 am	12:00 pm	03:00 pm	06:00 pm	09:00 pm	12:00 am	
OCEA MOL Chemical: 2 coats of rubber apoxy mixed with white cement and one coat of liquid rubber underneath for water proofing.	Inside	30.8	31.8	33.9	34.7	35.6	35	33.6	Temperature difference made by the solution is smaller, and thermal comfort level is low.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Flat fire clay tiles with Mud: 3 inch thick mud compacted + 1/2mm polythene sheet above and laying 1.75" thick flat brick tiles with cement slurry grouting at top.	Inside	31.9	32.5	32.7	33.1	33.7	33.8	33.9	Temperature difference as compared to an untreated is high, roof takes more time to transfer heat inside and cools down slowly because of more mass
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Gypsum Board False Ceiling: 8mm gypsum board ceiling fixed in panels of 2'x2', 8" below the roof slab suspended with the help of aluminum framing.	Inside	31.2	32.2	33	34.6	34.8	35	34.9	Temperature difference made by this solution is relatively smaller, roof takes more time to cool down gives a decorative finish to slab, commonly used.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Stabilized Mud: 4 inch thick stabilized mud having one part of cement and 12 parts of mud and cement slurry on the top surface.	Inside	32.6	33.3	33.9	34.8	35.4	35.5	35.4	Difference in temperature is smaller and roof takes much time to cool down because of heavy mass being provided on the top surface.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32	
Mud with thermo pole (Styro foam): 2 inch mud+2" thick thermo pole (Styro foam) + polythene sheet 1/2mm thick(transparent)+ 2" mud layer with 1" PCC (1:2:4) topping.	Inside	32.0	33.0	33.2	33.6	34.6	34.2	34.1	Temperature difference is satisfactory after the application of mud roof needs much time to get heated and to get cooled down.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Jambolon (Extruded Polystyrene): 1/2mm transparent polythene sheet+2"thick extruded polystyrene sheet with polythene sheet and 2" thick PCC (1:2:4) above.	Inside	30	31.1	31.9	32.2	32.8	32.6	32.0	Solution has shown very good results by maintaining high level of comfort for maximum period in day. Once heated it cools down very slowly.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Concrete Wizard Tile: 2 inch thick concrete wizard tile (light weight) placed and fixed in 1" thick cement sand mortar, cement grouting in joints.	Inside	31.8	33.1	33.8	34.7	35.4	35.9	35.6	Temperature difference being made by the solution is smaller and roof slab takes more time to cool down because of increased thermal mass.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32	
Smart Concrete Tiles: 2-3/4" thick smart concrete tiles, laid in 1" thick cement sand mortar with cement grouting in joints and 2 coats of white apoxy.	Inside	31.5	32.3	33.0	33.7	33.8	33.6	33.0	Significant improvement in temperature is observed temperature goes up very slowly and cools down solely.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Sachal Concrete Tiles: Light weight concrete tiles laid 1" thick cement sand mortar (1:4) with cement grouting.	Inside	31.1	32.4	33.8	34.0	34.2	34.3	34.0	Temperature difference is moderate and thermal comfort level is not much high. Roof slab cools down slowly once get heated.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Al Noor Fire Clay Hollow Tiles: Laid on the roof with provision of drainage at corners, no mortar is used.	Inside	31.3	32.1	33.2	34.1	34.2	34.1	33.8	Temperature difference being made by the solution is small and thermal comfort level is low. Slab cools down quickly.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	
Green Netting: Green net fixed with 1-1/4" square conduit pipe framing with provision of access to the roof.	Inside	32.5	33.1	34.7	35.1	35.4	35	33.7	Temperature difference being made by the solution is small and thermal comfort level is low. Slab cools down quickly.
	Outside	29.1	34.3	39.7	41.0	39.2	34.1	32.0	

APPENDIX III: MANUFACTURERS PARTICIPATION

Given below is a List of manufacturers who participated in the project under public private partnership at their own expense for the promotion of their product.

Manufacturer's name	Product's name	Material provided	Labour provided	Remarks
Diamond Foam	Extruded polystyrene (Jumbolon)	Yes	No	Extruded polystyrene sheets were provided by manufacturer.
Concrete Wizard	Insulating tiles	Yes	Yes	Tiles have been provided by manufacturer and Laying was also done by manufacturer's own labourers.
Munawar AC Tiles	Insulating AC tiles	Yes	Yes	Only cement/sand was provided by UN-HABITAT.
Al-Taiba Associates	Smart concrete tiles	Yes	Yes	Cement, sand and material carriage was done by UN-HABITAT.
SACHAL Engineering Works.	CLC tiles	Yes	Yes	Cement, sand was provided by UN-HABITAT.
Ghonsala (packages (Pvt. ltd)	Insulating Paper board	Yes	Yes	Total solution was done by manufacturer.

Note: All work on site has been done under strict supervision of UN-HABITAT.




Pakistan has been challenged with problems in electricity generation, increasing demand outpacing supply and resulting in extended load shedding especially in the summer. The price of electricity has increased dramatically, making life difficult for those on low and average incomes. Building improvements that reduce reliance on electricity are most important to reduce costs and improve comfort for low income families and to reduce the electricity consumption overall in Pakistan. While roofs pose a major problem in terms of heat gain (and heat loss in the winter), they are also easier to retrofit with improvement measures than other parts of the building. UN-HABITAT Pakistan in partnership with the Ministry of Environment and ENERCON initiated a project to test, demonstrate and compare traditional and new solutions to improve the thermal performance of RC slab roofs. The applications have been carried out on single storey Government houses in Street 31 of Islamabad's Sector G-6 /1 in partnership with the Capital Development Authority. All houses are of the same specification and condition and can be visited together to compare the results.

UN HABITAT

United Nations Human Settlements Programme
G.P.O. Box 1980, Islamabad Pakistan
Tel: +92 51 835 7358, Fax: +92 51 835 7359
mailbox@unhabitat.org.pk, www.unhabitat.org.pk