A Durable, Energy-Efficient, High-Performance and Sustainable Roofing System

[Excerpts from the Dr. Fixit LEC Systems Booklet, "Low Energy Consumption Systems for Sustainable Construction-2013" and http://high-performancebuildings.org/pdf/ECM2/ECM2_Technical_Information_Warm-Humid.pdf]

1.0 Introduction

Global temperature has risen significantly over the last century and causes a threat to our eco system. Weather elements like the sun and rain play havoc with the life and durability of concrete structures. This problem is compounded in urban living spaces which are characterised by concrete construction clusters, low vegetation and pollution from various sources. High temperatures lead to health risks of building occupants and higher energy consumption and demand, in turn, stress our environment. Water leakages and seepages also play a major role in impacting the longevity and durability of concrete structures.

Building roofs, in particular, are subjected to high sunlight exposure and rainwater lashing. This calls for an approach to sustainable roofing that can have the following objectives:

- Prevent water seepage and leakage through the roofs
- Ensure the health and comfort of the building occupants
- Reduce energy consumption needs, and most importantly
- Enhance durability of the construction through long term performance and extended service life

It is not only vegetative roofs or roof garden systems that are sustainable – the latest LEC (low energy consumption) roof system is also sustainable. It has integrated waterproofing as well as insulation features. Achieving sustainability with the above objectives is only possible through a well designed building envelope known as LEC system. This green roof system is based on a layered built-up that permanently weatherproofs the roof substrate from rain lash, hot and cold temperature and in turn, leads to high energy savings. This system is the ultimate armour for cool roofs of tropical climatic countries like India, where both rainfall and temperature are high.

2.0 Principle

Cool surfaces are measured by how efficiently they radiate heat (thermal emittance) and how much sunlight they reflect back (solar reflectivity). With this system, the amount of heat that is absorbed into the building's interior is reduced substantially, leading to greater comfort for the building occupants, lower energy costs and reduced energy needs. This system is designed to be highly reflective and emissive to ensure that the conversion of sunlight to heat is minimised, and the amount of heat radiated back is maximised. What's more, the strong built-up system also provides high quality waterproofing, ensuring years of trouble-free performance through this latest LEC system.

3.0 LEC System Components

The dilemma of balancing waterproofing and thermal performance for a LEC system or vegetative roof assembly needs to be assessed based on the site condition. The various climatic factors need to be considered, such as average annual rain fall, maximum and minimum rainfall, intensity of rainfall, highest and lowest temperature throughout the year, temperature fluctuations, humidity and desired performances of the system such as required heating and cooling load, energy savings, service life and overall cost efficiency. With such diverse factors affecting the system, it may not be ideal to design a particular system that can be applicable all over the country. Rather, one needs to choose the functional requirement first, and, based on the climatic conditions, the systems need to be upgraded to meet the specific requirement.

The requirements of an integrated LEC system for tropical regions consisting of a waterproofing system, thermal insulation system and protective finishing system are discussed as follows:

3.1 Waterproofing System

Waterproofing of a flat roof can be done with various types of liquid-applied coating that form a membrane because of their seamless application, along with suitable primer on a well prepared surface. A spray-applied coating forming material with high elongation and water impermeable properties is more suitable. Depending on the required waterproofing performances, the desired dry film thickness has to be evaluated and accordingly the material has to be sprayed to achieve the same result. Else, coverage of the material has to be calculated based on the manufacturer's specifications.

3.2 Thermal Insulation System

The roof requires significant solar radiation and plays an important role in heat gain / loss, day lighting and ventilation. Depending on the climatic needs, a proper roof treatment is essential. In hot regions, the roof should have enough insulating properties to minimize heat gains. A few roof traditional protection methods are as follows:

A cover of deciduous plants or creepers can be provided. Evaporation from roof surfaces will keep the rooms cool. The entire roof surface can be covered with inverted earthen pots like in northern India. It is also an insulated cover of still air over the roof shading device. This can be mounted close to the roof during the day and can be rolled to permit radiative cooling at night. The upper surfaces of the canvas should be painted white to minimize the radiation absorbed by the canvas. Consequent conductive heat gain through effective roof insulation can be provided by using vermiculite concrete. However, the heat gain through roofs can be reduced by adopting light coloured roofs having an SRI (Solar Reflectance Index) of 50% or more. The dark coloured, traditional roofing finishes have SRIs varying from 5-20%. A good example of high SRI is the use of broken china mosaic and light coloured tiles for the roof finish as traditional practices in western India, which reflect heat off the surface because of high solar reflectivity and infrared emittance, which prevents heat gain and thus helps in reducing the cooling load from the building envelope.

However, there are many different types of insulation materials to choose from when it comes to applying them on a commercial roof or reproofing an existing structure. The function of roof insulation is to insulate the building against heat inflow from outside during the day. Hence, the heat gain through roofs can be reduced by adopting an overdeck insulation system. In this system a thermal barrier or insulation is provided over the RCC, so that the heat of the sun is not allowed to reach the RCC slab of the roof at all. In this way the surface of the RCC is prevented from heating up. Once the RCC heats up, there is no other way for the heat to escape other than inside the building. So, even though the thermal barrier is provided under the RCC, as in under deck insulation, some heat passes through it and heats up the ambience of the room. This decreases the comfort level of the room and if the building is centrally air conditioned, increases the AC load. Hence, one can safely conclude that overdeck insulation has advantages over underdeck insulation. Overdeck insulation material should have adequate compression resistance, low water absorption, resistance to high ambient temperatures and low thermal conductivity. Overdeck insulation applications are carried out by either:

- Pre-formed insulation materials
- In-situ application

3.2.1 Preformed Insulation Material

Preformed insulation materials are further classified as expanded polystyrene slabs, extruded polystyrene slabs, polyurethane / polyisocyanurate slabs and perlite boards.

- Expanded Polystyrene (Fig. 1) (EPS, Thermocool) – It is a lightweight cellular plastic foam material composed of carbon and hydrogen atoms. It is derived from petroleum and natural gas by-products. Molded EPS does not involve the use of CFCs. Polystyrene is highly economical. EPS meets most of the performance.
- Extruded Polystyrene (XPS) – Extruded Polystyrene (Fig. 2) is an improvement over Expanded Polystyrene material. This material is also comprised of beads / globules which are compressed to form slabs and pipe sections. In the case of Extruded Polystyrene, the beads are very closely linked to each other so that the material becomes rigid and there is no air gap between the beads. It is a close cells material and a skin forms on the top which stops water absorption.
- Polyisocyanurate / Polyurethane Foam Slab - These are Urethane foam (Fig. 3) insulation materials with low thermal conductivity, low smoke emission and low water absorption.
- Perlite – Perlite insulation is an organic rigid board insulation. It is composed of expanded volcanic glas s (Fig. 4) and wood fibres bonded with asphaltic binders. This makes a rigid board, light in weight, dimensionally stable and good in compressive strength. In western countries, at one time, Perlite was the most common insulation material used for roof insulation. Although still popular, its low 'R'value, high 'K' value and tendency to absorb moisture have reduced its popularity.

Fig. 1: View of EPS material

Fig. 2: View of extruded polystyrene material

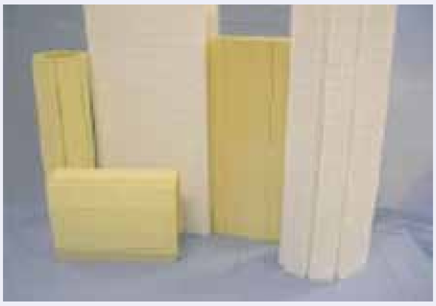


Fig. 3: View of Urethane foam insulation panels

Fig. 4: Materials used in Perlite insulation board

3.2.2 Extruded Polystyrene XPS Board Roof Insulation

Extruded Polystyrene is being widely used for insulation in India, its application method is given as follows:

- The recommended specification is for multiple-layer insulation. A double-layer applications is recommended especially when the total required thickness of XPS insulation is more than 50 mm. Cover boards are considered to be components of a multiple-layer insulation assembly.
- When double-layer XPS insulation is used, the joints of the insulation boards in the top layer should be vertically staggered and offset from the joints in the underlying layer. The end joints of adjacent rows of insulation boards should be staggered, and the edges of abutting insulation boards should be in moderate contact.
- During storage and handling, XPS insulation materials should be protected from the weather. XPS insulation also should be protected from petroleum-based solvents, adhesives and direct contact with certain coal-tar products. XPS insulation should be protected from direct contact with asphalt at temperatures more than about 120°C, and it should not be exposed to flames or other ignition sources.
- It is recommended that XPS insulation boards be covered with a complete roof membrane by the end of each day's work. For protected membrane roof systems using XPS insulation. It is suggested that the insulation be secured with appropriate ballast by the end of each day's work.
- At the end of each day's work, membrane temporary tie-in ply or plies should be installed, adhered to the roof membrane, and adhered or sealed onto the top or bearing surface of the roof substrate to protect the exposed ends of the insulation boards that have been installed that day. Unless water cutoffs have been specified and are to remain part of the finished roof assembly (in the same location where temporary tie-ins are applied), the tie-ins should be cut and adhered or removed entirely before additional insulation is applied.
- When XPS insulation is to be covered by a roof membrane, the roof deck should be relatively smooth, broom-clean and sufficiently dry to provide a proper surface for application of the insulation boards.
- Installation procedures for XPS insulation can vary, depending on the type and density of the insulation, type of roof deck, and type of roof membrane and securement method.

3.2.3 In-Situ Spray Applied Polyurethane Foam Technology

Unlike preformed materials, this is applied directly over the roof by spraying. This eliminates a separate fixing procedure. It is formed spontaneously when Isocyanate and Polyol are mixed in the presence of a blowing agent to create a close cell, homogenous, jointless insulation roof cover (Fig. 5). It is designed to combine highly efficient thermal insulation with great ease of application. It is ideal for a wide range of insulation applications, particularly for the roofs and walls of buildings. By nature, liquid-applied Foam Polyurethane adheres strongly to almost any surface, regardless of form. The seamless and monolithic nature of spray foam provides a full proof method of sealing cracks and rendering any surface moisture-resistant and drought-proof. The excellent adhesion of the sprayed material makes mechanical fastening redundant. The comparatively low density of the material adds little weight to the overall loading. Besides external use, sprayed foam can be applied internally as well.

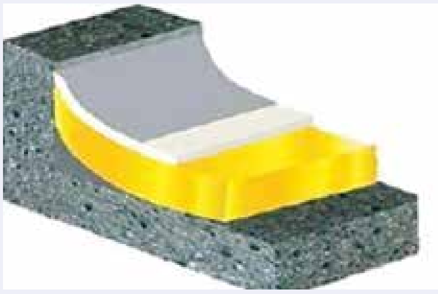


Fig. 5 : A view of PU foam insulation system over a concrete slab along with waterproofing and finishing material on top

3.3 Protective and Finishing System

Higher albedo materials can significantly reduce the heat island effect. The higher the albedo, the larger the amount of solar radiation reflected back into the sky. Roofs provided with high reflective coatings remain cooler than those with low reflectance surfaces and are known as cool roofs. Cool roofs can reduce the building heat gain and can save summertime air conditioning expenditures. These paints are highly efficient, energy-saving, flexible coatings, made from water-based pure acrylic resin systems filled with vacuumed sodium borosilicate ceramic micro spheres of less than 100 microns in size. Each micro sphere acts as a sealed cell and the entire mastic acts as a thermally efficient blanket covering the entire structure. These coatings are non-toxic, friendly to the environment, and form a monolithic (seamless) membrane that bridges hairline cracks. They are completely washable and resist many harsh chemicals. Roof coats have high reflectance and high remittance as well as very low conductivity value. They offer UV protection and low VOCs. They display excellent dirt pick-up resistance and retain their flexibility after aging. These roof coats reduce noise transmission and have an effective use range from –40° C to 375°C.

3.4 Integrated LEC System of Exposed Flat Roof

Considering the above factors for a pan India location, the integrated LEC system consisting of a combined waterproofing system, thermal insulation system and protective finishing system, can have a long durable service life of 25 years.

The waterproofing material can be sprayed at a rate of 1.5 l /m^2 or as per the recommendation of the manufacturer to achieve a dry film thickness of 1 mm, having high elongation upto 1600%, water vapour transmission of 0.2g/h/m^2, along with impact resistance and puncture resistance properties.

This system is based on a thermal insulation system consisting of spray applied 2-component PU (Polyurethane) foam, which excludes the possibility of any thermal bridges. Being spray-applied, the thermal insulation is fully bonded to the substrate. A special foam formulation allows a load of 2500 kg/m^2 to be installed above the foam. While the standard roofing system with an EPS (Expanded Polystyrene Slab) board of 75 mm thickness achieves a U-Value of 0.414 W/m^{2}K, this latest LEC system just requires a thickness of 40 mm special monolithic foam.

A protective system should consist of geotextile membrane of minimum 150 gsm, over which concrete screed of M20 grade, either from a concrete mixture or from a RMC pump, is placed to achieve a slope of at least 1:100. The finishing layer should be heavy duty acrylic-based white reflective coating or a heat insulating acrylic-based coating, containing hollow microsphere glasses, having solid content more than 60% and a solar reflectance index value of more than 80%.

A typical schematic diagram of a flat exposed roof terrace with both, a waterproofing and insulation system is shown in Fig. 6.

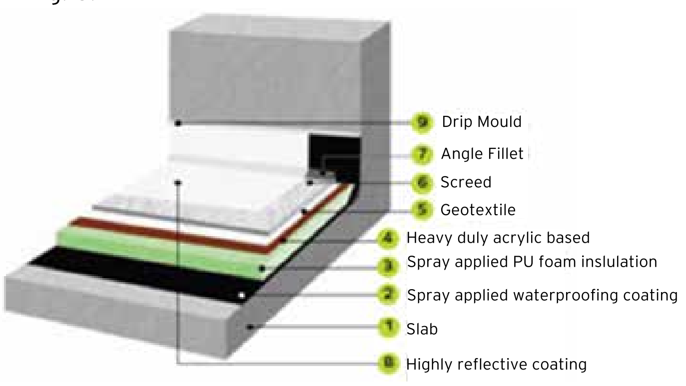


Fig. 6 : Schematic diagram for energy efficient high performance roofing system of an exposed flat roof

3.5 Integrated LEC System of Roof Garden

A roofing system through shading, insulation, evapo-transpiration and thermal mass reduces a building's energy demand for space conditioning. The green roof moderates the heat flow through the roofing system and helps in reducing temperature fluctuations due to the changing outside environment. The green roof system is partially or completely covered with vegetation and soil that is planted over the waterproofing membrane. If widely used, green roofs can also reduce the problem of urban heat island, which would further reduce energy consumption in urban areas.

The system components for waterproofing, thermal insulation and protective systems remain the same for exposed flat roofs and roof gardens. But instead of providing a finishing layer, as in the case of exposed flat roofs, a waterproofing system as required for roof gardens or vegetative systems should be introduced. A waterproofing layer with suitable primer has to be placed over the screed, followed by a geotextile membrane of minimum 150 gsm and a drain board. The waterproofing in this case may be either a torch-applied APP or an EPDM membrane. This has to be followed by a soil growth medium and plantation as per the requirement.

A typical schematic diagram of an inverted roofing system for a roof garden is shown in Fig. 7.

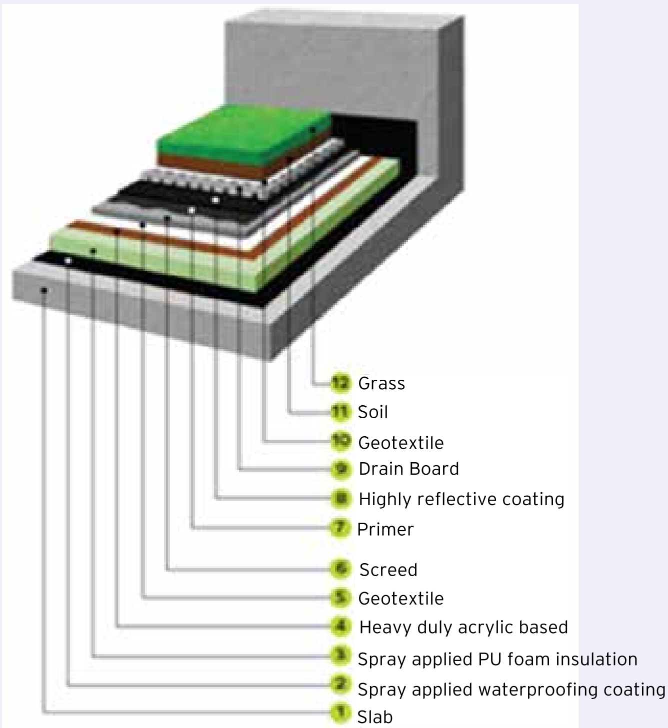


Fig. 7 : Schematic diagram for energy efficient high performance inverted roofing system for roof garden

4.0 Installation Methodology

The LEC system can be adopted for both, new as well as existing, roof terraces. Retrofitting the existing roof terrace needs more careful attention and assessment before the installation. The roof slab shall be inspected by a specialist and the acceptance for the application of the system is confirmed. The roof area shall be cleaned using a pressure wash or a compressed air system, to ensure that the substrate is free from dust, laitance, debris, etc. Appropriate repair materials shall be applied to make good any cracks, crevices, etc., in the substrate for old roofs. Any pipes or openings or protrusions shall be provided prior to taking up the surface preparation, as shown in Fig. 8.

Since this application would be quite thick, adequate provision must be made to provide water vents to the drain points in the roof, pointing upwards, so that the rainwater will drain with ease into them and pass off into the down-take rainwater pipes. In the case of large roof terraces, wherever the expansion joint is being provided, the detailing should be made as per Fig. 9.

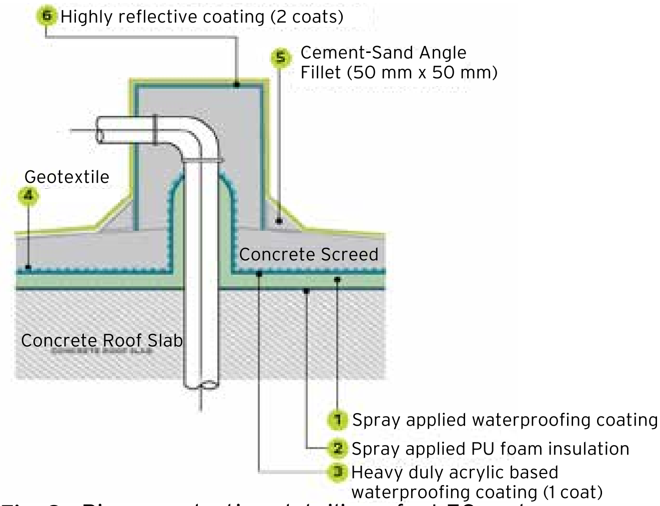


Fig. 8 : Pipe penetration detailing of a LEC system

4.1 Installation of Waterproofing System

The waterproofing material can be spray-applied quickly at 100 m^2 /h with a special spray gun, reducing crew size and job time. This waterproofing material is UV stable and weather-resistant, but is black in colour. It is lightweight and hence can be applied directly over an existing roof system, eliminating the need for wasteful and costly tear-offs.

4.1.1 Surface Preparation

Surface preparation is generally limited to pressure washing or compressed air cleaning to bond to the substrate.

4.1.2 Priming

Priming is required on some substrates prior to the application of this waterproofing membrane. Primer shall used for asphaltic-based substrates, as well as for concrete, to create a superior bond with the waterproofing membrane. An EPDM primer is used for EPDM and PVC substrates.

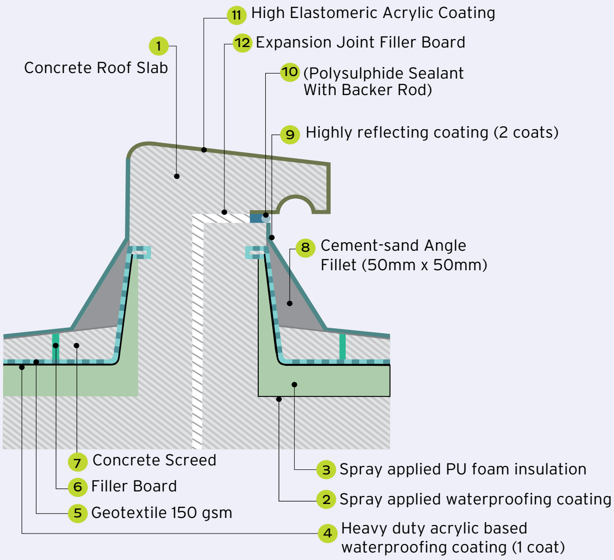


Fig. 9 : Expansion joint detailing of a LEC system

4.1.3 Application

A specially formulated spray-applied membrane forming shall be applied with a suitable spray gun, at an average thickness of 0.5 mm thickness. It cannot be sprayed through other types of commonly available sprayers without damaging the sprayer or the product. Coverage may vary depending on the profile and texture of the substrate to which it is being applied and on general application conditions. It is best to begin by spraying the lowest side of the roof and then work towards the higher points, to prevent the accelerator from running over clean substrate areas prior to spraying over them. If required, a quick setting repair mortar can be used as flashing and over-spray with this membrane system.

4.2 Installation of Insulation System

Polyurethane foam adheres to most surfaces, horizontal or vertical. It creates a fully-adhered, self-flashing, monolithic roof surface, with none of the critical failure points of most roof systems (seams and penetrating fasteners).With an insulation value of R 2.5 per mm, Polyurethane foam is the most efficient form of thermal insulation.

4.2.1 Surface Preparation

- The surface of application must be thoroughly prepared by mechanical means, to remove all loose particles, laitance, etc.
- Oil and grease, if any, must be de-greased with suitable solvents.
- Any surface undulations, cracks and crevices must be duly filled or repaired with cement sand mortar mixed with latex polymers.

4.2.2 Environmental Consideration and Substrate Temperature

Applicators must recognize and anticipate the climatic conditions prior to application, to ensure the highest quality foam and to maximize yield. Ambient air and substrate temperature, and moisture and wind velocity are all critical determinants of foam quality and selection, of the appropriate reactivity formulation. Variations in ambient air and substrate temperature will influence the chemical reaction of the two components, directly affecting the expansion rate, amount of rise, yield, adhesion and the resultant physical properties of the foam insulation. To obtain optimum results, this foaming system should only be spray-applied to substrates when the ambient air and surface temperatures fall within the range of 10°C and 48°C. All substrates to be sprayed must be dry at the time of application. Moisture in the form of rain, fog, frost, dew, or high humidity (> 85 R.H.), will react chemically with the mixed components, adversely affecting the Polyurethane foam formation, dimensional stability and physical properties of the finished product. Similarly, wind velocity in excess of 20 km/h may result in excessive loss of exotherm and interferes with the mixing efficiency, affecting foam surface, curing, and physical properties.

4.2.3 Application Equipment

- 2:1 transfer pumps are required for material transfer from container to the proportioner. The plural component proportioner must be capable of supplying each component within + 2% of the desired 1:1 mixing ratio by volume. Hose heaters should be set to deliver 50°C to 55°C materials to the spray gun. These settings will ensure thorough mixing in the spray gun mix chamber in typical applications.
- Optimum hose pressure and temperature will vary based on the equipment type and conditions, ambient and substrate conditions, and the specific application. It is the responsibility of the applicator to properly interpret equipment technical literature, particularly information that relates to the acceptable combinations of gun chamber size, proportioner output, and material pressure.
- The relationship between proper chamber size and the capacity of the proportioner's pre-heater is critical.
- Mechanical purge spray guns (specifically direct impingement or DI type) are recommended for highest foam quality.

4.2.4 Application

- Polyurethane foam is sprayed onto the prepared roof surface in two components (a polyol and an isocyanate), that when mixed, expand their volume to form a seamless layer of rigid foam. Within minutes this foam can be walked on and it cures to 90 percent of its full strength in about four hours.
- The Polyurethane foam should be applied @ 50 kg/m^3 density or as specified by the manufacturer to form an average thickness of 40 mm.

4.2.5 Precautions and Limitations of PU Foam Application

- If the components are below the suggested temperatures, the increased viscosity of the components may cause pump cavitation, resulting in unacceptable SPF application.
- If the components are above the suggested temperatures, there may be loss of the blowing agent, resulting in diminished yield.
- Extreme care must be taken when removing and reinstalling drum transfer pumps, so as not to reverse the 'A' and 'B' components.
- Store drums at 20°C to 25°C for a minimum of 48 hours before use.
- Materials in containers should be maintained at 20°C to 25°C while in use. Material temperature should be confirmed with a thermometer.
- Do not configure equipment to recirculate foaming component materials from the proportioner back into the drum.
- Do not recirculate or mix other suppliers' 'A' or 'B' component into the material system containers.

4.3 Application of Sealcoat Over PU Foam

Over the PU foam, a single coat of heavy duty, micro fibre reinforced, water-based acrylic coating should be applied with a roller. This shall be done over an acrylic-based primer, which shall be applied over Polyurethane foam. However a second coat of sealer coat may be applied on larger roof terraces.

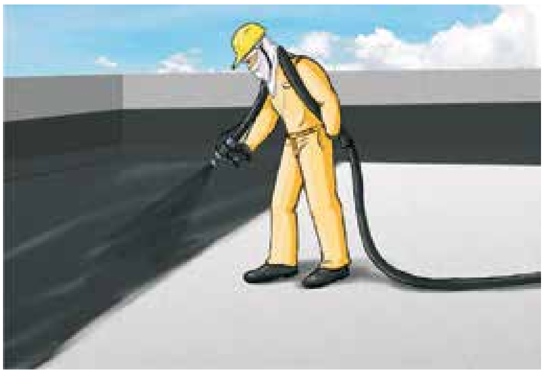
The first half of the step-by-step application method of a LEC system, right from surface preparation to waterproofing, as well as an insulation system, is shown in Fig. 10.

4.4 Ponding Test

A water ponding test shall be conducted after 5 to 7 days of the seal coat application. Water shall be filled up and retained for at least 24 to 48 hours.

a. Site Preparation

b. Compressed Air Cleaning



c. Application of spray applied water proofing coating

d. Application of spray applied PU foam insulation

e. Application of Heavy duty acrylic based waterproofing coating over Spray applied PU Foam insulation

f. Completed with heavy duty acrylic based waterproofing coating (2nd coat)

Fig. 10 : Step-by-step application method of a LEC system (cont.)

4.5 Application of Protective Layer

After completion of the ponding test and emptying the water, a geotextile membrane of 150 gsm shall be placed. A bitumen board meant for construction joints in screed shall be placed vertically at 3 to 4 m along the length and breadth of the roof area. Each rectangular bay formed in this manner shall not exceed 12 m^2. Concrete screed of M20 grade shall be cast into these bays, maintaining the requisite slope of at least 1 in 100. All around the roof at the parapet wall junction, an angular fillet of 50 mm X 50 mm shall be trowel-applied in cement-sand mortar in 1:3 proportions over the screed, in which the sand shall be cleaned and washed off its silt content. Curing of the concrete screed and angle fillet shall be done as per regular concrete curing practices, by means of regularly wetting a hessian cloth. A few days later, after the curing period, the bituminous filler board shall be exposed by means of a mechanical cutting machine, and lose mortar shall be cleaned or vacuum-sucked to make a clean surface. The grooves formed by exposing the filler board shall be applied with polysulphide sealant of a gun or pouring grade, or a PU sealant. The width and depth of the sealant fill shall not be more than 10 mm each.

4.6 Application of Finishing Layer

After 2 to 3 days of fixing joints with the sealant, a heavy duty, micro fibre reinforced, water-based acrylic coating or a heat insulating acrylic-based coating containing hollow microsphere glasses shall be applied over the screed, primed with acrylic primer, and over the angle fillet, right upto the flashing level on the parapet wall.

The second half of the step-by-step application method of a LEC system, right from the ponding test to the finishing coat, is shown in Fig. 11.

a. Water Ponding Test - 24 Hours

b. Fixing Filler Boards Over Geo Textile

c. Casting Concrete for Screed

d. Angle Fillet over Top Screed

e. Making Grooves on Screed

f. Filling Grooves with a PU sealant

g. Coating Screed with highly reflective coating

h. Completed Roof With Heavy duty acrylic based waterproofing coating/ highly reflective coating

Fig. 11 : Step-by-step application method of a LEC system

4.7 Safety Precaution

While spraying, one has to take safety precautions like wearing a respirator in areas of limited ventilation. Otherwise, a basic nose mask and goggles are recommended while spraying.

5.0 Comparison of Performances

The performance of this latest system is being considered by comparing various factors such as thickness of material, dead load per unit surface area, energy efficiency, cooling load, cost, durability and environmental sustainability.

As per ECBC (Energy Consumption Building Code) norms, the insulation requirement of roof should have minimum R value of 2.1 m.C/W of insulation alone and maximum U-factor of 0.409 W/m^{2}C of overall assembly for all 5 different climatic zones of India. Considering the minimum requirement of insulation for the R value for day time use of buildings other than hospitals, hotels and call centres, the required thickness of different insulation materials are proportionally shown in Fig. 12. It can be seen from Fig. 12 that the thickness of insulation material in LEC system is 50 times less than brickbat coba, 2 times less than EPS material and 1.6 times less than XPS type of material to achieve the same objective of getting R value of 2.1 m.C/W. The dead load of this insulation material in LEC system is only 1.9 kg/m^2 comparing to the dead load of 2990 kg/m^2 of a brick bat coba system. Thus this LEC system is very light weight and contributes hardly any dead load to the roof slab.

Fig. 12 : Comparison of thickness of different insulation material for meeting the requirement of ECBC for R value 2.1 m.C/W

India being a tropical climate, energy saving calculation is based only on measuring cooling loads. But in western countries both heating and cooling loads need to be evaluated for the same purpose. A comparison was made by calculating cooling load efficiency of different insulation materials available in India for which most commonly used EPS material was taken as standard reference material and the same is shown in Fig. 13.

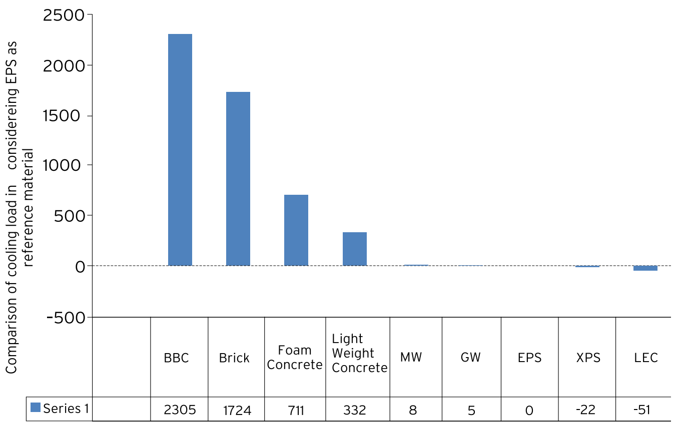


Fig. 13 : Expansion joint detailing of a LEC system

It can be seen from Fig. 13 that the cooling load efficiency of insulation material used in LEC system is 51 % less than EPS reference material while cooling load efficiency of brickbat coba system is 2305 % higher than EPS reference material. One can compare the energy efficiency of this insulation material used in LEC system over brickbat coba system. But still we are using the old traditional practices of brick bat coba even providing layer after layer for waterproofing as well as insulation. This shows still how much backward we are in adopting this latest material though the technology is available at our door step.

Considering the performances and durability, this system is meant for some decades not for few years. It is unwise to compare the initial cost of this system with traditional or any other system since the initial cost will be too high. But considering the benefits of energy saving and durable waterproofing performances in a long run, the system would be definitely economical. Hence the life-cycle-analysis for cost and environmental sustainability must be analyzed before taking a final decision for adopting a high performance waterproofing and insulation system.

6.0 Conclusion

Whether a LEC system or a roof garden / vegetative system, the percentage of adoption of such green roofing in India is very minimal as compared to other developed countries, because of a lack of awareness, the mindset of adopting a new system and the initial cost factor. The energy savings usually cover the cost of the roof system in a few years, and, by placing the insulation on the outside of the envelope, the foam reduces building expansion and contraction. The initial cost of installation of the system may be higher, but considering the cost for a longer period, or considering life cost analysis along with environmental benefits, this system will be more sustainable in all aspects like economical, environmental and technological issues. When it comes to roof waterproofing, sustainability has mostly not been the deciding factor. The main focus is laid on waterproofing properties but not on insulation. However, the latest LEC system is a complete roofing solution that combines thermal insulation and leak proof waterproofing for sustainable roofing, and is very much suitable in our tropical climate. Being a system which can be part of any LEED certification, this LEC system offers ecological and economical advantages against standard systems. This saves resources and is part of the LEED / GRIHA certification.