“State of the art roofing systems: PVC membrane roofing -- a new approach”

Key words: roofing, synthetic membrane, PVC, single ply roofing, thermoplastic.

Abstract:

Construction industry in India has been at its all time high growth rate for past couple of years. The growth is in all walks of construction world, be it infrastructure, industrial or residential. This exponential growth has also thrown a few challenges at the construction professionals all across India which has motivated them to look at newer approaches to tackle such challenges.

Waterproofing (including roofing) has seen two distinct changes in approaches in the recent times:

 # New technologies (Design driven)

 # New concepts (Construction driven)

Introduction of synthetic membrane roofing systems in India is one such step forward towards this new approach in terms of technology and concept.

With a high end, state of the art technology like PVC membrane based waterproofing and roofing systems, there can be serious value additions where conventional systems found to be less equipped to handle the higher demands like in the following typical applications;

- *case of re roofing of old bituminous and tiled roofs,*
- *metal deck applications,*
- *roof gardens,*
- *energy savings in buildings and green building requirements (LEED certified) from roofing materials*

In short, this means that this state of the art technology now provides the construction world with a solution which has evolved by taking care of such requirements and hence can be looked at as an option when conventional treatments give lesser performance.

Author biography:

Arijit Basu is a marketing professional with more than 13 years of cross functional experience in the field of construction chemicals in Indian market. He has been instrumental in new technology introduction and concept selling for entire part of his career. He has been associated with the Swiss multinational SIKA AG as Corporate Manager, Strategic Sales Unit responsible for Waterproofing/Roofing business in India. His core competence in strategic marketing, business communication and presentations and his track record of introducing and successfully establishing new technologies in competitive market have been appreciated and recognized in the industry.

He is a Bachelor in Science with Chemistry Major and also a Post Graduate Diploma holder in Business Management. But his biggest strength is what he has learnt ‘hands on’ over the years. He is a thorough professional with clear vision and also a person who comes across friendly and easy to approach. He loves reading, music, travelling and spending quality time with his family.

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Introduction:

Construction industry in India has been at its all time high growth rate for past couple of years. The growth is in all walks of construction world, be it infrastructure, industrial or residential. This exponential growth has also thrown a few challenges at the construction professionals all across India which has motivated them to look at newer approaches to tackle such challenges.

In this paper, an effort has been put together to share such developments and to discuss on the new approaches in waterproofing with a special emphasis on the state of the technology of synthetic membrane (PVC) roofing systems.

Why new approach?

Today, we are challenging the depths as well as the heights and creating structures with innovative designs and extended durability. What we are looking for in our methods and practices adopted to create such challenging structures are:

Speed of construction (time is money)

Security in terms of performance (risk control)

Minimum maintenance (life cycle cost analysis)

Economy (best return on investment)

Warranty (assurance of durability – proven technology)

To achieve these mutually opposing pre-requisites, construction world has felt the need for new approaches and systems in terms of technology and concepts. Waterproofing, being one of the key factors for the durability of structures, has also seen a lot of changes with new technology introduction and conceptual changes.

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What are the new approaches?

Waterproofing (including roofing) has seen two distinct changes in approaches in the recent times:

New technologies (Design driven)
New concepts (Construction driven)

Introduction of synthetic membrane roofing systems in India is one such step forward towards this new approach in terms of technology and concept.

With a high end, state of the art technology like PVC membrane based waterproofing and roofing systems, there can be serious value additions where conventional systems found to be less equipped to handle the higher demands like in the following typical applications;

- case of re roofing of old bituminous and tiled roofs,
- metal deck applications,
- roof gardens,
- energy savings in buildings and green building requirements (LEED certified) from roofing materials

In short, this means that this state of the art technology now provides the construction world with a solution which has evolved by taking care of such requirements and hence can be looked at as an option when conventional treatments give lesser performance. However, this does not necessarily mean that the existing waterproofing technologies will not deliver under situations which demands less performance criteria out of such applications.

Introduction to PVC based roofing systems:

Background:

The history of roofing market in India is pre dominantly ruled by brick bat coba and bituminous coatings and membranes. There is also a shift towards spray / roller applied liquid membranes like acrylics, urethanes and polyurea. However, the challenge with new structures and state of the art designs with higher exposure to atmosphere, has shown up the constraints and limitations specially related to such conventional system which need to be dependent on the substrate bonding for the long term performance.

PVC: A history of performance

PVC (polyvinyl chloride) roof membranes have the longest track record of any thermoplastic membrane, with the first PVC-based systems installed in Europe in the early 1960s. The use of PVC roofs continues to grow in the recent years all across the globe. According to RSI's 2001 State of the Industry Report, more than 20% of the average roofing contactor's volume was PVC, particularly for exposed membrane application. Reinforced PVC roof membranes have many important attributes that complement their proven track record and have spurred additional growth. Besides the important feature of heat-welded seam technology, PVC or vinyl roof membranes offer many other inherent features.

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These additional features include:

- a comprehensive history of product testing,
- an ability to be made in a spectrum of colors including reflective white,
- a high resistance to puncture and impact,
- an excellent resistance to flame exposure and subsequent fire propagation,
- proven durability against rooftop soiling and contamination, and
- good low-temperature flexibility and high-temperature tolerance.

PVC roof membranes are very user friendly and are installed by a variety of attachment methods. Vinyl roof membranes are aesthetically appealing and they provide excellent visual feedback of workmanship for the applicator during and after installation.

Specifically, vinyl is "polyvinyl chloride." PVC is a molecule comprised of carbon, hydrogen and chlorine (taken from salt). As mentioned above, today's reinforced vinyl membranes have a long history of installations worldwide; many that were installed over 20 years ago are still performing today. Vinyl membranes for roof applications were first developed in Germany and Switzerland in the 1960s and arrived in North America in the 1970s. The use of vinyl membranes in low-slope roofing has grown significantly and rapidly in North America ever since then. Vinyl membranes were the first single ply roof products to obtain a standard designation, D4434, from the American Society for Testing and Materials (ASTM). ASTM D 4434 was published in 1985 and has been updated several times since then.

The Thermoplastic Advantage:

Vinyl is the best known thermoplastic roof membrane. "Thermoplastic" means that when heated sufficiently, the material temporarily changes from a solid to a semisolid state enabling the sheets or panels that are overlapped to be fused together and return to a solid upon cooling, yielding one continuous membrane. It is this feature that enables the seam overlaps of vinyl roof membranes to be fused or heat welded together.

To accomplish the welding, specialized, electrically-powered welding equipment that is either self-propelled or handheld is used. These units operate on electricity and inject heated air into the seam area, softening the membrane surfaces. A roller that is either hand-held or part of the self propelled unit, presses the seam overlap together. As the welder moves away from a given seam location, the membrane quickly cools down to ambient temperature and the heat weld (thermo fusion) is made, providing a watertight bond.

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Basics of PVC chemistry:

PVC has been industrially produced for over 60 years. It is one of the best-known innovative synthetic polymers, with a consumption of over 30 million tons a year.

Worldwide, PVC is number three, behind polypropylene and polyethylene.In spite of continuously stronger competition by other materials, PVC accounts for about 16.5% of the worldwide plastics production. PVC has always kept pace with increasing demands – ecological, technological, and economic – and it still has potential, so PVC applications will continue to develop in the future. Taking the lead are the rapidly developing Asian countries with double-digit growth rates.

PVC is one of the best-researched of materials. The risks associated with manufacturing, use and disposal are largely known and will continue to be minimized.

The versatility of vinyl affords the membrane manufacturer many options when formulating for enhanced chemical resistance, flexibility and/or tensile strength. Vinyl roof membranes have great versatility of application. Vinyl roof membranes are usually mechanically-attached, adhered to the insulation or other substrate or held in place with stone or concrete as ballast. Some vinyl roof membranes are also offered in large prefabricated panels intended to reduce rooftop installation time. In addition, vinyl membrane can be readily produced with "fleece cushion" backing (typically polyester) that enables it to be installed over slightly rough surfaces and/or to be adhered with a variety of adhesives.

In order to complement this versatility of application, vinyl roof membranes can be manufactured in a variety of colors. This feature allows for the application of rooftop logos or multiple-color roofs. The look of steep slope metal can also be simulated with a colored vinyl membrane.

Under a new program, many vinyl membranes have the well-known Energy Star label from the United States Environmental Protection Agency (EPA) and the Department of Energy (DOE). This label assures the building owner that their roof membrane meets the energy saving specification of the EPA and DOE.

Another significant benefit of vinyl roof membranes is their fire resistance. Vinyl membranes are inherently self-extinguishing which enables them to perform exceptionally well in fire tests undertaken at organizations such as Underwriters Laboratories and Factory Mutual, etc. and to perform reliably in real-world flame exposure. In addition to fire resistance, vinyl membranes also meet or exceed other industry performance standards that involve water leakage, puncture resistance, hail resistance, wind-uplift resistance and so on.

Vinyl roof membranes also stand up exceptionally well to ponded rainwater, which often remains despite efforts for positive drainage, and to a variety of typical rooftop contaminants, such as air pollution, bird droppings, acid rain., etc.

Over a long period of time, vinyl roof membranes have earned the recognition of being a proven and versatile thermoplastic for rooftop applications.

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Manufacturing:

Vinyl roof membranes are manufactured by various methods, including extrusion, calendering, laminating, extrusion coating, spread coating or a combination of the above. In all cases, however, the finished vinyl roof membrane contains polyester or fiber glass reinforcement, vinyl resins, ultra-violet light inhibitors, heat-stabilizers, biocides, pigments and plasticizers. Polyester reinforcement imparts high tearing and breaking strengths needed for mechanically-fastened roofing systems.

Base materials for the production of PVC are petroleum and rock salt. As an intermediate product, naphtha is produced from petroleum, and from this ethylene is produced by thermal decomposition. Chlorine is electrochemically (alkali-chlorine electrolysis) produced from rock salt. Vinyl chloride (VC) is produced from ethylene and chlorine at the proportion of 43% to 57%. A new process for manufacturing VC from ethane is now being tested at the pilot scale.

VC is the monomer building block for manufacturing PVC (polyvinyl chloride). PVC is industrially manufactured by polymerising VC through three different processes:

Emulsion polymerisation	E-PVC
Suspension polymerisation	S-PVC
Mass polymerisation	M-PVC

These standard manufacturing processes for PVC influence chiefly the appearance – properties such as grain size, grain shape, and grain porosity, which is decisive for the absorption of plasticizers. The chemical nature of certain additives such as plasticizers, stabilisers, lubricants, fillers, pigments, expanding agents, antistatic agents, flame protection additives, UV-stabilizers, and others permanently affect the properties of the end product.

Characteristics:

PVC - Properties

Basis for the growth of the application possibilities is the outstanding properties of PVC, such as functionality, cost-efficiency, and environmental friendliness in many industry areas and countless applications:

- PVC is a thermoplastic and is thus heat-formable, hot-air weldable, solvent weldable, and high-frequency weldable.
- PVC is ageing resistant, weather resistant, water and chemical resistant, wear resistant, abrasion resistant, flame resistant, acoustically insulating, thermally insulating, dimensionally stabile, impact resistant, and colour fast. It can be made glass-clear, it allows many design possibilities, it is easy to print on, and it is suitable for a wide variety of applications.
- PVC is economical, robust, easy to care for, maintenance-free, and easy to form and work with.
- PVC is environmentally compatible, eco-efficient, recyclable, and it conserves resources.

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Depending on whether plasticizers are added, PVC articles are either rigid or soft and flexible. The material properties can be varied and optimized to suit specific applications by simple changes of the recipe.

E-PVC: fine grained, processed as a paste in spreading processes.
S-PVC: coarse grained, processed as dry-blend or granulate in calendar, extrusion, and injection moulding processes.
M-PVC: coarse grained, processed as dry-blend or granulate in calendar, extrusion, and injection moulding processes.

Recipe Components:

PVC:	S, E, M-PVC depending on the processing method and application of the end product.
Plasticizer:	gives flexibility and softness
Stabilizer:	gives heat and light resistance in processing and during service life
Pigments:	Organic and inorganic pigments
Additives:	Fillers, lubricants, flame retarding additives, anti-static additives, biocides. etc.

The selection of PVC membrane, thus, is crucial to the success and long term performance of the roofing system. The myth about PVC is generally that there is only one type, however, in reality PVC is of several types based on the formulation used. The expertise and experience of the membrane manufacturers play a very important role in establishing the right quality and performance of the systems used by construction professionals.

What does it take to make a good roofing application:

Roofing applications will always be critical as it has to take care of many challenging requirements like ultra violet exposure, wind uplift forces, substrate movement due to changing temperature, rain fall, pollutants in the air, etc. etc.

It is thus, needed to understand that a good roofing will require:

system design (roofing built up should be designed)

system components (products + accessories = system)

proven and tested (approvals, certificates, case studies, references)

installation (equipment + quality control + hand skill)

meaningful warranty (minimum maintenance roofing)

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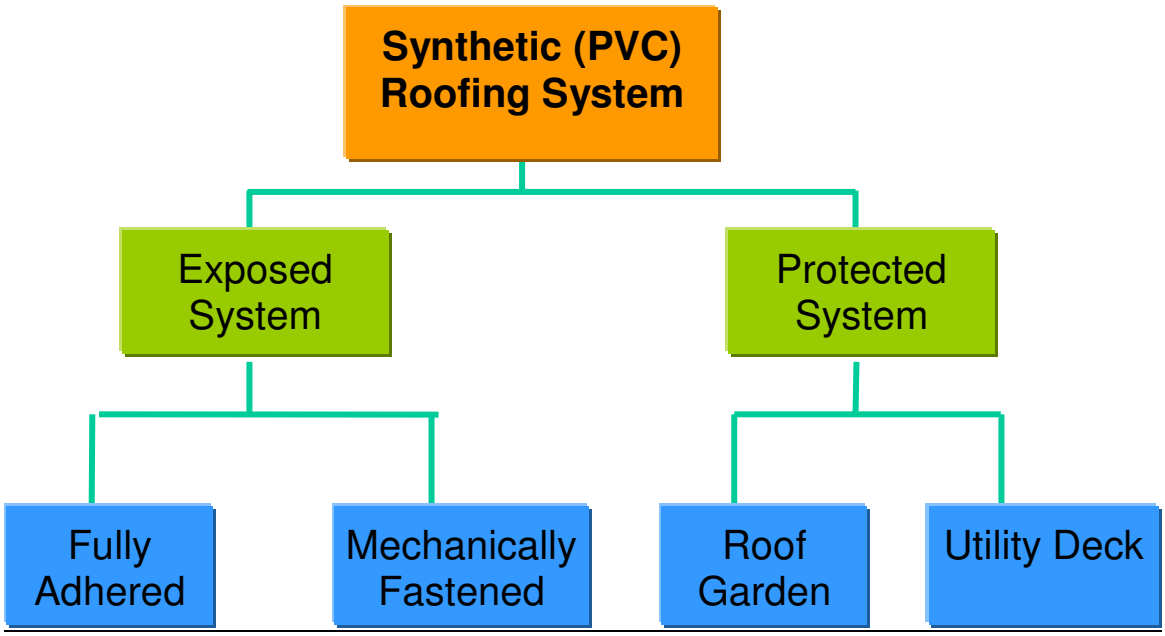
Typical synthetic(PVC) roofing membrane applications:



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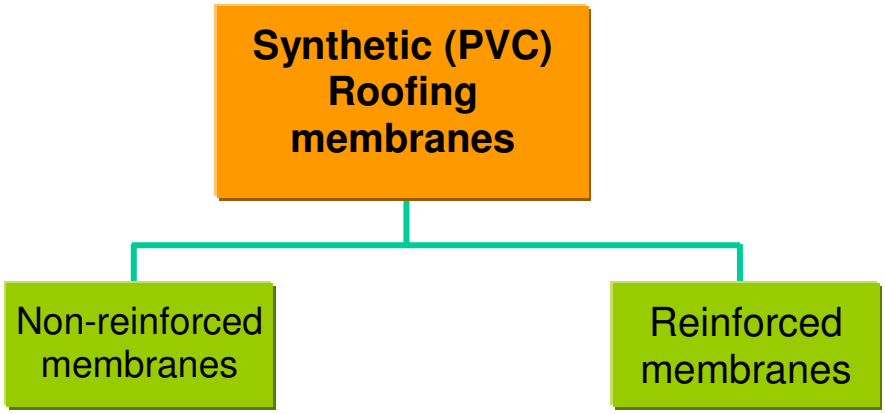
Types of PVC membranes:



Non reinforced membranes are generally used for mechanically fastened roofing applications and detailing areas. The usage of non reinforced PVC membranes are limited to non critical applications on flat roofs. Non reinforced membranes are also not commonly used under higher UV exposure as exposed applications (mostly used as concealed applications).

Reinforced membranes are generally reinforced with a special reinforcement in the form of either glass fabric or polyester fabric. Glass reinforced membranes are higher in elongation and generally used for fully bonded applications with suitable adhesive in designed roofs, roofs with special shape and geometry, gutter areas etc. The polyester reinforced PVC membranes are of lesser elongation and suitable for mechanically fastened applications for large flat roof. The reinforced membranes are having better dimensional stability.

However, please note that reinforcement is not a replacement for polymer thickness to achieve desired membrane thickness. A good quality PVC membrane should possess a certified polymer thickness. This should be given more priority than the commonly used ASTM nominal thickness which allows negative variances of as much as 10%. When multiple manufacturers are specified, a certified polymer thickness requirement establishes a more uniform basis of comparison.

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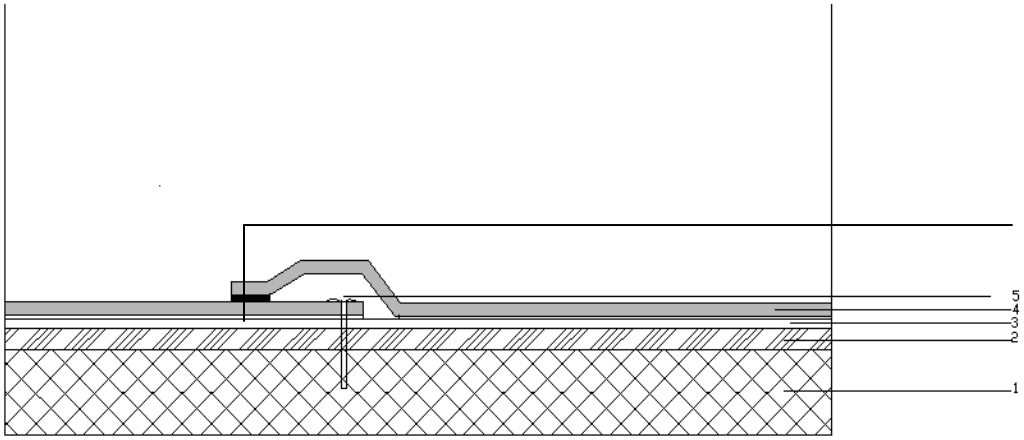
Typical built up of PVC roofing installations:

 # Concrete flat roof with mechanically fastened system:

Horizontal Lay-out



1 R.C.C. Roof deck
2 Protective Screed
3 Geotextile (300 gm/m^2)
4 Synthetic roofing membrane (PVC)
5 Fastener covered with PVC membrane
6 Hot air welding (Thermo fusion)

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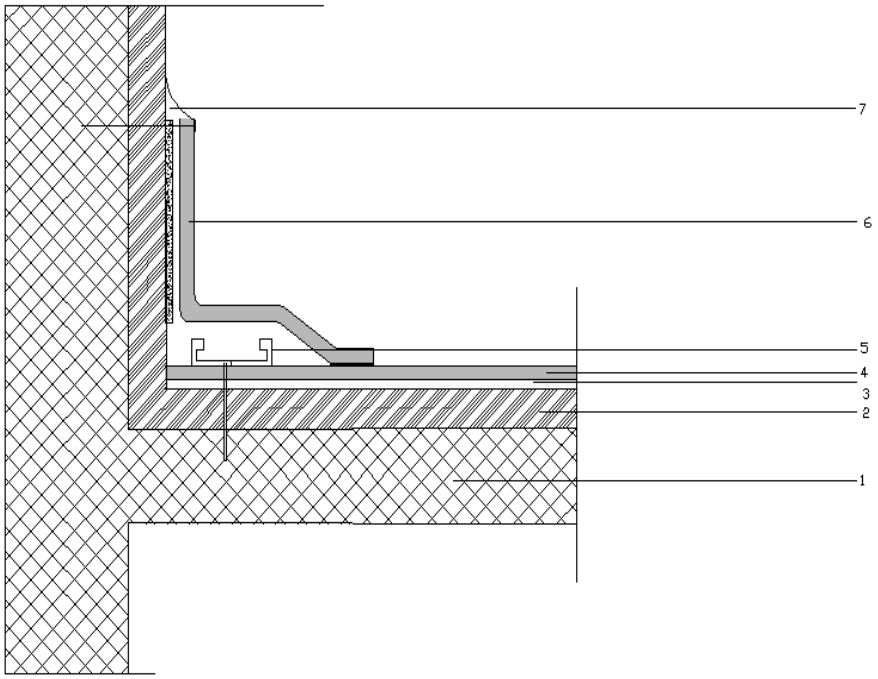
Roof- Parapet Junction



1 R.C.C. Roof deck
2 Protective Screed
3 Geotextile (300 gm/m^2)
4 Synthetic membrane (PVC)
5 U-Bar covered with PVC membrane/ welding cord
6 Synthetic membrane with adhesive
7 Sealant (PU)

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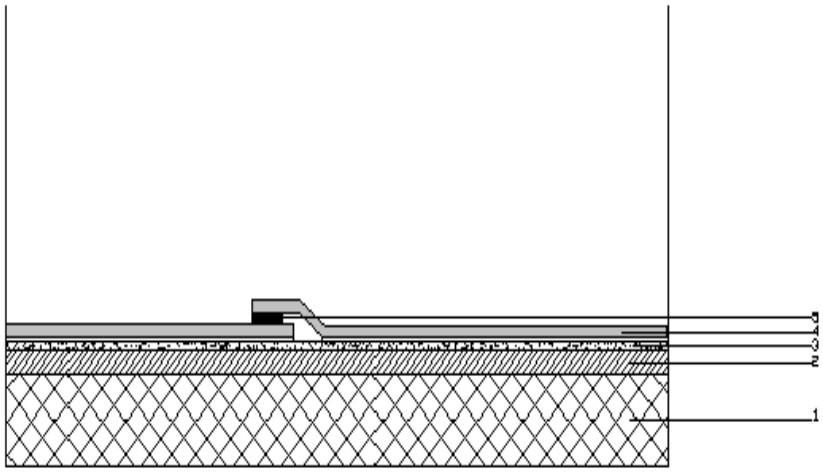
 # Concrete flat roof with full surface bonding application:



1	R.C.C. Roof deck
2	Protective Screed
3	Adhesive
4	Felt back PVC membrane
5	Hot air welding (Thermo fusion)

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PVC roofing : a new approach

PVC roofing is not only a state of the art technology in roofing, but also brings a completely new approach in roofing applications.

It is time that we look at roofing as an *Investment*. PVC roofing brings shear value additions for the end users in terms of the following:

long life expectancy (>30 years possible, better return on investment)

higher energy efficiency (refer to the case study)

self cleaning membranes with minimum maintenance (long term expenditure)

challenging shapes and geometry (without sacrificing water tightness)

re roofing solutions (without increasing dead load on the structure)

aesthetics (logo, colour, metallic look, rib pattern etc.)

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Re-roofing with PVC system – fast, secure and durable:

The major USP of PVC roofing in Indian context will be in the re roofing of the old bituminous and tiles roofs. (please refer to the following pictures which are self explanatory):

Before

After

Also, PVC roofing is unique and outstanding for metal deck roofing which has the following limitations:

corrosion (specially under saline conditions)
water leakage (from fastening points and overlaps)
wind clattering and vibration (makes the metal deck joints vulnerable)
high movement under temperature change
heating up under UV exposure
gutter areas (prone to water leakage)

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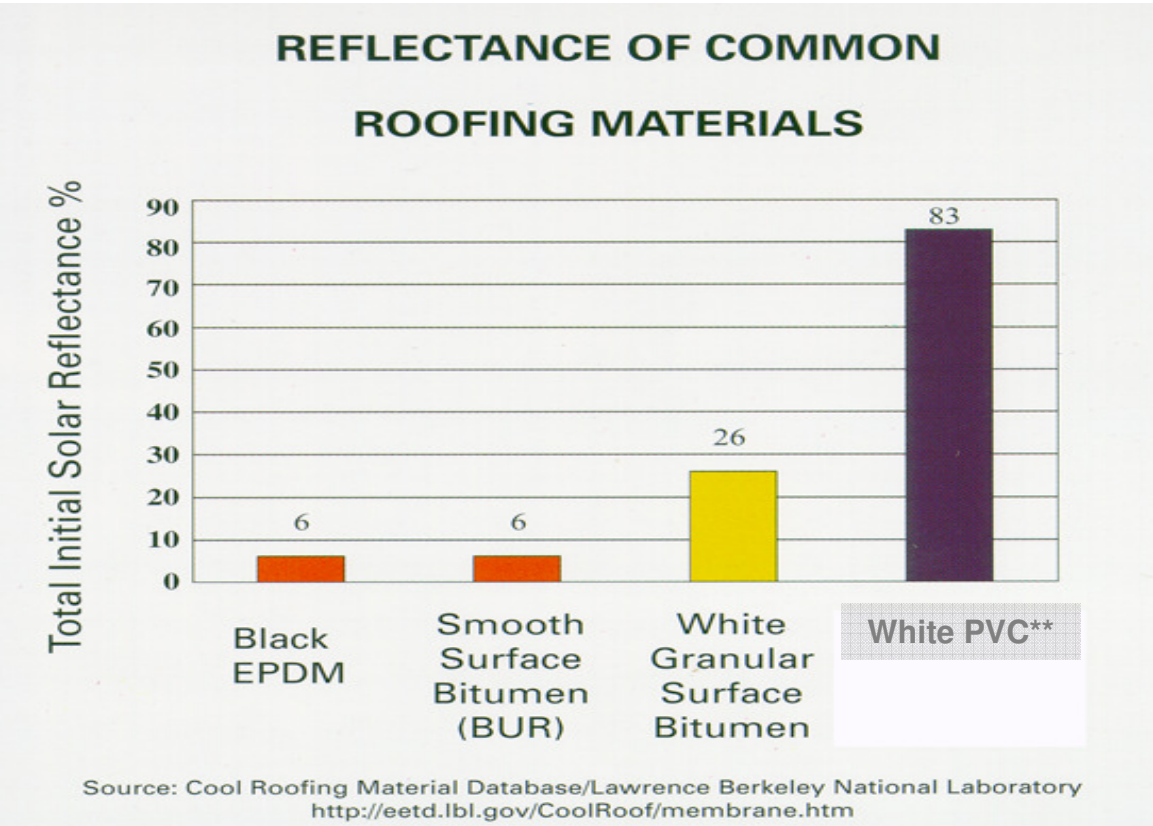
With a PVC roofing system, suitably adopted for a metal deck based on the shape, geometry, wind speed, UV exposure, etc., can solve the above limitations and provide an aesthetically pleasing long term, durable waterproofing solutions. This is also why PVC membranes are also popularly used on metal deck roofing in airports where the sound energy from the take off and landing of the air crafts is an additional force which acts on the metal deck.

Case Study : Energy savings with PVC membrane roofing



***Note: even a standard light grey PVC roofing membrane has 44% solar reflectance*

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In 2000, the U.S. Department of Energy and the Environmental Protection Agency conducted a study where a large retail store replaced a 100,000 sq. ft. black EPDM roof with a white PVC roof.

Findings -

The study confirms that the PVC roofing membrane reduced average summer time air conditioning peak demand (1- 4pm) by 14 percent and the total daily air conditioning energy usage by 11 percent.

Estimated the total annual air -conditioning savings to be US$7,200 or 7.2 cents per square foot.

Note: Even in a country like India where the summer is quite dominant in most part through out the year, a roofing with a standard light grey colour PVC membrane (solar reflectance close to 44%) can provide a 6-8% energy savings for a 10000 sq.m facility with centralized air conditioning. (data given based on best demonstrated practices and several years of track record of PVC roofing, this is just indicative in nature)

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PVC roofing – Sustainable and Green:

The U.S. Green Building Council (USGBC) created LEED™ with the goal of encouraging the use of established or advanced environmental principles, practices, materials and standards in commercial building projects. In 2002, the USGBC launched several new documents outlining performance criteria. These include commercial construction (LEED 2.3), existing buildings (LEED EB), commercial interiors (LEED -CI), core and shell, multiple buildings and residential.

Whether your project is new construction or renovation, energy efficient roofing is an important point to consider and a PVC roofing system makes it easy.

PVC Roofing and Waterproofing Systems Play a Key Role

Reflective roofing such as EnergySmart Roof® PVC roofing, or a "green" vegetated roof using a PVCl Green Roof System, qualify for one point under Sustainable Sites Credit 7: *Heat Island Effect: Roof, Req. 2, which states: "Use ENERGY STAR compliant (highly reflective) AND high emissivity roofing (emissivity of at least 0.9 when tested in accordance with ASTM 408) for a minimum of 75% of the roof surface; OR install a "green" (vegetated) roof for at least 50% of the roof area. Combinations of high albedo and vegetated roof can be used providing they collectively cover 75% of the total roof area."*




LEED certified buildings with PVC roofing or waterproofing systems

- Photo 1 – PLATINUM Certified: **The Donald Bren School** of Environmental Science and Management, UC Santa Barbara, California
- Photo 2 – GOLD Certified: **The William and Flora Hewlett Foundation**, Menlo Park, California.
- Photo 3 – Certified: **Olympic Oval Speed Skating Arena**, Kearns, Utah – one of the first 12 LEED certified buildings in the U.S.
- Photo 4 – Certified: **Premier Automotive Group’s** North American headquarters for Ford Motor Company’s Jaguar, Volvo, Land Rover and Lincoln brands – includes a vegetated roof over 75 percent of its 60,000 square foot roof.

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Conclusions:

Finally, it's important and crucial to realize that for the success with waterproofing jobs, it's not just the technology which can only make it happen. Equally, if not more, important are the construction practices to be adopted (including the design aspects) and the application at the job site.

Hence it is also a necessity that in any waterproofing project, there is an interaction and team work amongst the technology supplier, the design and construction teams along with the specialized contractors (applicators).

One of the very basic ways of creating such team work and having a common understanding of the job at hand is to create a more detailed and informative Bill Of Quantities (BOQ) incorporating even the seemingly trivial issues like detailing and special applications.

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