

# 2 System Design

The selected Firestone EPDM System is only technically acceptable if all conditions and requirements outlined in this section have been met, assuming that general codes of practice, national regulations and installation specifications have been complied with.

The information provided within this chapter may assist the specifier and contractor in determining which Firestone Roofing System is most suitable for a particular roofing application. It may also help him to identify the basic design criteria for each roofing system. This chapter contains the following sections:

2.1	System Application	3
2.2	System Selection	4
2.3	Load Bearing Capacity	9
2.4	Roof Slope/Shape	10
2.5	Substrate Considerations	12
2.6	Reroofing Considerations	14
2.7	Expansion Joints	16
2.8	Vapour Control Layer	17
2.9	Insulation	18
2.10	Insulation Attachment	22
2.11	Membrane	23
2.12	Membrane Securement	24
2.13	Fastener Considerations	26
2.14	Wind Design	30
2.15	Roof Penetrations	31
2.16	Flashing Upstands	32
2.17	Care and Maintenance	33
2.18	Membrane Repair	34

The same principles of assessment given in this section may also apply to the use of system components or techniques developed by other suppliers. In that case the instructions of the manufacturer concerned should also be complied with. The responsibility for the selection of products made by other manufacturers and for their effectiveness rests exclusively with the designer and the component manufacturer.

Roofs that are subject to special conditions and design considerations not contained within this chapter, should be discussed with Firestone's Technical Department.





## 2.1 System Application

The Firestone EPDM Systems that are described within these guidelines are applicable for roofing installations on commercial, industrial, administration and residential buildings.

The information within this publication is not appropriate for:

- Non-roofing applications, such as plaza deck construction, basement waterproofing, lining, etc.
- Roofing applications where structural conditions are insufficient to support the load of the completed roof installation and/or other anticipated loads as identified by the designer.

The Firestone EPDM Systems are not applicable without special approval from Firestone's Technical Department for:

- Roofs subject to chemical discharge
- Roofs subject to positive pressure, such as air infiltrating decks, canopies or overhangs
- Buildings with large openings in a wall (greater than 10% of the wall surface) which could accidentally be left open in a storm, such as aircraft hangars, loading terminals, etc.
- Buildings located within specific areas, which are not mentioned in these specifications and require particular attention, such as down slope areas of hills, etc.

For roofs subject to local code requirements or special regulations that are not mentioned in this section, contact the local building authorities and Firestone's Technical Department.



## 2.2 System Selection

The selection of a technically sound roofing system is not always simple. It requires knowledge of the characteristics and application conditions of all system components by the designer and/or contractor.

It has become increasingly difficult for manufacturers of roofing membranes to provide simple guidance on design, the reason being that the roofing industry offers a wide range of options for structural decks, insulation boards, membranes, fastening systems and other accessories. As a result, numerous combinations appear to be possible, but not all are technically acceptable.

To simplify the design process, Firestone has identified the most frequently used Firestone EPDM roof assemblies. These assemblies are presented in 4 different "selection-tables", starting with the structural deck. The following charts in this section cater for in-situ concrete, precast concrete, metal and wooden decks and provide information to determine the most applicable Firestone Roofing System.

By consulting the relevant selection-table, the designer and/or contractor will find general information on various structural conditions of the building (deck, load bearing capacity, slope) and also the technical requirements for the underlayers to the membrane (thermal insulation, substrate).

The following codes are used for the different insulation materials:

- EPS : Expanded Polystyrene
- XPS : Extruded Polystyrene
- PUR : Polyurethane
- PIR : Polyisocyanurate
- MW : Mineral Wool
- IPB : Perlite Boards
- ICB : Cork Boards

For more specific information on insulation materials, substrate considerations, re-roofing, membrane securement and insulation attachment, refer to the respective items provided further in this section.

Installation of a Firestone EPDM Roofing System over structural decks and insulation boards other than the ones mentioned in the following charts, are only accepted following approval by Firestone's Technical Department.

## Structural Deck

# IN-SITU CONCRETE (1)

## Thermal Insulation

## Firestone System

EPS	XPS	PUR/PIR	MW	IPB	ICB	None/Direct Application
Ballasted (2,3,4)	Ballasted (2,3)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3,8)
Adhered (5)	Inverted (2,3,8)	Adhered (7)	Adhered (5)	Adhered (5)	Adhered (6)	Adhered (9)
R.M.A. (3,4)		R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3,8)
M.A.S. (3,4)		M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3,8)
B.I.S. (3,4)		B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3,8)

## Design Criteria

### Structural Conditions

- (1) Concrete needs to be structurally sound.
- (2) Minimum load bearing capacity required.
- (3) Roof slope is limited.

### Thermal Insulation

- (4) Minimum density required.
- (5) Requires an approved overlayment/facing.
- (6) High compressive strength.
- (7) Facing must be compatible and provide sufficient adhesion.

*Note: Installation of vapour control layer should be determined by the designer.*

### Substrate

- (8) Installation of a protective mat (polyester fleece, minimum 200 gr/m<sup>2</sup>) is required over rough substrates.
- (9) If the substrate is smooth (wood float finished), clean, dry, free of sharp edges, fins, loose or foreign materials, oil, grease or other products which may damage the membrane.



Structural Deck

Thermal Insulation

Firestone System

## METAL DECKING (1)

EPS	PUR/PIR	MW	IPB	ICB
Ballasted (2,3,4)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3)	Ballasted (2,3,6)
Adhered (5)	Adhered (7)	Adhered (5)	Adhered (5)	Adhered (6)
R.M.A. (3,4)	R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3)	R.M.A. (3,6)
M.A.S. (3,4)	M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3)	M.A.S. (3,6)
B.I.S. (3,4)	B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3)	B.I.S. (3,6)

Design Criteria

### Structural Conditions

- (1) Metal decks require a minimum thickness of 0.75 mm.
- (2) Minimum load bearing capacity required.
- (3) Roof slope is limited.

### Thermal Insulation

- (4) Minimum density required.
- (5) Requires an approved overlayment/facing.
- (6) High compressive strength.
- (7) Facing must be compatible and provide sufficient adhesion.

*Note: Installation of vapour control layer should be determined by the designer.*

## Structural Deck

# PRECAST CONCRETE (1)

## Thermal Insulation

## Firestone System

EPS	XPS	PUR/PIR	MW	IPB	ICB	None/Direct Application
Ballasted (2,3,4)	Ballasted (2,3)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3,8)
Adhered (5)	Inverted (2,3,8)	Adhered (7)	Adhered (5)	Adhered (5)	Adhered (6)	Adhered (9)
R.M.A. (3,4)		R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3,8)
M.A.S. (3,4)		M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3,8)
B.I.S. (3,4)		B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3,8)

## Design Criteria

### Structural Conditions

- (1) Precast concrete decks are in dense or lightweight auto-claved concrete.  
The joints between the deck units should be filled with a sand and cement mortar.
- (2) Minimum load bearing capacity required.
- (3) Roof slope is limited.

### Thermal Insulation

- (4) Minimum density required.
- (5) Requires an approved overlayment/facing.
- (6) High compressive strength.
- (7) Facing must be compatible and provide sufficient adhesion.

*Note: Installation of vapour control layer should be determined by the designer.*

### Substrate

- (8) Installation of a protective mat (polyester fleece, minimum 200 gr/m<sup>2</sup>) is required over rough substrates.
- (9) Installation of an approved recovery board or acceptable insulation is required.

*Note: Mechanical attachment in precast concrete panels requires an appropriate fastening system and special consideration.*

**Structural Deck**
**WOODEN DECKS (1)**
**Thermal Insulation**
**Firestone System**

EPS	XPS	PUR/PIR	MW	IPB	ICB	None/Direct Application
Ballasted (2,3,4)	Ballasted (2,3)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3)	Ballasted (2,3,6)	Ballasted (2,3,8)
Adhered (5)	Inverted (2,3,8)	Adhered (7)	Adhered (5)	Adhered (5)	Adhered (6)	Adhered (9)
R.M.A. (3,4)		R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3)	R.M.A. (3,6)	R.M.A. (3,8)
M.A.S. (3,4)		M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3)	M.A.S. (3,6)	M.A.S. (3,8)
B.I.S. (3,4)		B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3)	B.I.S. (3,6)	B.I.S. (3,8)

**Design Criteria**
**Structural Conditions**

- (1) Timber boards (well seasoned, tongued and grooved), minimum thickness 19 mm. Plywood, exterior grade, minimum thickness 16 mm.
- (2) Minimum load bearing capacity required.
- (3) Roof slope is limited.

**Thermal Insulation**

- (4) Minimum density required.
- (5) Requires an approved overlayment/facing.
- (6) High compressive strength.
- (7) Facing must be compatible and provide sufficient adhesion.

*Note: Installation of vapour control layer should be determined by the designer.*

**Substrate**

- (8) Installation of a protective mat (polyester fleece, minimum 200 gr/m<sup>2</sup>) is required over rough substrates.
- (9) Acceptable over plywood if the surface is clean, dry, smooth, free of sharp edges, fins, loose splinters, foreign materials, oil, grease and other materials which may damage the membrane. Timber decks require the installation of a recovery board.

## 2.3 Load Bearing Capacity

The roof deck serves as a primary support for the roofing system. Structurally, it transfers the weight of live and dead loads to supporting purlins, joists and beams. Live loads include snow, rain, moving installation equipment and wind. Dead loads include skylights, HVAC units, roof deck, thermal insulation, membrane and ballast.

Deck deflections should be limited as required by local codes to accommodate the stresses of either concentrated or uniform loading.

When determining the structural ability of the deck to support the load of the completed roof installation, the designer must consider the weight of ballast required to comply with local wind uplift requirements. Ballasted and Inverted Roofing Systems require under normal conditions a minimum load of 50 kg/m<sup>2</sup> in the field area of the roof and for some cases up to 100 kg/m<sup>2</sup> in perimeter and corner areas.

When concrete pavings are required, the weight and arrangement should be calculated as part of the dead loads of the roof. Care must be taken when placing mass ballast onto the roof prior to distributing it locally. Install ballast and/or pavers on a daily basis. Do not stock pile ballast materials.

Finally, Firestone assumes no liability for structural analysis but strongly recommends that a structural engineer be consulted prior to the completion of the roof specification and job start.

## 2.4 Roof Slope/Shape

### 2.4.1 Positive Drainage

Roof deck designs should provide a fall for positive drainage to avoid ponding water around drain outlets and roof penetrations. Firestone's definition of "inadequate drainage" is a condition existing on any area of the roof where water remains for more than 48 hours after precipitation.

The effective minimum finished fall should be in accordance with national code of practice.

Positive falls may be formed in the structure or within the layers above the deck.

The slope in the structure can be provided by :

- Adjusting the height of beams and/or purlins
- Tapered supports
- Installation of furring pieces under the deck

The slope above the deck can be provided by :

- Screed or lightweight concrete
- Tapered insulation

Attention should be given to provide proper flashing height at upstands, parapets and penetrations, when an additional slope has to be provided.

Drains should be located at the lowest points in the roof (maximum deflection), not at columns or bearing walls (points of minimum deflection). The number and size of drains should be calculated in accordance with National Standards.

## 2.4.2 Maximum Slope

The following table is provided to assist in determining the most applicable Firestone EPDM System based on the slope or shape of the roof.

Slope/Shape		System		
		Ballasted / Inverted	Adhered	R.M.A. / M.A.S. / B.I.S.
Slope 0 - 10%	< 6°	A*	A	A
Slope 10 - 33%	≥ 6° and < 19°	NA	A	A
Slope > 33%	>19°	NA	A	A**
Arch, Barrel shape		NA	A	A

A : applicable.

NA : not applicable.

A\* : If the roof has a slope of over 5% , additional precautions should be taken to restrain the movement of ballast. This can be achieved by :

- increasing size or weight of the ballast
- installation of minimum 50 mm thick concrete pavings at the lowest point of the ballast installations to protect gutters and drains

A\*\* : applicable only after special consideration from Firestone.

## 2.5 Substrate Considerations

Prior to installation of the system, the surface of the roof should be inspected by the roofing contractor. It is the responsibility of the contractor to assure that the substrate finishing is suitable to receive the Firestone EPDM System.

The following table may assist you in identifying the general substrate requirements for direct application of the various EPDM Systems.

General requirement	Specific description
<b>Smooth</b>	free of sharp edges, fins. All rough surfaces that could damage the EPDM membrane and flashing materials should be properly isolated with a leveling layer (protection mat, recovery board or insulation). <i>NOTE: In order to ensure the maximum working life of Firestone EPDM membranes it is necessary to separate them from abrasive surfaces such as rough concrete, cementitious screeds, plywood, timber boarding, wood wool slabs and galvanized steel. Firestone recommends the use of a polyester fleece (min.200 gr/m<sup>2</sup>).</i>
<b>Dry</b>	ponded water, snow, frost and ice must be removed from the work surface.
<b>Compatible</b>	any contact between EPDM materials and incompatible products such as grease, animal fats, coal tar, oil based products (mineral and vegetable origin), strong acids and fresh bitumen should be avoided.
<b>No voids</b>	all voids, greater than 5 mm wide must be properly filled with an acceptable fill material or overlaid with insulation.
<b>No hot surfaces</b>	avoid continuous contact between EPDM and steam or heat sources in excess of 82°C.
<b>Clean</b>	heavy dirt must be removed with a hard bristled brush.

In addition to the information provided previously, the following specific substrate requirements are applicable:

- **Metal Decks (steel or aluminium)**

It is assumed that the deck is detailed in such a way that it provides adequate support for the insulation at all perimeters and penetrations. Attention should also be paid to the direction of the flutes of the deck, so as to minimise the risk of ponding water being entrapped under the roofing system during installation.

- **In-situ Concrete**

The finished surface should be as smooth as possible and should be provided by a power or wood float. Concrete and cementitious screeds contain considerable amounts of water. Construction water should be drained by drilling temporary holes at the underside of the slab. Concrete screeds are not acceptable for mechanical attachment.

- **Precast Concrete**

All joints in the substrate should be filled with a sand and cement mortar. Closed joints will minimise positive air pressures.

- **Wooden Decks (plywood-timber)**

The decks must be secured using fasteners which provide a smooth profile. The use of nails is not permitted. Treated plywood may be used, provided it has not been treated with ammonium phosphates. When using timber planking, only seasoned boards will be accepted. Tongue and grooved boards are recommended.

## 2.6 Re-roofing Considerations

In re-roofing applications, the performance of the new roofing system significantly depends upon the quality of the existing roof. Apart from the considerations mentioned previously, additional measures need to be taken with regard to adaptation, overlayment and/or replacement of the existing system.

Inspections are required for every re-roofing project to evaluate the moisture content of the existing roof, to identify any errors of design, and to determine the limiting factors that will influence the design of a new system. The inspection must take into account the condition of the structural roof deck, insulation and roofing membrane.

Structural decks must be inspected to determine their capacity of taking the additional loads during the re-roofing installation, including the storage of materials on the roof. The contractor should also investigate the condition of the deck.

Metal deckings are limited by their deflection and need to be assessed for their pullout resistance. Wooden decks and other degradable supports should always be fully examined for their quality (dryness,...) and pullout resistance. Any wet or unsound portions must be replaced with new materials prior to the installation of the membrane system.

Insulation boards need to be replaced if they are wet or degraded. It may be necessary to inspect the quality of the attachment of the insulation to the deck. Compatibility of new insulation boards with the existing roofing system must also be considered.

The condition of the existing roofing membranes, which are to be left in position, will determine the necessity for a separation layer. The existing roofing membrane must be basically sound, rot-free, not saturated with water and, for a fully adhered application, free of blisters. The table on the following page provides specific substrate requirements for various Firestone EPDM re-roofing applications.

Flashing heights may be limited. Existing building details (i.e. doors, windows) may not allow for sufficient clearance to provide proper termination above the potential water level. Detailed consideration of this condition is critical to the integrity of the roofing system.

## Substrate requirements for re-roofing

Existing membrane	System		
	Ballasted/ Inverted	Adhered	R.M.A. / M.A.S. / B.I.S.
Bituminous / Gravel	3	3	3
Bituminous / Chippings	2	1	2/3
Bituminous / Smooth	1	1	1
Mastic Asphalt	4	4	4
Coal Tar	3	3	3
Single Ply	4	4	4

- 1: Direct application, when the substrate meets general substrate requirements.
- 2: Roof deck requires installation of protection mat (polyester fleece - min. 200 gr/m<sup>2</sup>).
- 3: Roof deck requires installation of approved recovery board or insulation.
- 4: Consult Firestone's Technical Department.

*Note: Adhered systems may be installed directly over existing smooth surfaced bituminous felts that have not been re-saturated or coated, providing the bitumen has a softening point above 85°C. Verify that the existing roofing system is firmly attached to the deck and that interply adhesion is adequate and continuous.  
Bituminous flashings will not be suitable for re-use and need to be stripped off, if interply adhesion is not adequate and continuous.*

## 2.7 Expansion Joints

The need for expansion joints, as well as type, placement and location should be determined by the architect. Consideration for roof expansion joints should be investigated at all locations where:

- expansion or contraction joints are provided in the building structure.
- structural framing elements such as joists, purlins or steel deck change direction.
- different types of roof deck, e.g. steel and concrete, abut each other.
- additions are connected to existing buildings.
- movement between vertical walls and roof deck is anticipated.
- roof areas are larger than 60 m in any direction.

Consideration for expansion joints should also be investigated at junctions where interior heating conditions change, such as heated spaces abutting an unheated space.

In ballasted and inverted systems Firestone EPDM membranes may be installed without any special precautions straight over many simple expansion joints, where movement is expected in only one plane. The elasticity of the membrane allows it to accommodate such movements without failure. Note however that other components on the roof may not have the same elasticity as the membrane, and may require particular attention.

Refer to the following section for additional information with regard to installation of expansion joints. In some cases it will be necessary to provide a compressible infill (insulation material) between the ends of the insulation boards to create a loop in vapour retarder and/or membrane.

## 2.8 Vapour Control Layer

A vapour control layer may be necessary to protect certain roofing components or to avoid internal condensation in the roof when high interior humidity is of concern. In some situations, a vapour control layer may serve as an air block for buildings under positive pressure.

The requirement for a vapour control layer, as well as its type, installation and location should be determined by the designer/specifier. Consideration for use should be investigated if any of the following conditions exist:

- Projects where outside average January temperatures below 5°C are expected and where average-winter interior relative humidity of 45% or more is anticipated.
- Buildings with high humidity internal conditions, such as swimming pools, textile mills, food and other wet-process industrial plants. These buildings will have continuous internal temperatures above 20°C and a relative humidity of minimum 70%.
- Construction elements that may release moisture after the roof is installed, such as interior concrete and masonry, plaster finishes, cementitious roof screeds, fuel burning heaters, etc.

Since the requirements and climatic conditions vary from country to country, the designer/specifier should refer to national codes for recommendations on vapour control layers.

Firestone EPDM membranes have a relatively low resistance to water vapour. For more specific information with regard to the characteristics of the membrane, consult the technical data sheet.

Vapour control layers are available in synthetic materials (polyethylene, PVC, etc.). Bituminous felts, including metal lined, can be used, provided there is no contact between the EPDM membrane and fresh bitumen with a melting point below 85°C.

The surface of decks containing large amounts of construction water (in-situ concrete, cementitious screeds, ...) should be adequately cured and dried before the vapour control layer is installed. Drying out will be restricted by the presence of a vapour control layer. In that case, drainage holes will have to be drilled to the underside of the deck to allow for drying.

## 2.9 Insulation

The function of thermal insulation in a roofing system is a complex one. Insulation is used to reduce heat loss and to limit internal condensation. It is also used to provide a substrate that is:

- firm and compatible for the membrane.
- properly attached against wind forces.
- stable to minimize stresses to the membrane.
- of sufficient compressive strength to accept traffic and loading over the roof during construction, without being damaged.

Since requirements for thermal insulation vary from country to country (fire regulations, insulation level), the designer/specifier should refer to National Codes for recommendations.

Due to the many types of insulation available, it is not possible to provide a complete listing of all insulations for use as immediate substrates for the Firestone EPDM systems. Therefore, a brief summary and description of the most commonly used insulation materials are provided in the chart on the following page. If the product to be used does not meet the technical requirements outlined in this table, it will be necessary to consult Firestone's Technical Department for approval.

The table also provides information with regard to applicable insulation materials for each Firestone EPDM System.

For specific data regarding the insulation materials, refer to the technical literature of the insulation manufacturer.

Insulation	Thermal Insulation				Roofing System				R.M.A. / M.A.S./ B.I.S.
	Thermal Conductivity W/mK	Volumic Mass kg/m <sup>3</sup>	Compressive Strength kN/m <sup>2</sup>	Ballasted	Inverted	Adhered			
Expanded Polystyrene	0.034	Min. 20	Min. 100 (10% compression)	1	NA	2	1		
Extruded Polystyrene	0.026	Min. 33	Min. 300	1	1	NA	NA		
Polyurethane	0.023	Min. 30	Min. 100 (10% compression)	1	NA	1	1		
Poly-isocyanurate	0.023	Min. 30	Min. 100 (10% compression)	1	NA	1	1		
Perlite	0.047	155	Min. 300 (10% compression)	1	NA	2	1		
Mineral Wool	0.036	165-200	Class III UEAtc	3	NA	2, 3	3		
Cork	0.044	Min. 120	Min. 100 (10% compression)	1	NA	1	1		
Cellular Glass	0.042	120	Min. 600	4	NA	4	NA		

Note: 1: Direct application.

2: Acceptable overlayment or facing required.

3: Only high-density boards are acceptable.

4: Consult Firestone's Technical Department.

NA : Not applicable



Each insulation material to be used within the Firestone EPDM roofing systems needs to meet one or more of the specific technical requirements mentioned hereafter, such as:

- **Compressive strength**

Additional consideration should be given to the long-term resilience of the insulation board, so that it remains capable of withstanding installation and general roof traffic.

Some compressive boards, such as mineral fibre boards, do not accept unlimited traffic and loading without being damaged. Equally, some cellular foams with outstanding insulation efficiency, have relatively thin foam cell walls that can easily be broken by traffic across the roof.

- **Compatibility**

Firestone EPDM membranes are chemically inert and therefore compatible with the basic material of all insulation boards. However, specific precautions are to be taken for the application of some insulation boards. Polystyrene materials should not come in contact with adhesives, primers and cleaning products. The solvents used in these products are aggressive to polystyrene.

Firestone recommends the application of a polyethylene film under the joints of adjacent EPDM panels to be seamed and under reinforced perimeter strips at base-tie-in details.

- **Acceptable facer**

Most mineral wool boards are not suitable for direct application of a Fully Adhered System since they do not provide sufficient adhesion between the EPDM membrane and the top facing. Some insulation boards are finished with facers not suitable for adhesion. Consult Firestone's Technical Department for additional information. Polyurethane and polyisocyanurate boards with glass fibre tissue or bituminous impregnated felt facer are suitable for adhesion.

The following table may assist you in calculating the required thickness of the insulation board. In the first column of the chart, you'll find the different individual steps of the calculation method. These are illustrated with an example in the second part of the table.

Individual Steps	Example
Determine required U-value (Refer to National Standards)	$U = 0.40 \text{ W/m}^2 \text{ K}$
Calculate R1, required thermal resistance (Inverse of U-value)	$R1 = 1/0.4 = 2.5 \text{ m}^2 \text{ K/W}$
Calculate R2, thermal resistance non-insulated roof (Sum of thermal resistances of individual layers, plus an allowance of 0.15 m <sup>2</sup> K/W for external and internal resistances)	$R2 = 0.0012/0.06 + 0.15/1.4 + 0.15$ $= 0.28 \text{ m}^2 \text{ K/W}$
Calculate R3, required thermal resistance to meet standard. $R3 = R1 - R2$	$R3 = 2.5 - 0.28 = 2.22 \text{ m}^2 \text{ K/W}$
Calculate d = required thickness of insulation. (Multiply R3 with thermal conductivity of insulation material)	$d = 2.22 \times 0.036$ $= 0.07992 \text{ m}$ $= 80 \text{ mm}$

Note : U-value (W/m<sup>2</sup> K) expresses the rate of energy loss through a structure.

For the above illustrated example, the following materials and indicative values were used.

Material	Thickness (m)	$\lambda$ -value (W/mK)
EPDM-Membrane	0.0012	0.06
Mineral Wool	0.08	0.036
Concrete Deck	0.15	1.4

The U-value is calculated by inverting the sum of the thermal resistances of all layers of the roofing system. Thermal resistances of each individual layer are determined by dividing the thickness of the layer by the thermal conductivity ( $\lambda$ -value) of the material. The above-calculated value indicates the minimum thickness for fully supported insulation. Consult the insulation manufacturer for maximum flute spans when installing over steel decks.

## 2.10 Insulation Attachment

### 2.10.1 General Installation Requirements

Insulation must be neatly fitted to all roof penetrations, projections, upstands, etc.

Care should be taken not to install more insulation than can be covered with EPDM membrane and waterproofed before the end of each working day or the onset of inclement weather.

### 2.10.2 Specific Installation Requirements

**Ballasted And Inverted Systems** do not require an attachment of the insulation. When insulation attachment is specified, acceptable plastic insulation plates which lock and recess the fastener heads shall be used. Expanded polystyrene insulation shall not be pre-attached.

**Fully Adhered Systems** require that the insulation is installed in accordance with the fastening rate and pattern as specified by the designer and/or the insulation manufacturer. Firestone does not recommend insulation attachment with bitumen. However, if this method of attachment is selected by the designer, the following requirements must be met:

- The proposed insulation shall be compatible with the roof substrate, the proposed bitumen and the requirements of the system.
- Bitumen with a high melting point (above 85°C) shall be used.
- Insulation attachment directly to steel deck is not allowed.
- Expanded or extruded polystyrene shall not be attached with bitumen.
- Excess of bitumen between adjoining insulation boards shall be removed prior to installation of the membrane.

**Mechanically Attached Systems (R.M.A. / M.A.S. / B.I.S)** require that the insulation attachment is designed independently from the requirements for membrane securement. Insulation must be installed in accordance with the fastening rate and pattern as specified by the designer and/or the insulation manufacturer. Fastening patterns may vary for code compliance (i.e. additional fasteners in corner areas, ...). Consult local standards for additional information.

## 2.11 Membrane

Type and thickness of the membrane may vary in function of specific code requirements. Refer to the table below for recommendations regarding the most appropriate Firestone EPDM membrane.

Membrane	System			
	Ballasted/ Inverted	Adhered	R.M.A./ M.A.S.	B.I.S.
Non-Reinforced 1.14 / 1.52	A	A	A	A
Non-Reinforced 2.28	A*	A*	NA	NA
Reinforced 1.14 / 1.52	NA	A	NA	A

A : Applicable

A\* : Specific installation details are necessary. Contact Firestone's Technical Department for additional information, when specifying this membrane.

NA : Not applicable

All membranes mentioned in the above chart are standard grade. An FR grade (Fire Retardant) membrane is available for specific requirements regarding fire resistance. Contact Firestone's Technical Department for more specific data.

Panel size may vary in relation to the selected system and building conditions. Refer to the following table for recommendations regarding the width of the EPDM membrane to be used.

System	Ballasted/Inverted	Adhered	R.M.A. / M.A.S.	B.I.S. (1)
Width (m)	3.05-6.10-9.15- 12.20-15.25	3.05-6.10	6.10-9.15-12.20	1.67-2.28-3.05

Notes:

- 1: Width of EPDM panels is subject to spacing requirements between batten strips and type of membrane (reinforced - unreinforced).
- 2: The above indicated widths have to be adjusted in function of site conditions such as number, type and spacing of roof obstructions, size of building, wind, etc.

## 2.12 Membrane Securement

There are three methods to secure the EPDM membrane to the substrate: ballasting, bonding with adhesive and mechanical attachment with fasteners. The following information outlines the various options for securement of the EPDM membrane in the field.

### 2.12.1 Ballast

The designer shall be responsible for the design and selection of the ballast on a specific building. Ballast shall be of adequate size and weight as to provide proper protection against wind uplift.

The following table may assist you in identifying the ballast material to be used and protection requirements for the EPDM membrane. Refer to local building codes for additional information regarding requirements for coverage rate.

Ballast Material	Description	Protection Requirements
River washed gravel	Smooth, river washed aggregate with rounded edges and corners, without broken pieces. Nominal 16/32 mm. Minimum weight of 50 kg/m <sup>2</sup> .	None
Crushed gravel	Crushed stones, free of excessive fractures, sand or foreign substances. Minimum weight of 50 kg/m <sup>2</sup> .	Protection mat Polyester fleece of min. 200 gr/m <sup>2</sup>
Concrete pavers	50 mm thick with smooth trowel finish. Maximum spacing between pavers: 10 mm.	Protection mat Polyester fleece of min. 200 gr/m <sup>2</sup>

### 2.12.2 Fully Bonding

The EPDM membrane shall be completely (100%) bonded to a dry and clean substrate with Firestone Bonding Adhesive applied to both mating surfaces, the substrate and the back side of the membrane.

### 2.12.3 Mechanical Attachment

There are three mechanically attached systems available to secure the membrane to a suitable substrate. Fastener layout should be determined in compliance with the designed wind load and pullout resistance of the fastener/deck system.

In the non-penetrating R.M.A. system, the QuickSeam R.M.A. strips are mechanically attached using batten strips or plates and fasteners. The membrane is subsequently adhered to these strips using conventional seaming techniques.

In the M.A.S. system, the EPDM membrane panels are to be attached to the substrate with batten strips running over the membrane, which are then covered with a self-adhesive QuickSeam Batten Cover Strip.

In the B.I.S. system, the EPDM membrane panels are to be attached to the substrate with a continuous row of batten strips installed in the centre of the side laps. When necessary, additional batten strips can be placed on top of the membrane to comply with the required fastener layout plan.

As an alternative to mechanical attachment, the perimeter zone of the roof may be fully adhered. The substrate to be adhered to shall be identical to the mechanically attached area. This area shall be installed in accordance with the requirements for the adhered system. The adhered perimeter zone shall be separated from the centre zone of the roof by a continuous batten bar in the M.A.S. and B.I.S. system or a QuickSeam R.M.A. strip in the R.M.A. system.

#### 2.12.4 Base Tie-In

Additionally to securement of the membrane in the field as described above, mechanical attachment of the membrane is required in all Firestone EPDM systems at all locations where the membrane terminates or goes through an angle change greater than 15% such as roof edges, curbs, interior walls, etc. Exception is made for round pipe penetrations, less than 125 mm in diameter and square penetrations less than 100 by 100 mm.

For the smaller, residential type of applications (< 100 sqm) in ballasted and fully adhered systems, the mechanically attached base tie-in detail can be replaced by an alternative detail:

**Ballasted systems:** the mechanical base tie-in detail can be replaced by adhering the EPDM membrane to the horizontal for about 20 cm and installing two rows of small solid concrete tiles (25 cm by 25 cm) or one row of large solid concrete tiles (50 cm by 50 cm). The vertical upstand needs of course also to be fully adhered and properly terminated at the top with an approved Firestone detail (counterflashing, metal coping, etc.).

**Fully adhered roofing systems:** the membrane is fully adhered to both substrate and upstand and is properly terminated at the top of the upstand with an approved Firestone detail.

Any mechanically attached system, independent of the surface of the roof, requires the installation of a mechanical base tie-in detail.

Drainage outlet flanges must be secured to the deck with acceptable fasteners, installed at 100 mm centres with a minimum of 8 fasteners (2 per flange side).

## 2.13 Fastener Considerations

The following table may assist you in selecting the appropriate roofing fastener for mechanical attachment of the EPDM membrane. The fastener must be compatible with Firestone Batten Strips, Firestone Termination Bars or edging profiles, and their installation requirements. The following table will also provide information with regard to the minimum pullout and penetration requirements of the fastener into the substrate, the calculation values of the fastener and the type of batten strip to be used.

Application	Substrate	Fastener	Penetration (P) Embedment (E) (mm)	Minimum Pullout (kN)	Suggested Safety Factor	Calculation Value (kN)
Membrane	Steel (1,3) Min 0.75 mm	Firestone AP Buildex HRG	15 (P)	1.8	3 (Y)	0.6
Membrane	Plywood (1) Min. 16 mm	Firestone AP Buildex HRG	25 (E) 38 (E)	4.5	X	-
Membrane	Timber (1) Min. 19 mm	Firestone AP Buildex HRG	25 (E) 38 (E)	4.5	X	-
Membrane	Concrete (2)	Firestone HD Hammerplug Ø 8 mm	30 (E)	3.0	X	-
Membrane	Lightweight (2) Concrete	-	-	2.4	Z	-
Membrane	Aluminium (2) Min. 0.9 mm	Peel Rivet	32 (P)	1.3	Z	-
Base Tie-in	Vertical Concrete (2)	Firestone HD Hammerplug Ø 8 mm	30 (E)	0.9	X	-
Base Tie-in	Masonry (2,4)	Firestone HD Hammerplug Ø 8 mm	30 (E)	0.9	X	-

- Notes:
1. Use Firestone Polymer Batten strips when fixing to these substrates.
  2. Use Firestone Metal Batten strips when fixing to these substrates.
  3. Verify pullout capacity of substrate when fixing to thinner profiles (i.e. cladding structures).
  4. Consult Firestone when fixing into hollow brickwork.
- X. Site pullout tests need to be conducted on new and re-roofing projects to determine substrate quality. A safety factor will be determined in accordance with test results.
- Y. Site pullout tests need to be conducted only on re-roofing projects to determine deck quality. A safety factor will be determined in accordance with test results.
- Z. Consult Firestone's Technical Department for an acceptable solution.



Fig. 2.13.1: Firestone A.P. fastener



Fig 2.13.2: Buildex H.R.G. fastener

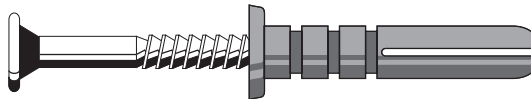


Fig 2.13.3: Hammerplug



Fig 2.13.4: Peel Rivet

Firestone All Purpose Fasteners can be substituted by Firestone Heavy Duty Fasteners for any roofing system requiring a more superior performance than usual.

For fasteners to be used with other substrates, contact Firestone's Technical Department.

Determine the required screw length of Firestone's A.P. fasteners or Hilti Hammerplug by using the following table.

Minimum Fastener Length In Relation To Thickness Of Roof Assembly						
Thickness (mm) roof assembly	Steel Firestone A.P.		Wood Firestone A.P.		Concrete HPS-Hilti	
	Min. length required (mm)	Type fastener (inch)	Min. length required (mm)	Type fastener (inch)	Min. length required (mm)	Type fastener
0	15	1 1/4"	25	1 1/4"	30	HPS 8/5
10	25	1 1/4"	35	1 5/8"	40	HPS 8/12
15	30	1 1/4"	40	1 5/8"	45	HPS 8/12
20	35	1 5/8"	45	2 1/4"	48	HPS 8/25
25	40	1 5/8"	50	2 1/4"	53	HPS 8/40
30	45	2 1/4"	55	2 1/4"	58	HPS 8/40
40	55	2 1/4"	65	2 7/8"	68	HPS 8/60
50	65	2 7/8"	75	3 1/4"	88	HPS 8/60
60	75	3 1/4"	85	3 3/4"	98	HPS 8/60
70	85	3 1/4"	95	3 3/4"	110	HPS 8/80
80	95	3 3/4"	105	4 1/2"	120	HPS 8/80
100	115	4 1/2"	125	5"	125	NA
120	135	6"	145	6"	145	NA
150	165	7"	175	7"	175	NA

NA : Not applicable, consult Firestone's Technical Department for an alternative solution.

Any substrate (deck or wall) that is to provide mechanical attachment of the roofing system must provide a minimum pullout capacity per fastener as indicated in the previous table. If the substrate cannot provide the required minimum pullout value, contact Firestone for an alternative system of fastener spacing in accordance with the actual fastener pullout capacity.

Due to the variety of physical conditions that can affect pullout resistance, Firestone recommends that on site tests be conducted by a Firestone representative or an independent testing organisation to determine actual pullout values. Refer to the first table for decks requiring pullout tests. All sections of the substrate where integrity is in question should be tested. Test areas shall include corners and perimeters.



The minimum number of pullout tests required is in relation to the roof size, as indicated in the following table.

Roof size (m <sup>2</sup> )	Minimum number of tests
<1000	6
1000 - 5000	10
5000 - 10000	20
>10000	1 per 500 m <sup>2</sup>

When new construction prevents preliminary on-site tests, the deck manufacturer should supply estimated pullout values for design and estimating purposes. On-site verification of the pullout capacity shall be confirmed prior to system installation.



## 2.14 Wind Design

As wind passes over the roof surface of a building, both positive and negative pressures are created by its acceleration. These pressures act on every part of the roof and have to be resisted by the system.

As a result there is a general level of wind uplift force across the roof that will differ in local areas such as perimeters, ridges, roof steps, areas around penthouses, etc.

Besides this, in some cases air will leak into the building through cladding around openings (windows, doors, ...) and cause internal pressures on the membrane, when the roof deck is air permeable (metal decking, timber, ...).

Impermeable decks such as concrete will prevent additional internal pressures.

The designer/specifier shall be responsible for the design of the system. Calculations should take into account the following factors:

- wind speed
- building location (topography of surroundings)
- building dimensions (height, length, width)
- roof substrate (permeable, impermeable)
- roof details (openings,...)
- security

Calculation methods differ from country to country, therefore Firestone cannot offer a uniform method. Refer to local calculation methods for estimation of the maximum wind loads and local wind areas.

For Ballasted/Inverted Systems, the minimum ballast coverage rate is 50 kg/m<sup>2</sup>. If a gravel stop is used at the building perimeter, its height above the roof system surface must be a minimum of 50 mm and higher when it is required to retain the ballast.

Refer to national standard codes or wind design guidelines for Ballasted Single-Ply Roofing Systems for more specific information with regard to ballast.

For Mechanically Attached Systems, R.M.A./M.A.S. and B.I.S., the density of fasteners and the spacing between the Batten strips / QuickSeam R.M.A. strips depend on the following factors:

- design value of wind load
- pullout strength of fastener
- safety factor

Perimeter and corner areas can be fully adhered or incorporate additional rows of fasteners to comply with higher wind loads.

For Fully Adhered Systems, tests performed in accordance with European specifications indicate that on substrates with high cohesive strength, the adhesion of the system is sufficient to resist the effects of wind uplift pressures up to 3.5 kN/m<sup>2</sup> with a safety factor of 2, provided that the substrate is sufficiently anchored and the membrane properly installed.

## 2.15 Roof Penetrations

### 2.15.1 Skylights

Skylight flanges should be firmly secured to the substrate with acceptable fasteners at 300 mm centres (maximum). Bowing of the skylight flange between the fixings is not allowed. The field membrane must be mechanically attached at the base of the upstand. Skylight upstands shall be flashed with either EPDM field membrane, separate EPDM strips or FormFlash/QuickSeam FormFlash.

### 2.15.2 Pipes

Wherever possible, all round rigid pipe penetrations ranging in size from 25 to 175 mm outside diameter shall be dressed with Firestone QuickSeam Pipe Flashings. Smaller rigid penetrations ranging in size from 13 to 64 mm shall be dressed using the QuickSeam Conduit Flashing. If it is not possible to install a pre-molded pipe flashing onto the pipe due to site conditions (difficult access,...), Firestone requires the use of FormFlash/QuickSeam FormFlash in accordance with the details outlined in the following section. Pre-molded pipe flashings should not be cut or patched to accommodate a pipe penetration.

Pre-molded flashings and FormFlash/QuickSeam FormFlash should not be installed around hot pipes (temperature in excess of 82°C). Hot pipes require the installation of an insulating sleeve, prior to being flashed. Rigid pipe penetrations with an outside diameter larger than 175 mm should be covered with FormFlash/QuickSeam FormFlash in accordance with Firestone details.

### 2.15.3 Penetration Pockets

The following situations require the installation of a penetration pocket:

- rigid pipes with an outside diameter less than 13 mm
- flexible pipes
- cluster of pipes
- unusual shapes such as structural beams, channels, etc.

Firestone requires a minimum clearance of 25 mm between the pipes etc. on all sides of the penetration pocket, in order to assure adequate space for the application of Pourable Sealer.

### 2.15.4 Roof Drains

Firestone requires that either a clamping system or an insert piece is used in connection with the EPDM membrane at these locations. Installation of Water Block Sealant is required.

The following materials can be used for insert drains: EPDM, zinc, flexible PVC, galvanised steel, stainless steel. The base flange of the insert piece shall be smooth and covered with a field fabricated flashing in accordance with Firestone details.

## 2.16 Flashing Upstands

Where possible, provide the minimum design height required by local building regulations for all upstand terminations. Upstand height shall be at least as high as the potential water level that would be reached as a result of a blocked drainage system. The installation of a Firestone Termination Bar is required wherever the vertical termination height is 125 mm or less. Do not flash over existing through-wall flashings, weep holes and overflow scuppers.

If existing built-up felt flashings are to remain, they must have firm attachment to the substrate and have adequate and continuous interply adhesion. The existing flashing must be totally covered with FormFlash/QuickSeam FormFlash or EPDM membrane. Terminations shall be made directly to the vertical substrate and not to the existing waterproofing material. If existing built-up felt flashings are coated, they must be overlaid with exterior grade plywood which should be attached as required for structural integrity.

When using a surface mounted termination (Termination Bar, counterflashing,...) ensure that the termination provides a constant seal at the wall using Water Block Sealant and that the surface above the termination is watertight.

Stucco, textured masonry, corrugated metal panels or any uneven surface are not suitable substrates to be dressed. Such surfaces must be prepared to provide an acceptable substrate by installing an exterior grade plywood or acceptable insulation board.

Counterflashings, copings and other perimeter or penetration metal work shall be properly fastened and sealed by the roofing contractor. Care should be taken to ensure that the membrane is not in contact with sharp edges and corners, and that it is not unsupported over voids bigger than 5 mm.

## 2.17 Care And Maintenance

Firestone EPDM membranes and flashings do not require an additional protection against weathering, U.V. light or ozone.

All components of the EPDM system should be protected from discharges such as petroleum products, greases, oils (mineral and vegetable), organic based solvents, animal fats and fresh bitumen. Any direct contact with steam or heat sources where the in-service temperature is in excess of 82°C should be avoided.

Protect the Firestone EPDM Roofing System from mechanical damage by others. Sharp or rough edged foreign materials such as screws, metal shavings, nails, etc. can be the cause of damage to the membrane and should be removed from the roof during annual inspections. Use a suitable plank of wood or insulation whenever ladders are used on top of a Firestone EPDM Roofing System, to avoid damage to the membrane and/or insulation.

Firestone EPDM roofs will accommodate reasonable and limited traffic for occasional maintenance but are not designed to support frequent traffic. The building owner is responsible for maintaining walkways in specific areas such as access points to the roof (doorways, ladders,...) and on roofs subjected to traffic more frequent than once per month.

For Mechanically Attached Systems, Firestone recommends to use Firestone Walkway Pads, concrete pavers are not acceptable. For Ballasted and Inverted Systems, Firestone requires to substitute the Walkway Pads by concrete pavers within 3 m of the edge of the roof.

When expanded or extruded polystyrene is used as an immediate substrate, Firestone requires the installation of a protection layer underneath the membrane at all locations where Walkway Pads are to be installed to reduce the heat transfer.

Rainwater outlets, scuppers and gutters can become blocked and should be inspected annually to ensure that roof drainage is able to perform as designed.

For aesthetic reasons an acrylic PC-100 Coating may be applied onto the EPDM membrane or flashing surfaces. Like most coatings, periodic re-application of the coating will be required to maintain its aesthetic value.

The addition of new details to the roof such as roof lights, drains, extracting fans, etc. will require an adjustment of the existing roofing system. This should be performed by a Firestone licensed contractor in accordance with Firestone's recommendations.

Roof membrane surfaces (especially on slopes) can become slippery when covered by water, ice or snow. Care should be taken when walking over these surfaces to avoid personal accidents.

## 2.18 Membrane Repair

If damage occurs to the Firestone EPDM Roofing System, it can easily be repaired to its original water-tight condition by patching.

Firestone FormFlash material should be repaired with FormFlash material. Firestone EPDM membrane can be repaired with EPDM membrane or FormFlash/QuickSeam FormFlash depending on the nature of the damage. Small damage such as pinholes and cuts less than 50 mm may be patched with FormFlash material. Larger damage should be repaired with cured EPDM membrane. Repairs with non-Firestone materials are not allowed.

Prior to any repair, water that has entered through the damaged area should be removed. Residual dampness will in most cases evaporate through the EPDM membrane. The surface around the damaged area must be clean and dry. Clean the area to be repaired thoroughly with Splice Wash. For general cleaning, warm soapy water may be used. Install the patch in accordance with Firestone's installation specifications.

