



ROOFING



GUIDE TO

PLAZA

CONSTRUCTION

**with STYROFOAM
Brand Insulation**



The Plaza Deck

Thirty years ago a building complex with a plaza area was a novelty. Today, buildings with plaza terraces, parking decks, and play areas are being constructed everywhere. And you know why. Today's cities are cramped for space. The square foot dollar value of a vacant lot is astronomical in some areas. For this and other reasons, when an owner contemplates construction of any kind, he's looking for the greatest possible utility from his building dollar.

The plaza deck environment is a demanding one. It is important that materials used in construction can withstand that environment. Some insulations may perform well for a short time, but STYROFOAM* Brand Insulation will perform over the long term. STYROFOAM Brand Insulation is manufactured by an extrusion process first developed by The Dow Chemical Company. This extrusion process, in combination with the hydrophobic polymer, polystyrene, results in a closed cell structure which resists the ingress of water. This high level of moisture resistance allows the product to maintain its thermal insulating value for the long term. In protected membrane roofing, STYROFOAM ROOFMATE* Brand Insulation is a proven material in a proven system. In plaza construction, STYROFOAM PLAZAMATE* Brand Insulation has proven its utility and performance.

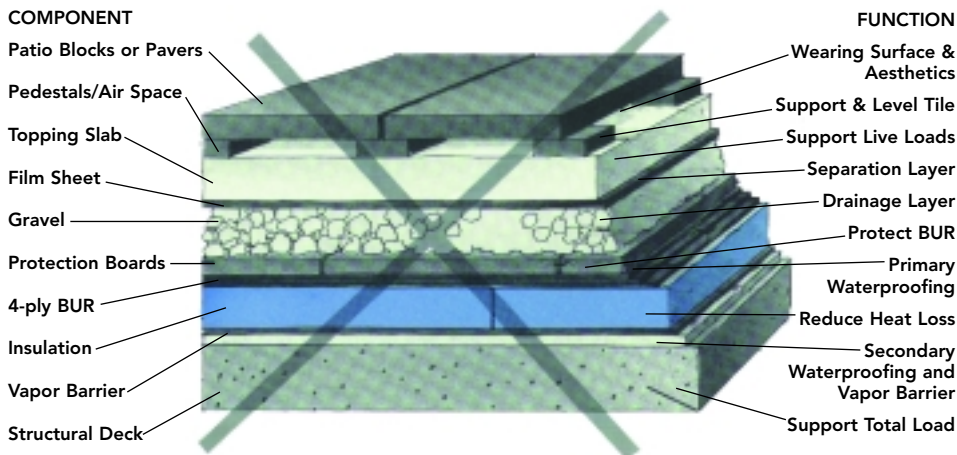
Compounded Errors—Many plaza builders attempt to avoid the monumental problems of leak repair by specifying the plaza with a "belt and suspenders" approach. Following is a cross section of such a plaza.

Common sense tells us that when a leak occurs in this type system, it is not only going to be expensive to repair, but perhaps impossible to locate without dismantling the whole plaza. Water can travel between layers and then drip into the building far from the original source of the leak. In fact, extra layers in a plaza system often cause headaches when trying to trace a leak back to its source.

The contemporary architect endeavors to design a plaza which will be aesthetically pleasing and meet the owner's needs. He also strives to specify a system which offers the highest assurance of performance. Tearing up a plaza to repair a leak must be avoided. Repairs can easily become more costly than the original construction!

Experience leads us to believe that the most realistic approach is to use sound engineering principles when designing a plaza. Over-designed systems cannot prevent poor workmanship, nor can they eliminate the opportunity for construction activities to damage a waterproofing membrane. The alternative to the "over-designed" plaza is to use *proper materials in a logical sequence*. The following section develops the logical sequence based on sound engineering principles.

The Old "Belt and Suspenders" Approach



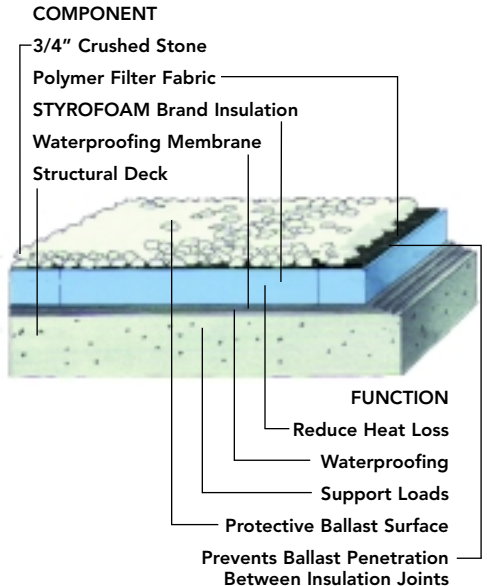
The PMR Approach to Waterproofing

More than 20 years ago, The Dow Chemical Company began work on an insulated roofing system. This system was known as IRMA (Insulated Roofing Membrane Assembly)[†]. Today it is commonly referred to as a PMR (Protected Membrane Roof). The four components are shown below. Notice that all components have their counterparts in plaza applications. In fact, if a wearing surface were added to this cross section, it would be a plaza deck.

The key to the PMR system is the fact that the insulation is placed above the membrane. This configuration protects the membrane from thermal cycling. In conventional roofs, the membrane often experiences a 100°F change in temperature during a 24 hour period. With PMR, STYROFOAM Brand Insulation keeps the membrane at a nearly constant temperature at the same time it insulates the building. Freeze/thaw cycles at the waterproofing layer are eliminated. The sun is not burning away the volatiles from the built-up membrane. In this position, the membrane also serves the function of a vapor barrier. This assures that the dew point is located above the membrane. In this position, the insulation also provides mechanical protection for the membrane. Long-term performance is attained with *basic materials sequenced in the right order*.

[†] Patent No. RE. 3, 411, 256, RE 31007 (8/82)

PMR System



Properties of STYROFOAM Brand Insulation

Average Properties ¹	ASTM Test Method	STYROFOAM Brand Plastic Foams	
		ROOFMATE	PLAZAMATE
ASTM C578-98		VI	VII
Physical Properties Compressive Strength ² (perpendicular to board face, psi at 5% deformation)	D 1621	45 (Typical) 40 (Minimum)	70 (Typical) 60 (Minimum)
Water Resistance Properties Water Absorption (% by volume) Water Vapor Permeance (perm/in.)	D 2842 E 96	1.0 0.4	1.0 0.4
Thermal Properties Thermal Resistance (°F • ft. ² • h/Btu) at 40°F mean at 75°F mean	C 177 or C 518	5.4 5.0	5.4 5.0
Maximum Service Temp., °F		165°F	165°F

(1) STYROFOAM ROOFMATE and STYROFOAM PLAZAMATE Brand Insulation meet or exceed the requirements of ASTM C578-95 for Type VI and Type VII materials respectively.

(2) For structural applications involving continuous high compressive load, non-uniform loads, or high temperature, provide an adequate safety factor on design-stress levels to minimize creep.

(3) Water vapor permeance varies with thickness. Value applies to a 1" thickness.

Why STYROFOAM Brand Insulation In PMR?

Why hadn't insulation been used to protect a roofing membrane before Dow developed the system? The answer to that question is simple. No insulation had been developed which could withstand

the exposure to the environment inherent in the PMR system. That is, not until STYROFOAM Brand plastic foam was tried as a roof insulation above the membrane.

STYROFOAM Brand Insulation is a closed cell extruded polystyrene foam manufactured specifically for the roofing application. The fact that it is closed cell is extremely important in the PMR system.

STYROFOAM ROOFMATE Brand Insulation: Problem Solving Element in PMR

Problem	How STYROFOAM ROOFMATE Brand Insulation Handles the Problem
Inverted sequence exposes insulation to water for long periods of time.	Absorption of water is minimal even when STYROFOAM Brand Insulation is submerged for long periods of time. See Graph I.
During cold seasons, water on the insulation will freeze.	STYROFOAM Brand Insulation has the toughness to withstand repeated freezing and thawing and without picking up water. See Graph II on page 3.
A temperature differential will exist across the insulation, there will be water on the membrane, therefore a vapor pressure differential results, driving moisture into the insulation.	STYROFOAM Brand Insulation has closed cells to limit water absorption from this vapor pressure drive. See Graph III on page 3.

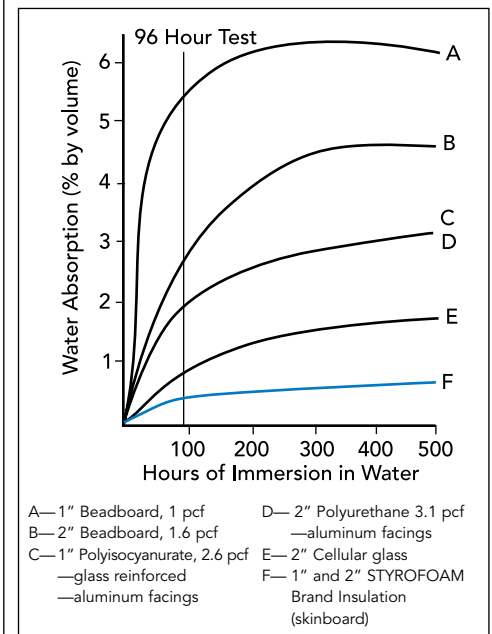
In addition to STYROFOAM ROOFMATE Brand Insulation for roofing, The Dow Chemical Company has developed a specific product, STYROFOAM PLAZAMATE Brand Insulation, for the plaza environment. This extruded polystyrene skinboard insulation has a minimum compressive strength of 60 psi. This allows it to function as a supportive layer to carry the normal loads found in plaza constructions and as a protection board to defend the waterproofing membrane from construction abuse.

The following graphs illustrate how STYROFOAM Brand Insulations compare with other insulations in specific tests.

Due to the many variables involved in field applications, these tests do not exactly simulate the actual performance of these products in the PMR system. If the tests were continued for a longer period of time, all of the materials would continue to pick up water.

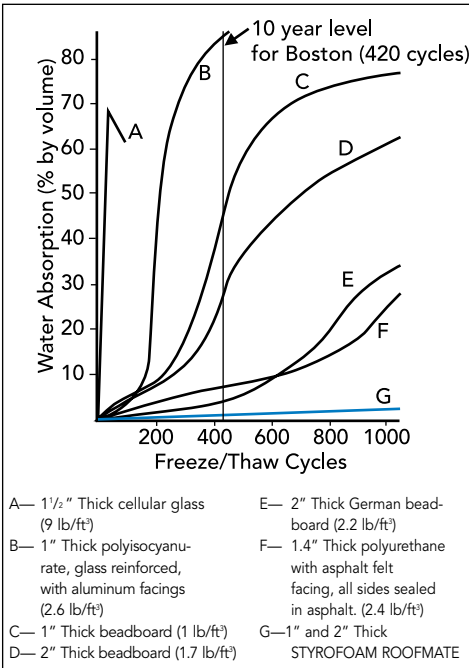
These laboratory results illustrate that STYROFOAM Brand Insulations pick up much less water than other materials tested. The absorption of moisture, through any of the three mechanisms, will have an adverse effect on the thermal conductivity of the insulation. Years of work at many

Graph I—Water Absorption



This test measures the volume of water absorbed per unit volume of foam. The 96 hour test is described in ASTM D 2842-69. Since longer periods of immersion can occur in the inverted roof application, the test was run for 500 hours (21 days).

Graph II—Freeze/Thaw



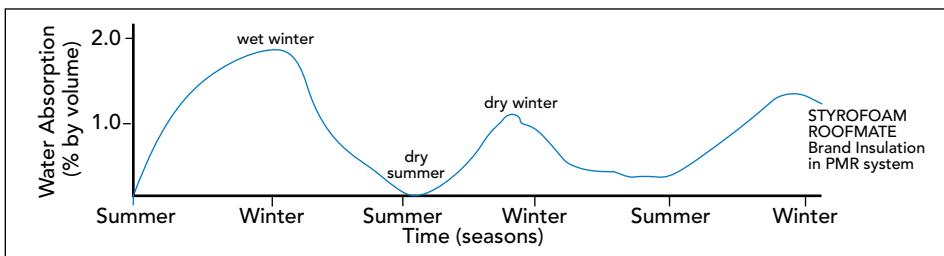
Tested in accordance with ASTM C 666-73 (freezing in air, thawing in water). (This test does not simulate field conditions, but is useful in determining relative performance of insulations in applications where freezing and thawing occur in the presence of water).

different research facilities in various countries have been needed to quantify this effect.

When a loss of thermal efficiency occurs, the cost of heating or cooling changes proportionately. From that viewpoint, the issue of what causes the insulation to pick up water becomes academic. When operating costs are considered, the *in-service R-value* is what counts, not the *originally purchased R-value*.

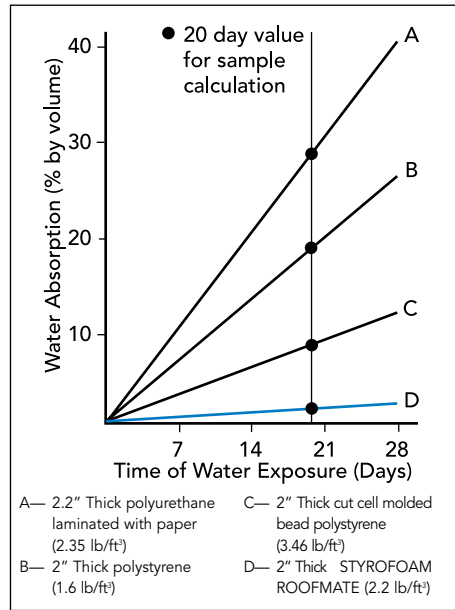
Actual Performance—The proof is in experience. After 13 to 22 years, actual samples of STYROFOAM Brand Insulation were recovered from PMR systems. On an average, STYROFOAM Brand Insulation retained 96% of its original R value.

Graph IV—Typical Seasonal Performance in the PMR System



Accumulation of data on field performance of STYROFOAM Brand Insulation installed in the PMR roof system, Dow USA 1970-1977. This graph is based upon the performance history of the PMR roof system installed in various geographical areas under different field conditions. The curve represents the full range of performance that can occur for the seasons indicated.

Graph III—Water Vapor Diffusion



German water vapor diffusion test. Temperature gradient of 50°C (90°F) was maintained on each sample throughout the 28 day test. All samples were 5-6 cm, \approx 2 inches, thick. Test conducted in 1976 by Dow Europe.

To put the end use application in wet environments into perspective, a look at STYROFOAM Brand plastic foam in a PMR system is in order. The preceding graph illustrates the water absorption that typically takes place over the course of several years in a roof with the PMR system.

The curve shows that drying occurs during some parts of the year in the PMR system. In plaza construction, where there is increased opportunity for water to be trapped within the system, taking advantage of the superior resistance of STYROFOAM Brand plastic foam to water absorption in any form offers the best way to maintain insulating value.

The Components of Plazas

Many plaza construction questions may remain. STYROFOAM Brand Insulation works well in roofing, but is it really applicable to plaza construction? A specific look at the individual plaza components should help answer that question.

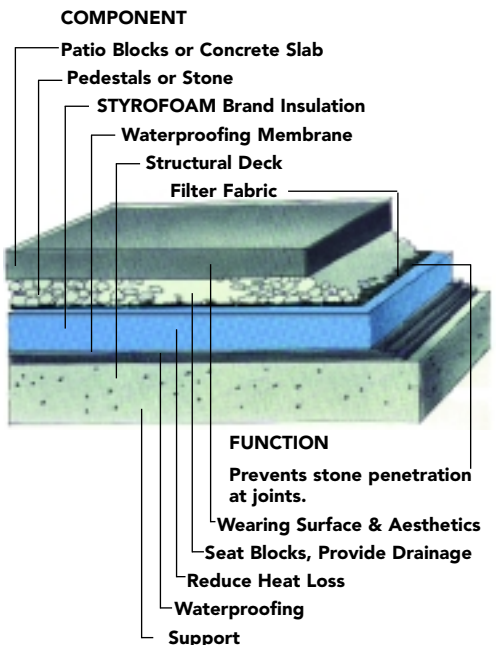
Although every plaza is different, they can all really be stripped down to a cross section similar to the one below. Notice this is the PMR system with a wearing slab on top.

Structural Deck—The structural deck is the base layer in a plaza. Its primary function is to carry the loads of the plaza system. This will include dead loads from the weight of the materials used in the plaza construction as well as live loading such as cars moving across a parking deck. It is with a full understanding of these load carrying demands that the architect and structural engineer design the structural slab.

In order to assure good performance of the next component, the waterproofing membrane, the deck surface must be smooth and clean. When necessary, expansion joints should be included in the structural deck to control stresses in large buildings.

Waterproofing Membrane—The purpose of this component is to keep water out of the building. When the deck is properly prepared and the membrane is going to be protected by insulation, it is difficult to demonstrate that putting

Plaza Deck



down a second membrane elsewhere in a "belt and suspenders" approach will result in any better performance.

Many types of membranes have been used in plaza construction. The built-up-roof (BUR) consists of alternating layers of roofing felts and moppings of hot asphalt or cool tar bitumen. Adhesion to the deck is normally good, limiting horizontal water migration.

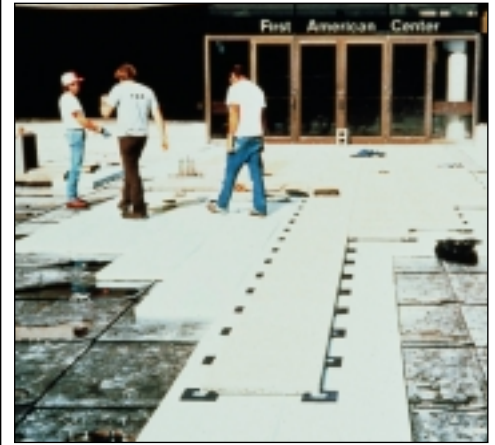
More recently, alternate types of membranes have received a lot of attention in plaza construction. One example is the sheet membrane. In this system a water-tight sheet is constructed over the deck and flashed onto the building. This membrane has desirable elastic properties to relieve membrane stresses, but many systems lack membrane-deck adhesion which can cause problems with lateral water movement and leak location.

Hot applied rubberized asphalt membrane systems which cool into a monolithic layer are perhaps the most logical type of membrane being used in the PMR plaza. Most of these systems are also elastic. They can be easily applied and will adhere to the deck well, preventing the problem of horizontal water migration. Some of the products have more than 20 years of proven performance in plaza construction. When a liquid membrane system is used with STYROFOAM Brand Insulation, it is important that the system be compatible with the insulation. If a cool tar pitch membrane is used, a separator sheet must be installed between the membrane and the foam to prevent solvent attack. 4-mil polyethylene is a typical choice for the separator sheet.

Insulation—STYROFOAM Brand Insulation is easy to install. The insulation units are installed in an unadhered fashion over the membrane.

Extruded polystyrene insulations are ideal for plaza construction for the same reasons they work so well in the PMR system. The logical sequence leads to the conclusion that the membrane should be insulated. This in turn exposes the insulation to moisture since it is above the waterproofing membrane. STYROFOAM Brand Insulations are the only foam insulations which combine resistance to water with the toughness to withstand crushing and freeze/thaw cycling to provide good long-term insulation value.

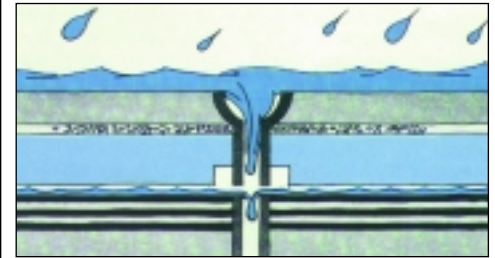
Drainage—A properly built plaza will be capable of handling a heavy rain in its drainage system without having it pond



on the top surface. *It will also allow drainage at the membrane level so that water cannot become trapped in the system.*

To assure proper drainage, the architect must determine how many drains will be needed. Their location is equally important. Ideally a sloped surface is then provided to cause the water to flow to the drains. Unfortunately, sloping the plaza components is usually expensive and may be detrimental to the appearance of the plaza. For this reason, the wearing surface is often kept level while some or all of the sublayers are sloped to facilitate drainage. The four cross sections shown below illustrate some basic variations and the expected results.

These cross-sections all utilize a specific drainage layer to aid water removal. This may take the form of a gravel layer, or it may be the airspace created by supportive pedestals below a patio block surface. Stone used for this drainage layer must be clean and have a low percentage of fines. A suitable synthetic



fabric should first be placed over the insulation to protect the joints and keep them open for drainage. "No fines" concrete has also been used successfully as a drainage layer. This stone drainage layer or air space is important because of the very low permeance of STYROFOAM Brand Insulations. If the wearing surface is installed in direct contact with the insulation, moisture may be trapped at the interface, causing the insulation to retain moisture over time. And, freeze-thaw cycling can cause spalling of the bottom of the wearing surface. This is not a concern in areas with less than 3000 heating degree days.

Drainage Examples

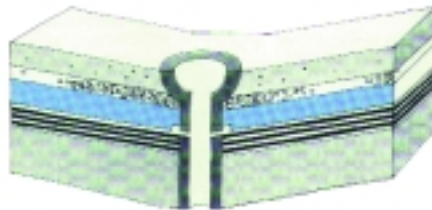


Fig. 1—Excellent Surface and Membrane Drainage. Increased Cost. Affects Appearance.

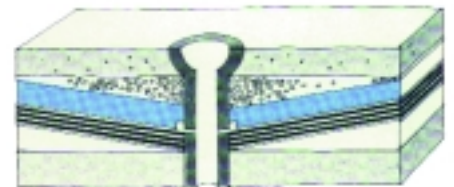


Fig. 3—Excellent Membrane Drainage. Increased Cost. Fill materials can cause leak location problems.

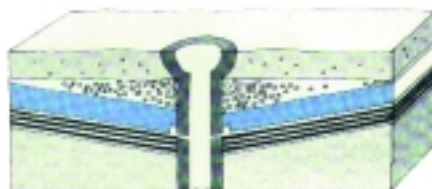


Fig. 2—Excellent Membrane Drainage. Increased Cost. Thick cross section.

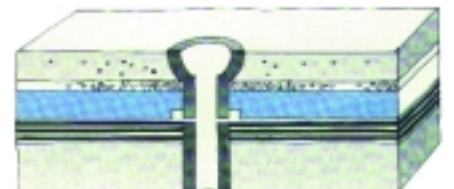


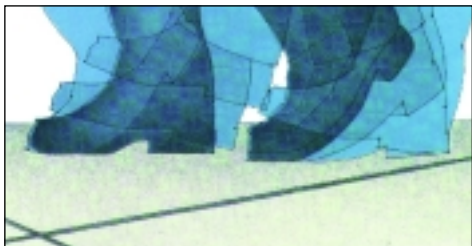
Fig. 4—Effective Membrane Drainage. Cost Controlled. Construction simplified.

STYROFOAM PLAZAMATE Brand Insulation is manufactured with a drainage channel on the bottom edge. Water is held above the drain level by the displacing effect of the insulation. A head of water exists in the joints of the insulation boards, and this forces water through the channels to the drains at the membrane level. The result is improved drainage in all of the above cross-sections.

Drainage is a complicated and important part of plaza construction. The above illustrations cannot answer the specific problems each different plaza will present, but they do provide a beginning understanding of what is involved. The specific details of design and construction necessary to assure proper drainage are important responsibilities which must be carefully addressed by the architect and engineer.

Wearing Surface—This is what the plaza is all about. The wearing surface is where the architect has the opportunity to beautify a building, and the owner has the opportunity to optimize his investment. Many surfacing materials are available for uses as a wearing surface, including paving slabs, a monolithic concrete poured-in-place top covering or soil and vegetation.

In many plaza applications, a reinforced concrete slab is used as a wearing surface. This alternative has a much greater load-carrying capability and eliminates the joints between blocks. (When pouring concrete, Dow also recommends the use of a water permeable sheet above the stone drainage layer in order to prevent concrete from filling the voids.)



Structural Design Considerations

The concept of plaza construction should now be in better perspective, but specific questions about the use of STYROFOAM PLAZAMATE Brand Insulation must be addressed. Illustrations are used to show why Dow offers a range of products with differing compressive strengths for the wide range of needs in plaza construction.

CAUTION—This is NOT a design manual. The following examples represent ideal situations. The effect of edge conditions of the plaza have been disregarded. The analysis in no way addresses the design of the structural deck. With respect to the wearing slab, only the insulation's function as a base is considered. The following are illustrations of how Dow believes its insulation will typically perform under given conditions. Each application requires the attention of an architect and/or structural engineer.

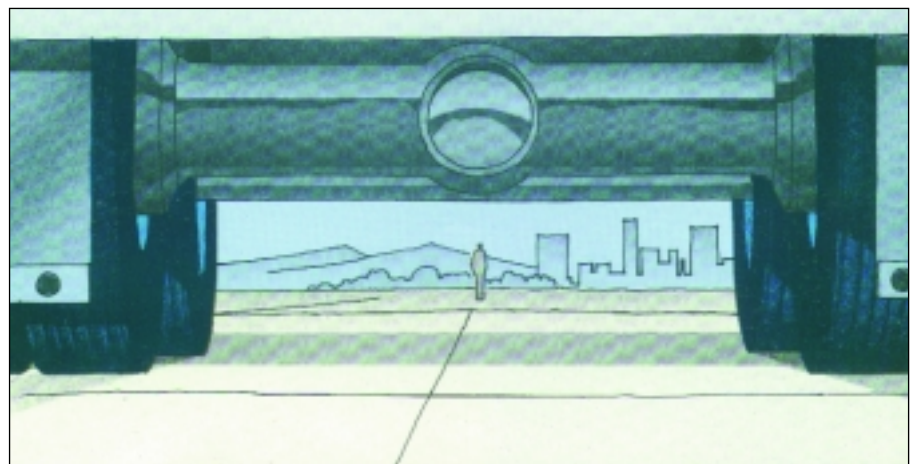
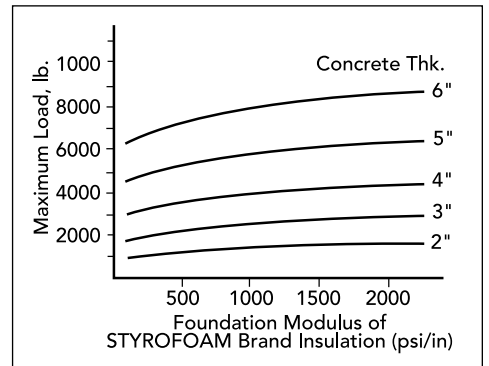
Monolithic Wearing Slabs—Through research done by The Dow Chemical Company, it has been shown that STYROFOAM Brand Insulations will perform in plaza type applications according to the theory of plates on elastic foundations. A detailed discussion can be found in Chapter 8, *Theory of Plates & Shells*, by S. Timoshenko and S. Woinowski-Krieger, McGraw-Hill Book Company, Inc., 1959.

Dow, in full scale experiments, generated data which agrees with this theory. Based on this knowledge, it was shown that the critical component with respect to design strength is the wearing slab, not the insulation. The thickness and

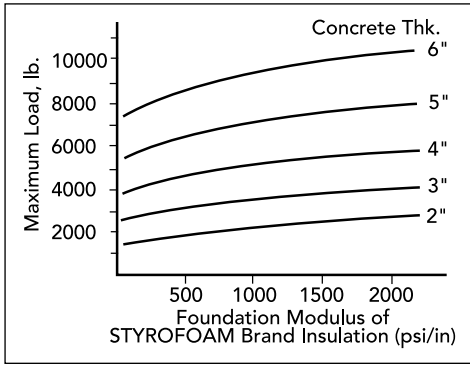
modulus of rupture of the wearing slab must be adequate to carry the design loads safely in accordance with the theory of plates on elastic foundations. The wearing slab is likely to fail in bending before the insulation is overloaded in compression. Load transfer across joints must be assured by incorporation of continuous reinforcement, slip rods, or other means if vehicular traffic is anticipated. Final decisions in this regard must be made by the architect and engineer in each project.

Parking Decks—The parking deck is a common insulated plaza type application. Normally, a monolithic wearing slab is required to carry the loads imposed on a parking deck. The following charts illustrate the theoretical maximum allowable wheel loads on concrete slabs of various thicknesses as a function of the foundation modulus of the STYROFOAM Brand Insulation. If these loads are exceeded, theory would predict that the slab will fail and crack. Concrete with a compressive strength of 3500 psi at 28 days and a flexural modulus (modulus of rupture) of 550 psi is assumed for these calculations. A 2:1 safety factor was used for the development of these charts.

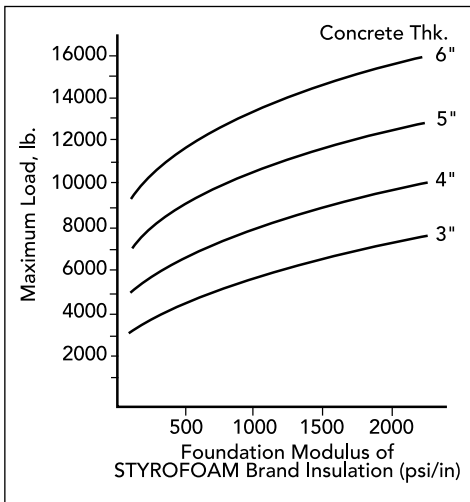
Maximum Fork Lift Wheel Load (Tire Area = 28 in.²) vs Foundation Modulus



Maximum Car/Light Truck Wheel Load (Tire Area = 60 in.²) vs Foundation Modulus



Maximum Truck Dual Wheel Load (Tire Area = 200 in.²) vs Foundation Modulus



Foundation Modulus PSI/In. for STYROFOAM PLAZAMATE Brand Insulation

Board Thickness	Number of Layers		
	1	2	3
1 1/2"	1400	700	475
2"	1250	625	425
2 1/2"	1100	550	375
3"	1000	500	350
3 1/2"	950	475	325

Pedestrian Malls or Terraces—These types of plaza decks may incorporate a monolithic wearing slab with a desirable surface finish, but are frequently designed with a pedestal and paver system for aesthetic reasons. A common terrace cross-section of this type is shown on the following page. The number, placement, and protection of drains at the membrane level is critical when paver joints are left open.

Pedestal Systems—In this application, deformation of some insulations under the pedestal could eventually lead

to an unlevel patio block surface. STYROFOAM Brand Insulation has and maintains a high compressive strength to provide a strong supportive layer for a pedestal system. For proper design, a complete evaluation of the loads which will be transferred through the pedestals to the surface of the insulation must be considered. STYROFOAM Brand Insulations are viscoelastic materials, so relatively high safety factors are required in all load-bearing designs. To limit the effect of creep, the maximum allowable static (dead) load on STYROFOAM PLAZAMATE Brand Insulation is 20 psi. To minimize fatigue, the maximum allowable dynamic (live) load is 12 psi. For example, with 2' x 2' patio blocks supported by 6" x 6" pedestals, 108 psi live loading is permissible over STYROFOAM Brand Insulation. *Pedestal systems are usually not capable of carrying vehicle wheel loads.* The thickness and modulus of rupture of the paver, support span, and the elastic foundation modulus must all be taken into consideration in the design of pedestal and paver systems. A large, thin paver may crack under a concentrated load even though the insulation is not overloaded.

Construction Staging—Membrane Protection—An additional demand for the tough properties of STYROFOAM Brand Insulation occurs no matter what type of top covering is specified in a plaza. That demand evolves from the inevitable need to provide for some amount of construction staging.

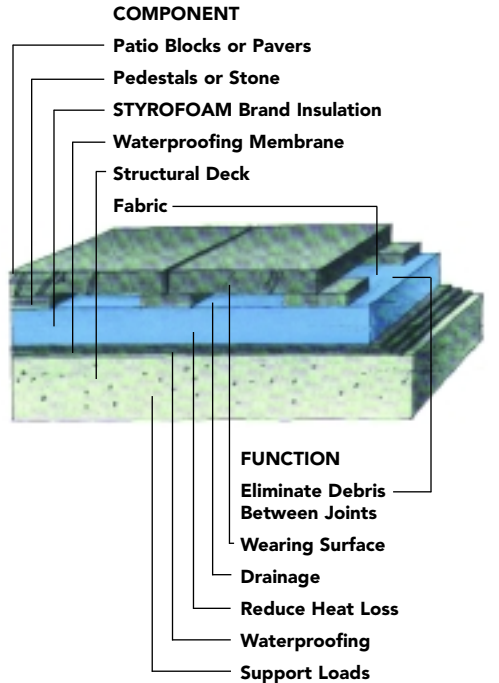
The first stage of plaza construction is the structural deck. A delay after this is complete is not usually critical. The frustrations increase after the second stage has been completed because the integrity of the waterproofing membrane is at stake. At this stage, proper attention to good workmanship practices is very important.

Normally, the need for restricting construction traffic occurs. The extra cost of protection boards becomes involved, and perhaps the most nerve-racking is the possibility that as the waterproofing layer sits out there waiting for the insulation and the wearing surface, it may be damaged. Gouged, pierced, torn, split—it doesn't matter how, what matters is that the damage may go unnoticed when the construc-

tion is completed, thus making the repair of leaks impractical.

STYROFOAM Brand Insulation, placed over the waterproofing layer as it is constructed, can provide protection board which functions from the day the roofers leave the job to the day the wearing slab is complete. Eight-foot lengths of STYROFOAM Brand Insulation should be installed in an unadhered fashion and ballasted.

Plaza with a Patio Block Surface



Summary

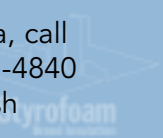
Hopefully, these examples have put the use of STYROFOAM Brand Insulation into perspective. With a properly designed wearing slab, a compressive strength of 60 psi can more than handle the typical demands of a parking deck. Pedestal systems will result in more acute loading on the insulation, but since the design loading is often much less severe, STYROFOAM Brand Insulation again does the job. From the standpoint of staging and membrane protection, a minimum 60 psi compressive strength allows the insulation to take the kicks and gouges of construction and keep right on insulating and protecting.

For plaza designs with even more severe loading requirements, higher compressive strength products, up to 100 psi are available from Dow.

For further information contact your Dow Sales Representative.



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