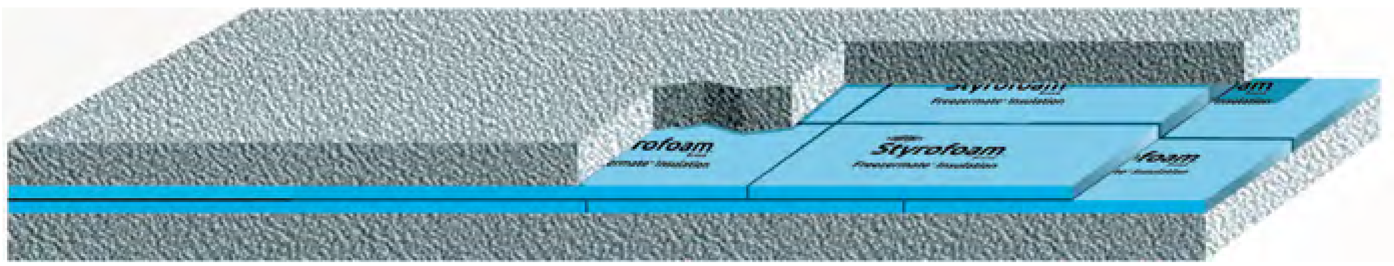
DuPont™ Styrofoam™ Brand Insulation

For Controlled Environment Building Floors



Structural Design Considerations for Controlled Environment Building Floors

Recent changes in the design of controlled environmnent buildings in the form of rack supported roof structures and taller rack storage systems have made the proper design of the floor system critical in avoiding the bending and cracking problems which can occur in inadequately designed floor systems. Floor designs which have performed well in the past may no longer be able to withstand the high floor loadings present in modern controlled environment facilities.

The typical floor design has not changed for many years. The insulation is laid in multiple layers on a vapor retarder either over a subslab or directly over the soil. An under insulation heating system is installed under the subslab when the floor is under a building space continuously operating below 32° F. Reinforcement and slip sheets are positioned where necessary and the concrete for the wearing slab is poured directly onto the insulation. After the wearing slab has cured, it must be able to support the live and dead loads imposed by any moving equipment, storage racks and stored materials. As design loads increase, the insulation plays a more important role in providing support for the wearing slab.

When designing for the load carrying capacity of a controlled environment building floor, there are two important factors which must be taken into account: the foundation modulus and compressive creep of the insulation. These factors are different for the various types of plastic foam insulation, and these differences can have a significant impact on the design and performance of the facility floor.

The Foundation Modulus

When designing floor systems to withstand the loads produced by fork-lift trucks and storage racks, one of the most important rigid insulation properties is the foundation modulus. This critical parameter can be used to help determine the thickness of the concrete wearing slab, its strength, and the type of reinforcement combination that it needs to withstand the expected floor loading.

The foundation modulus of an insulation system is probably the best way to describe its load carrying characteristics. Although the foundation modulus is related to the compressive strength of the insulation, the only way to determine the foundation modulus is to compress the insulation and measure the force as the insulation deflects.

The foundation modulus describes the relationship between the load applied to an insulation system and the amount of sagging or deflection that occurs as a result of the load. For example, if a 20.0 lb/in^2 (psi) load is applied to an insulation board and as a result of that load the insulation deflects 0.1 in., then the foundation modulus for that insulation is 20.0 psi/0.1 in. = 200 psi/in. The psi/in. term is commonly referred to as “pounds per cubic inch” or pci. The foundation modulus for an insulation system varies with the number of insulation board layers used in the system. If a 20.0 psi load were to be applied to two layers of the same insulation board considered in the above example, the deflection would be twice as much as that measured for one layer because each layer deflects 0.1 in. for a total of 0.2 in. of deflection. The foundation modulus for this system of two insulation boards would be 20.0 psi/0.2 in. = 100 pci. This second example illustrates an important point: *the foundation modulus for multiple layer systems is equal to the foundation modulus of one of the layers divided by the total number of layers, if the layers are identical.*

For more complicated systems incorporating layers of insulation which have foundation moduli that vary from layer to layer, the system foundation modulus (K_t) can be found by adding the foundation moduli for the individual layers (K_1, K_2, etc.) in the following manner:

$$1/K_t = 1/K_1 + 1/K_2 + 1/K_3 + \cdots 1/K_n$$

It is easy to see that the foundation modulus for a given insulation system depends upon the type and thickness of rigid insulation being considered and the number of layers in the system. Table 1 gives the foundation modulus of various thicknesses of Styrofoam* Brand plastic foam insulations.

Table 1. – Foundation Modulus for Styrofoam™ Brand Insulation[1]

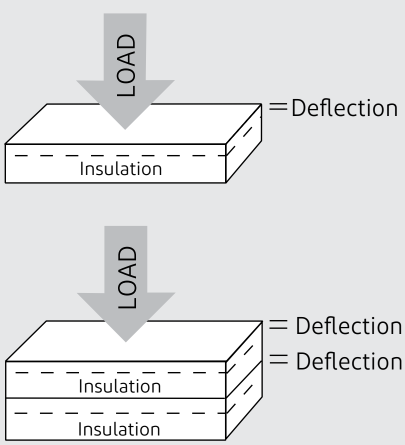
Grade of Styrofoam™ Brand Insulation	Thickness of Insulation (in.)					
	1	1.5	2	2.5	3	4
FreezerMate™	–	–	700	655	610	525
High Load 40	1275	1100	980	850	750	600
High Load 60	1600	1400	1250	1100	1000	800
High Load 100	2300	2050	1800	1600	1400	1100

[1]All figures are in lb/in.[3]

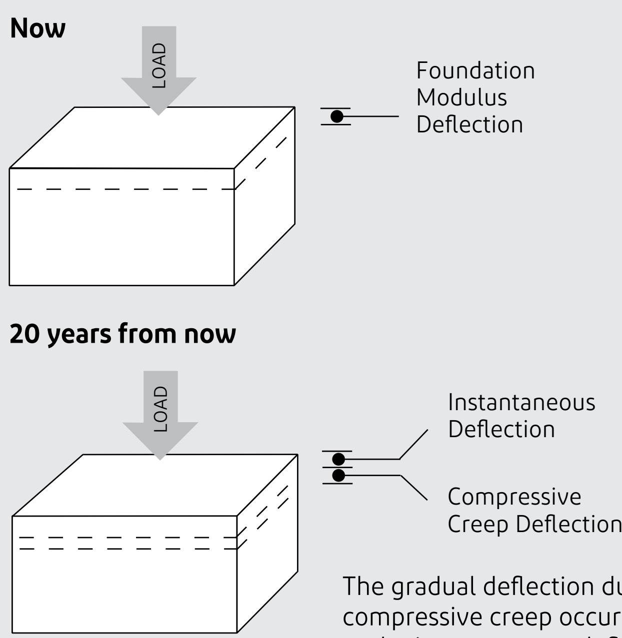
Compressive Creep

When a compressive force or load is applied to any plastic foam insulation, an instantaneous deformation takes place (as described by the foundation modulus). If this load is maintained on the foam for a long period of time, the deformation will increase as time passes. This gradual, permanent deformation of the plastic foam, in addition to the instantaneous deformation described by the foundation modulus, is known as compressive creep. In a low temp floor system which has been designed inadequately, either because of incorrect assumptions regarding compressive creep or the anticipated loads, sagging or cracking can occur over a long period of time as the insulation deforms under the wearing slab. This potential sagging can be critical if the flatness of the floor is important to the operation of the low temperature facility.

The compressive creep characteristics of the Styrofoam™ Brand plastic foam insulations used in low temperature construction have been extensively investigated. It is generally accepted that the compressive creep of an insulation system should be limited to 2% of the insulation thickness over a 20-year period. If the compressive dead load on Styrofoam™ Brand insulation is kept to less than one third of the design compressive strength of the insulation, then the creep exhibited by Styrofoam™ brand insulation will be less than 2% of the insulation thickness over a 20-year period. Live compressive loads should be no greater than one fifth of the design compressive strength. These limits apply only to Styrofoam™ Brand insulation.



Multiple layers of a plastic foam insulation deflect more than a single layer of the same insulation under the same load because each layer deflects and adds to the total deflection.



The gradual deflection due to compressive creep occurs in addition to the instantaneous deflection

Table 2. – Recommended Live and Dead Load Limits for Styrofoam™ Brand Insulation

Load Limit	Grade of Styrofoam™ Brand insulation			
	FreezerMate™	High Load 40	High Load 60	High Load 100
Live (lb/in.^{2})	6.0	8.0	12.0	20.0
Dead (lb/in.^{2})	10.0	13.3	20.0	33.3

Other brands of plastic foam insulating materials will require limits of some kind, although not necessarily the same as those for Styrofoam™ Brand insulation.

Table II outlines maximum allowable live and dead loads for various grades of Styrofoam™ Brand plastic foam insulation.

Design of Controlled Environment Building Floors

Experiments performed on selected typicalcontrolled environment floor designs incorporating Styrofoam™ Brand insulations have shown that the Theory of Plates on Elastic Foundations[2] accuratel describes the deflection/load characteristics of such systems.

The Theory of Plates on Elastic Foundations predicts the deflection of the wearing slab given the slab properties and the imposed load. The general form of the equation is:

$$W = \frac{F}{8\sqrt{KD}}$$

where W = the deflection of the slab, in.

F = the applied load, lb.

K = the foundation modulus of the insulation, lb/in.^{3}

D = $Eh^3/12(1-u^2)$

where E = modulus of elasticity of the concrete, lb/in.^{2}

h = thickness of the concrete, in.

u = Poisson's ration for the concrete

According to the relationships defined in this equation, the instantaneous deflection (W) exhibited by a slab under a given point load (F) is determined by the foundation modulus of the insulation under the slab (K) and the properties of the wearing slab (D). If the foundation modulus of the insulation is increased fourfold, the deflection exhibited by the slab would be cut in half.

For example, a typical concrete wearing slab might have a modulus of elasticity (E) of 10^6 psi and a Poisson's ration (u) of 0.15. If this wearing slab is 5 inches thick (h), then the term D for this slab is:

$$\begin{aligned} D &= Eh^3/12(1-u^2) \\ &= 10^6(5^3)/12(1-0.15^2) \\ &= 1.07 \times 10^7 \text{ lb-in.} \end{aligned}$$

If a point load of 10,000 pounds is placed on this wearing slab and the insulation system under the wearing slab has a foundation modulus (K) of 200, then the deflection in the wearing slab is predicted to be:

$$W = \frac{F}{8\sqrt{KD}} = \frac{10{,}000}{8\sqrt{(200)(1.07\times10^7)}} = \mathbf{0.0271\ in.}$$

[2]Theory of Plates and Shells, Timoshenko and Woinowsky-Krieger: McGraw-Hill 1959

For more information visit us at styrofoam.com/freezermate or call 1-833-338-7668

DuPont™ Styrofoam™ Brand Extruded Polystyrene Foam Insulation

CAUTION: This product is combustible. Protect from high heat sources. A protective barrier or thermal barrier may be required as specified in the appropriate building code. For more information call the DuPont Contact Center at 866-583-2583 or contact your local building inspector. For emergencies contact Chemtrec 800-424-9300, CCN (Contract Number) 7442.

WARNING: Rigid foam insulation does not constitute a working walkable surface or qualify as a fall protection product.

Building and/or construction practices unrelated to building materials could greatly affect moisture and the potential for mold formation. No material supplier including DuPont can give assurance that mold will not develop in any specific system.

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