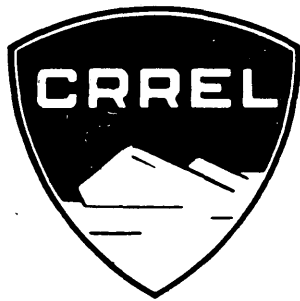TR 249

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MOISTURE AND FREEZE-THAW EFFECTS ON RIGID THERMAL INSULATIONS

Chester W. Kaplar

April 1974

CORPS OF ENGINEERS, U.S. ARMY
COLD REGIONS RESEARCH AND ENGINEERING LABORATORY
HANOVER, NEW HAMPSHIRE

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PREFACE

This report was prepared by Chester W. Kapler, Research Civil Engineer, Applied Research Branch (Albert F. Wuori, Chief), Experimental Engineering Division (K.A. Linell, Chief), U.S. Army Cold Regions Research and Engineering Laboratory. The report was technically reviewed by W.C. Cullen, Building Research Division, National Bureau of Standards, and by Dr. K.B. Woods of Purdue University.

The study was administered by the Civil Engineering Branch (Mr. F.B. Hennion, Acting Chief), Engineering Division, Directorate of Military Construction, Office, Chief of Engineers. The work was part of Military Construction Investigations (MCI) project SP 48, *Materials in Cold Climates.*

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MOISTURE AND FREEZE-THAW EFFECTS ON RIGID THERMAL INSULATIONS

by

Chester W. Kaplar

INVESTIGATIONAL PROGRAM

Introduction

This report covers an investigation of some physical properties of rigid thermal insulating materials proposed for use in construction. Since rigid thermal insulation is commonly used for roofs, beneath slabs on grade, and in perimeter locations with embedment in the ground, it is likely to be exposed to moisture absorption. As data on moisture absorption are lacking, the chief interest in this investigation was the evaluation of moisture absorption properties because of their probable adverse effects on the thermal insulating properties. Results of studies of effects of moisture absorption on thermal conductivity are presented elsewhere.[12] Strength and flammability characteristics were also evaluated.

There were five main categories of tests:

1. Physical strength and other physical properties
2. Moisture absorption during shallow submersion
3. Moisture absorption under hydrostatic pressure
4. Moisture absorption during embedment in moist soil
5. Resistance to freeze-thaw under wet conditions.

The tests are described and results presented and discussed in the order indicated.

Materials

A number of the most common types of rigid insulation were obtained (Table I). Most were purchased on the open market, while a few were samples submitted by contractors for construction projects. On open-market purchases, panels 2 in. thick were specified but 1- and 1½-in.-thick boards were accepted when 2-in. boards were not available. The following materials, mostly foamed plastics, were investigated:

Beaded polystyrenes
Extruded polystyrenes
Polyurethanes
Other insulation types

Table I lists the prices of the materials. Most of the insulations used were polystyrene products, which are well known, cheap, and popular in the construction industry. They were of two

Table I. Types of insulation tested.

Insulation*	Manufacturer	Trade name	Approx Density (lb/ft³)	Approx Thickness (in.)	Price (1966)
Polyurethanes					
PU 1	Unknown		1.6	2	Unknown
PU 2	Dow Chemical Co.	Thurane FR	1.9	2	Unknown
PU 3	Deleted	Deleted	2.2	2	91¢/bd ft
Beaded polystyrenes					
BPS 1a	Armstrong Cork Co.	Armalite†	0.9	2	11¢/bd ft (0-15,000 ft)
BPS 1b	Armstrong Cork Co.	Armalite Self-Extinguishing†	0.9	2	11½¢/bd ft (0-15,000 ft)
BPS 2	Sinclair-Koppers Co.	Dylite	1.6	2.5	Unknown
BPS 3a	Deleted	Deleted	1.2	2	Unknown
BPS 3b	Deleted	Deleted (self-extinguishing)	1.2	2	Unknown
Extruded polystyrenes					
EPS 2	Dow Chemical Co.	Styrofoam 22	1.7	2	9¼¢/bd ft (15,000 ft +)
EPS 3	Dow Chemical Co.	Styrofoam BB	1.9	7	15.1¢/bd ft
EPS 4	Dow Chemical Co.	Styrofoam FB	1.9	7	Unknown
EPS 5	Dow Chemical Co.	Styrofoam FR	1.9	2	9¢/bd ft (15,000 ft +)
EPS 6	Dow Chemical Co.	Styrofoam CB	2.0	2	9½¢/bd ft (15,000 ft +)
EPS 7	Dow Chemical Co.	Styrofoam 33	2.1	2	9¼¢/bd ft (15,000 ft +)
EPS 8a	Dow Chemical Co.	Styrofoam SM (1½ in.)	2.4	1½	17.6¢/bd ft (15,000 ft +)
EPS 8b	Dow Chemical Co.	Styrofoam SM (2 in.)	2.4	2	Unknown
EPS 9	Dow Chemical Co.	Roofmate	2.5	2	$200/1000 ft³ 11¢/bd ft
EPS 10	Dow Chemical Co.	Scorbord	2.5	2	17¢/bd ft (15,000 ft +)
EPS 11	Dow Chemical Co.	Styrofoam HD-1	3.1	2	20¢/bd ft (15,000 ft +)
EPS 12	Dow Chemical Co.	Styrofoam HD-2	3.6	2	36.1¢/bd ft (15,000 ft +)
Miscellaneous					
Cellular glass (CG)			9.2	2	33.2¢/bd ft (1-5400 ft)
Fiber glass 1 (FG1)	Owens-Corning Fiberglas Corp.	Fiberglas AE-6	9.5	4	1½¢/bd ft
Fiber glass 2 (FG2)	Owens-Corning Fiberglas Corp.	Fiberglas AE-F†	11.3	4	1½¢/bd ft
Perlite (P)	Deleted	Deleted	10.7	1	7.6¢/bd ft
Asbestos board (AB)	Johns-Manville Corp.	Thermobestos	14.8	2	30¢/bd ft
Cork board	Deleted	Deleted	15	1.6	Unknown
Mineral wool board (MWB)	Johns-Manville Corp.	Rock-Cork†	15	2	13½¢/bd ft

* The designations in this column are used in the figures and in some cases in the text.
† No longer manufactured.

types: 1) extruded, homogeneously expanded foam-boards, and 2) expanded polystyrene beads molded into boards. Both types had a closed cell structure and appeared to be equivalent, but laboratory tests revealed a significant difference in moisture absorption characteristics between them.

Other insulation types were:

Three extruded polyurethanes.

Cellular glass. A very rigid closed-cell glass foam available in many preformed shapes. It is considered fire, vermin and vapor proof, moisture repellant, noncorrosive, and does not warp, swell or shrink.

Fiberglas. The types examined were rigid board treated with a protective coating of asphalt for strength and moisture repellancy.

Thermobestos. A molded, rigid high-temperature-resistant insulation of hydrous calcium silicate bonded with asbestos fibers.

Perlite. A rigid, compacted material primarily of flame-expanded perlite with an organic fiber filler. It was claimed to be noncombustible.

Cork board. A coarse, granulated cork bonded with a special asphaltic binder sandwiched between two heavy sheets of asphalt-saturated paper.

Rock-Cork. A compressed mineral wool with binder.

Standard tests for physical characteristics

Since properties other than thermal are also important in the use of insulations, tests were made to determine mechanical properties. These were chiefly standard strength tests and flammability tests. (In remote areas, the Arctic especially, fire is a most serious hazard.) Additional tests such as surface indentation were made to evaluate resistance to abrasion and damage during construction.

Results of the physical tests are summarized in Tables AI and AII (Appendix A). Additional engineering data and physical characteristics of a wide range of foamed insulations have been compiled by the New York Naval Shipyard[1] and by Bender.[2] However, data on moisture absorption and its effect on thermal properties are lacking.

TOTAL MOISTURE ABSORPTION DURING SUBMERSION IN WATER

Exploratory long-term submersion tests on two rigid insulations (Group A)

Cork board. Two specimens, cut to 6 × 6 × 1.6 in., with no edge sealant, were submerged slightly in water. Weight increase was measured periodically during 108 days of soaking. Before each weighing the specimens were allowed to drain for about 10 minutes after removal from the bath and their surfaces were dried by wiping them with paper towels. They were then weighed and returned to the bath.

After 108 days of immersion the specimens were oven-dried. At this time the specimens were beginning to deteriorate; pieces of granulated cork were falling off the edges and the asphaltic paper was loosening up. The increase in water content as a percentage of original volume versus time is given in Table II and Figure 1. These data have been averaged and plotted in Figure 6b for comparison with other materials.

Table II. Water absorption by cork board.

(Specimens 6 × 6 × 1.6 in. submerged in water.)

Specimen	Dry unit wt as received (lb/ft³)	Moisture absorbed (% volume)			
		1 day	15 days	45 days	108 days
C	16.28	4.99	6.26	14.72	13.63
D	14.74	4.79	5.83	10.37	12.11

Table III. Water absorption in two foamed extruded polystyrene boards (Styrofoam).

	Specimen			
	S-33A	S-33B	S-22C	S-22D
Size (in.)	2.06 × 3.91 × 10	2.05 × 3.96 × 10	2.07 × 3.96 × 10	2.07 × 3.94 × 10
Dry wt (lb)	0.094	0.095	0.084	0.083
Dry unit wt (lb/ft³)	2.017	2.016	1.761	1.757
Volume (ft³)	0.04661	0.04698	0.04744	0.04720
31 days				
Water (lb)	0.1198	0.1224	0.0944	0.0917
Volume (%)	4.12	4.18	3.19	3.11
119 days				
Water (lb)	0.1337	0.1320	0.1178	0.1132
Volume (%)	4.60	4.50	3.98	3.84
299 days				
Water (lb)	0.1462	0.1586	0.1200	0.1193
Volume (%)	5.03	5.41	4.05	4.05
610 days*				
Water (lb)	0.14879	0.15659	0.11663	0.11541
Volume (%)	5.12	5.34	3.94	3.92
1107 days†				
Water (lb)	0.1538	0.1584	0.12075	0.12212
Volume (%)	5.29	5.40	4.08	4.15

* Small areas of rust-colored stain and possibly small areas of surface deterioration.

† Large areas of rust-colored stain and areas of deterioration coated with bluish mold.

Styrofoam 22 and 23. This initial exploratory set consisted of two different foamed polystyrene boards, S-22 and S-33. Two specimens of each, approximately 2 × 4 × 10 in., were submerged in tap water at room temperature. The edges were not sealed. Weight readings (following a 10-minute drain and surface wiping) were taken after 31, 119, 300, 610 and 1107 days. The water absorbed, computed as a volume percentage increase based on the original volume of the specimen, is shown in Table III and Figure 2. Photographs of two of the specimens are presented in Figure 3.

Submersion tests on board insulations (Group B)

As a result of the observations made on the cork board and the two extruded foamed polystyrenes a slightly expanded program of moisture absorption tests was carried out on a number of other common board-type thermal insulations:

Cellular glass
Styrofoam HD-1 brand (polystyrene)
Styrofoam HD-2 brand (polystyrene)
Armalite (fused polystyrene beads)
Armalite SE (fused polystyrene beads, self-extinguishing)
BPS 3a (polystyrene bead board)
BPS 3b (polystyrene bead board, self-extinguishing)
Fiberglas AE-6 (fibrous glass sandwich board)
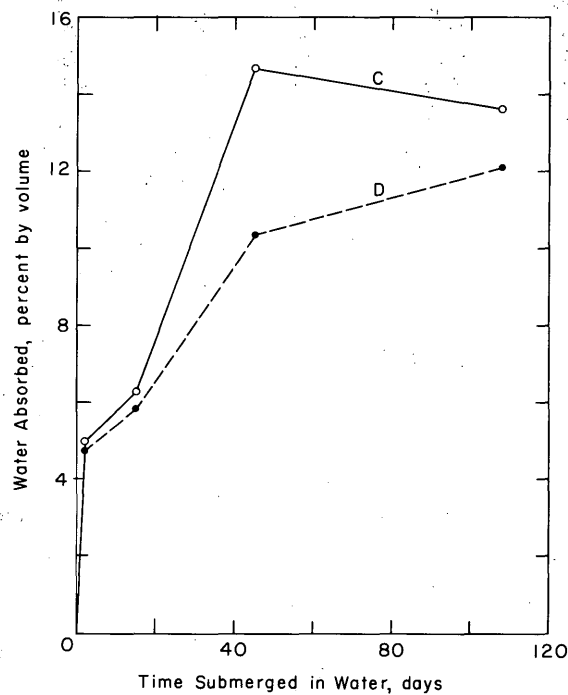
Figure 1. Moisture absorption vs time, cork
board (Group A).
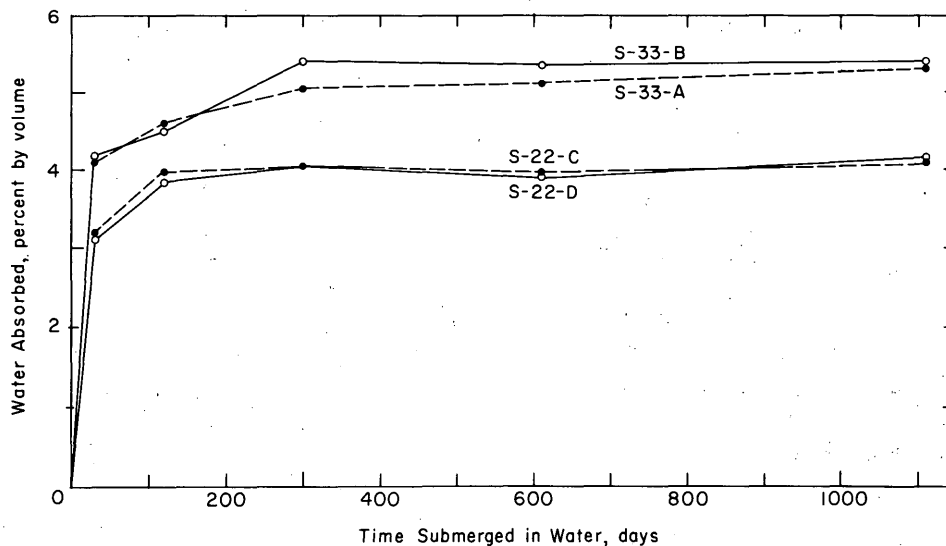
Figure 2. Moisture absorption vs time, Styrofoam 22 and 33 (Group A).
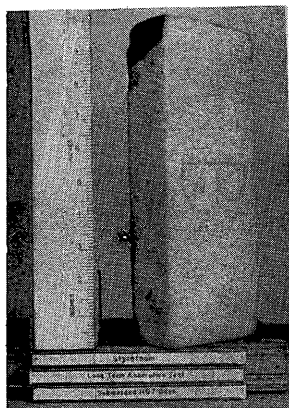
a. Specimen S-33B.
Slight rust stain on sur-
faces. Two highly rust-
ed spots, each about 1 in.^{2}
Narrow ends have a moldy
green stain.
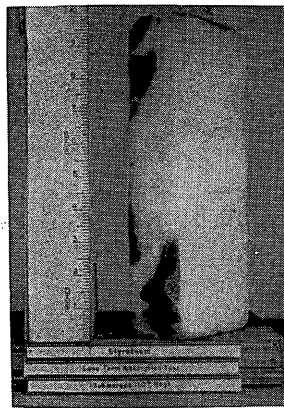
b. Specimen S-22D.
Slight rust stain over most
of surface. Narrow ends
have a moldy green appear-
ance. Four dark rusted
spots, each about 1 to 2
in.^{2}

Figure 3. Polystyrene specimens after 1107 days of submersion (Group A).
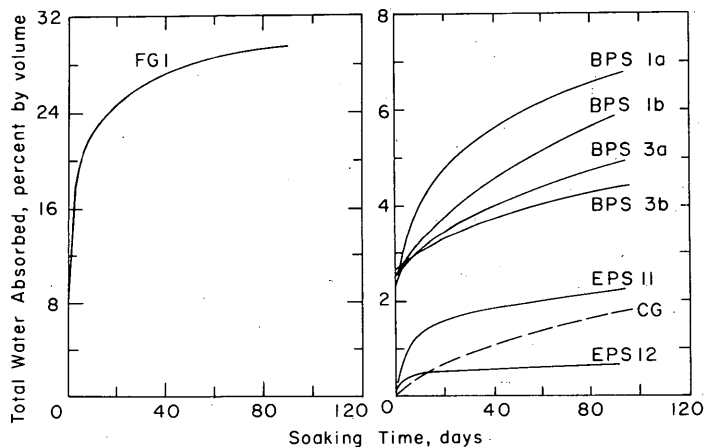
Figure 4. Moisture absorption vs time (Group B).

ASTM procedure C-240 was followed except that the soaking time was extended from 24 hours to 90 days. Other physical characteristics were also measured using ASTM procedures: flexural strength, compressive strength, density, thermal conductivity (dry), flammability and impact resistance. The results of all tests are given in Table AII. Table AIII compares the results with data supplied by the manufacturers. For the most part, the data are comparable but occasionally substantial differences may be noticed, probably because of variations in the materials as a result of the manufacturing process.

The results of the moisture absorption tests of Group B are shown in Figure 4. After an initial period of rapid moisture absorption a continuing, almost linear increase in moisture with time is
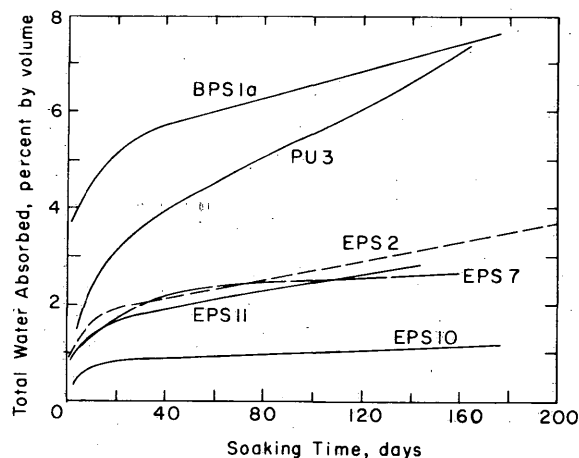
Figure 5. Moisture absorption vs time (Group C).

indicated, approaching some distant asymptotic value. (Dow Chemical Company studies of moisture absorption due to vapor gradients also show a straight line absorption relationship with time.[1])

Long-term moisture absorption tests on rigid insulation boards (Group C)

One undesirable effect of moisture absorption by a thermal insulation is an increase in thermal conductivity. To obtain thermal conductivity data on soaked insulations[12] a small group of rigid insulations (Group C) was selected.

        Styrofoam 22 brand (polystyrene)
        Armalite (fused polystyrene beads)
        Styrofoam HD-1 brand (polystyrene)
        Styrofoam 33 brand (polystyrene)
        Scorbord brand (polystyrene)
        PU 3 (polyurethane)
        Rock-Cork (mineral wool board)

It was planned to use 2 × 12 × 18-in. boards for this soaking series. However, because of the small soaking tank and the scarcity of material the size was reduced to 2 × 6 × 12 in. Because of the smaller specimens it was decided to seal off all the narrow edges and limit absorption to the two faces. A plastic adhesive tape 2 in. wide was used as a seal. On some materials it seemed effective but on others some moisture may have penetrated at the tape edges, thus affecting the results to some degree. After completion of the soaking tests thermal conductivity determinations were made on several of the soaked specimens using the transient step temperature change method.[4]* The guarded hot plate apparatus was used for dry specimens when two sufficiently large specimens were available. Thermal conductivity results are presented elsewhere.[12]

The results of water absorption tests on Group C specimens are plotted in Figure 5. The data for mineral wool board (Rock-Cork) are plotted in Figure 6 to a different scale because of the large amount of moisture absorbed by this material.

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* A theoretical analysis of the effect of specimen dimensions on the test results using the step temperature change method has been made, utilizing the computer.[12]

Table IV. Water absorption during soaking: rigid insulations (Group D).

(Edges of specimens not sealed.)

Material	Type	Approx. size (in.)	Unit dry wt (lb/ft³)	Water absorption – % by volume					
				2 hr	1 day	14	28	90	365
Roofmate brand	Polystyrene	12 × 12 × 2.3	2.49	0.124	0.336	0.508	0.567	0.763	0.902
Styrofoam BB	Polystyrene	12 × 12 × 2	1.92	0.368	1.574	2.796	3.551	4.028	5.50
Scorbord brand	Polystyrene	12 × 12 × 2.1	2.49	0.085	0.359	0.614	0.699	1.041	1.210
Styrofoam CB	Polystyrene	12 × 12 ×2	2.02	0.276	0.574	1.685	2.247	2.586	2.686
Styrofoam FB	Polystyrene	12 × 12 × 2	1.96	0.271	0.683	1.973	2.987	3.427	3.991
Styrofoam FR	Polystyrene	12 × 12 × 2	1.93	0.230	0.651	1.367	1.574	2.159	2.238
Styrofoam SM	Polystyrene	12 × 12 × 1.5	2.32	0.091	0.223	0.327	0.446	0.558	0.697
Thurane FR brand	Polyurethane	12 × 12 ×2	1.91	0.442	0.673	1.323	1.634	2.083	2.80
PU 3	Polyurethane	12 × 12 × 2	2.18	0.514	0.650	1.626	2.307	3.047	4.328
Thermobestos	Calcium silicate	6 × 6 × 2	14.6	85.73	87.77	89.518	89.727	89.811	
Perlite	Perlite plus fibers	6 × 6 × 1	4.0	0.802		8.057		39.933	82.073
Dylite	Polystyrene fused beads	18 × 12 × 2.5	1.62	0.106	0.719	1.868	1.758	2.72	

Additional long-term moisture absorption tests (Group D)

This group was tested primarily to measure the long-term moisture absorption characteristics of a number of new rigid plastic insulations. A large proportion were prefoamed, extruded polystyrene products. Some were replacements for discontinued types such as Styrofoam 22 and 33. All are listed in Table IV.

The specimens were submerged vertically in water with the top edge just below the surface. Since the specimens were larger than those previously used, no attempt was made to seal the edges against moisture penetration. The amount of moisture absorbed was determined by weighing after various time intervals (initial period: 2 hours) for a total period of one year. The results are given in Table IV. The increase in moisture, in percent of volume vs time, is plotted in Figure 6. Other physical characteristics, determined using appropriate ASTM procedures, are given in Table AII and compared with manufacturers' values in Table AIII.

Discussion

The data in Figures 1, 2, 4, 5 and 6 indicate that all the rigid insulators tested absorb moisture with time, to some extent. However, there is a difference in absorptive capacity between materials. Some of the newer closed-cell foamed plastic thermal insulating boards are remarkably resistant to water absorption even when completely submerged.

Figures 1, 2, 4 and 6 show that porous and fibrous materials like corkboard, perlite with organic fibers, mineral wool, calcium silicate, and glass fiber board are more moisture-absorbent than foamed plastics. It is obvious that highly absorbent materials would be inappropriate for use where contact with water might occur.

Figure 6 shows that the closed-cell polystyrenes, especially those with a dense surface skin layer, such as Styrofoam SM, Scorbord and Roofmate have the lowest absorption characteristics. Figures 4 and 5 show that the fused polystyrene bead board absorbed the most water up to 160 days of immersion. This is undoubtedly due to the granular structure of the board and the interconnecting channels between the beads. However, high moisture absorption is not restricted to beaded materials since extruded foamed polystyrenes and polyurethanes may also be moisture-absorbent because of incompletely closed cell structure. This is believed to be the case with PU 1
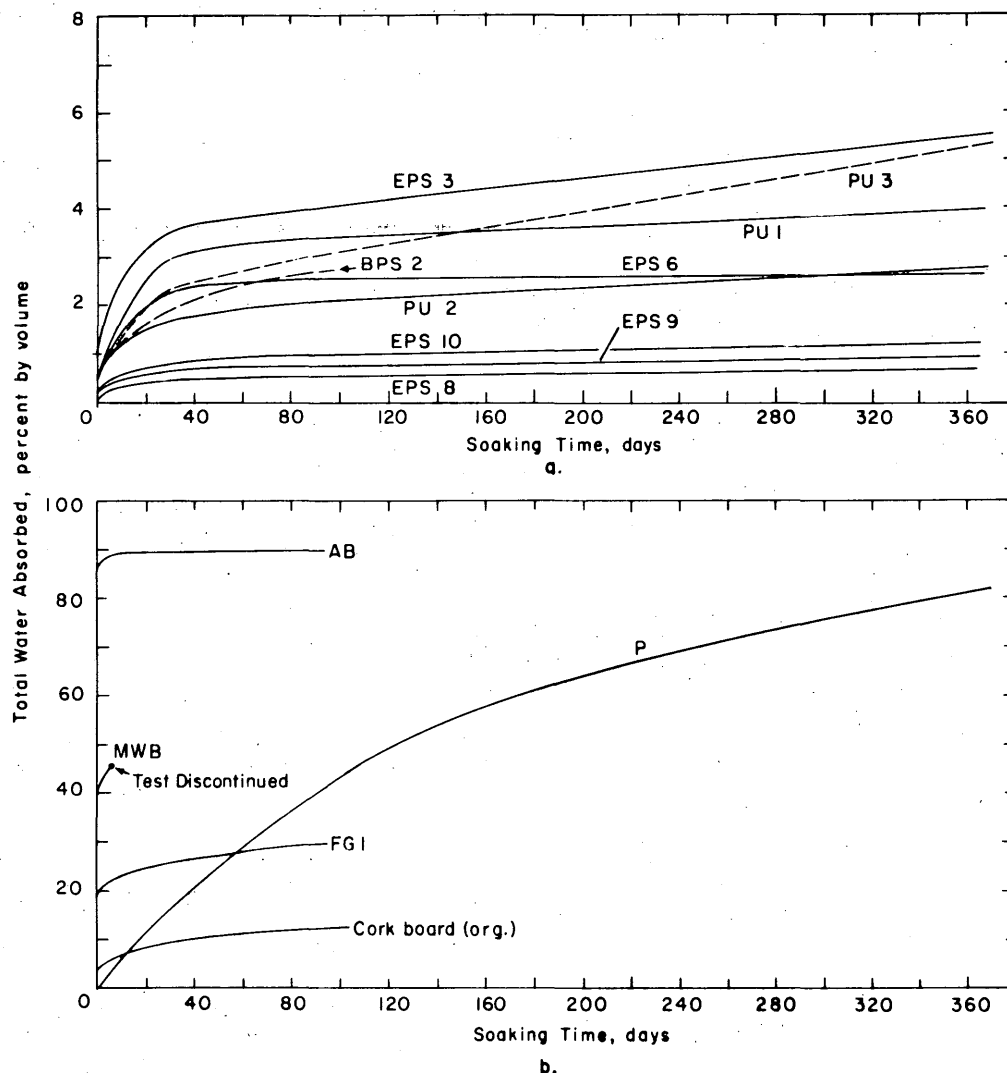
Figure 6. Long-term moisture absorption vs time.

and PU 3 (Fig. 4, 5). The lower density polystyrenes are likely to absorb greater amounts of moisture (see Table IV). The less absorbent materials generally have a unit bulk density greater than 2 lb/ft³ while the more absorbent products have a density less than 2 lb/ft³. PU 3 has a density greater than 2 lb/ft³ but is still relatively highly absorbent. The quality of the cell structure depends greatly upon the controls in the manufacturing process.

It can be readily seen from Figures 4 and 6 that even the most absorbent of the plastic foams show much less absorption than materials containing fibrous or organic components. Even cellular glass (curve CG in Figure 4b) shows a slightly greater tendency/for long-term moisture absorption than the newer polystyrene products represented in Figure 6a.

From these data it appears that many of the extruded foamed polystyrenes and closed-cell cellular glass insulations are highly resistant to moisture absorption even under long-term immersion. There is also some indication that either chemical or bacterial attack may have some effect

on polystyrenes submerged in water for long periods of time. There was evidence of discoloration and deformation of some of the specimens. No specific effort was made to study this aspect.*

INTERNAL MOISTURE ABSORPTION DURING SUBMERSION IN WATER

Shallow submersion

For proper evaluation of insulation, it is necessary to know the extent of moisture penetration and its effect on the heat conductivity of the material. To obtain data on internal absorption, six insulating materials were submerged in water (conditions similar to those of the Group D tests) for a period of 18 months and then sectioned in thin slices parallel to the flat faces for determination of moisture content.

Procedures. The original specimens were 6 × 12 × 2 in. thick. After they were removed from the water, 2 in. was cut from each end and 1 in. from the side edges so that a specimen approximately 4 × 8 × 2 in. remained for sectioning (Fig. 7). Flat parallel slices were cut as indicated for water content determination. The data obtained indicated the extent and amount of moisture entering the material through the flat faces only.

Results. Figure 8 shows that moisture penetrated into the 2-in.-thick specimens. Absorption properties varied between different products. The apparently open structure of the fused polystyrene beads (Armalite) resulted in a greater amount of moisture absorption than in other materials. PU 3 again showed higher absorption values than extruded polystyrene foams. Quantitatively, the internal absorptivity of the various products as plotted in Figure 8 follows closely the order of overall total moisture absorption recorded in the Group C tests (Fig. 5), particularly for the beadboard Armalite and PU 3.

Discussion. The majority of the test specimens had a relatively high moisture content in the outside slices directly in contact with water. This is not surprising since trimming and cutting during the manufacturing process often damages the cellular structure near the surface. Evidence of internal absorption indicates that internal cells may be connected by minute orifices large enough to admit moisture or vapor. A Dow Chemical Company study[3] showed that water vapor may enter the inner cells through thin cell walls under large vapor pressure gradients.

The relative effectiveness of a special surface densification treatment on polystyrene Scorbord appears to have been effective in reducing the absorptivity of the outside slices. This particular product appears to have a denser surface layer (skin) on the flat faces (but not edges) with consequent greater resistance to moisture penetration.

Submersion under pressure

To further explore the effect of very wet locations and hydrostatic pressures on rigid thermal insulations a series

Figure 7. Sketch of specimen sectioning procedure for water contents.

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* Several samples of foamed plastics were sent to the Chemical Laboratory, Frankford Arsenal, Philadelphia, for inclusion in their Panama studies of plastics. The insulations were buried in the ground and periodic observations for bacterial and fungal attack were made. After two years none of the specimens, polyurethanes or polystyrenes, showed any evidence of bacterial or fungal attack although numerous root holes and imbedded roots were found in the specimens after removal from the ground.

Figure 8. Internal moisture distribution after 18-month soak.

of tests were planned to observe moisture absorption after exposure to hydrostatic pressure of approximately 15 psi (equivalent to approximately 34 ft head of water).

Procedures. The 12 materials used for the hydrostatic pressure tests are listed in Table V. Two 5-in.-square representative specimens of each material were cut from larger boards and 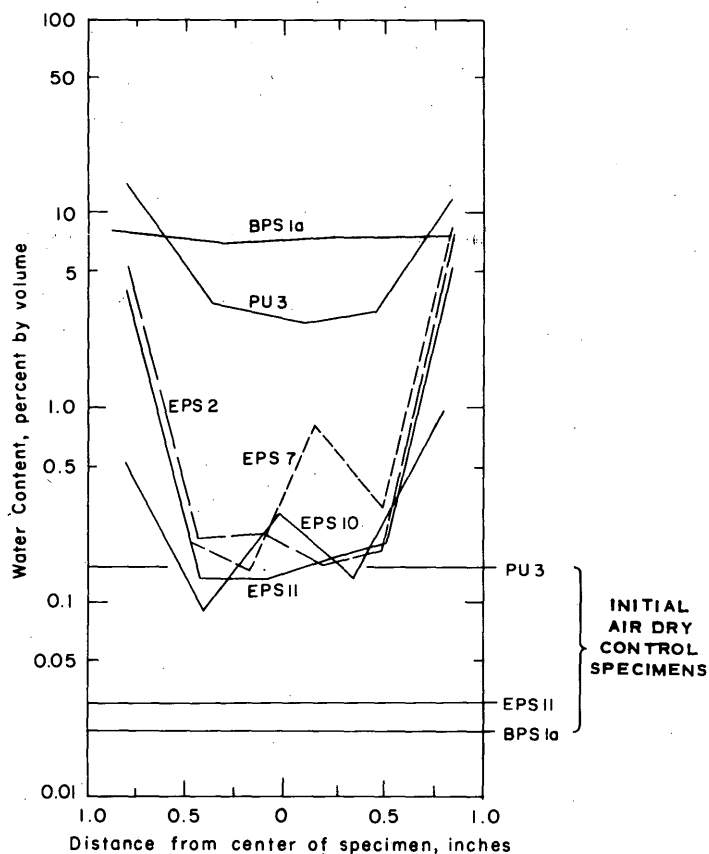ovendried at 60°C before being placed in soaking chambers. Since the samples were newly purchased, one 5 x 5-in. specimen was submerged at nominal zero pressure (1-in. water cover), and the other placed in water in a pressure chamber for testing at approximately 15 psi air pressure on the water. The zero pressure series was to provide a basis for comparison with the 15-psi pressure series.

All specimens of both series (nominal 0 and 15 psi) were subjected to shallow submersion for 7 days except Perlite (P). After 7 days the zero pressure series group was removed and each 5 x 5 x 2-in. specimen was drained for two minutes on absorbent paper and weighed. A 1-in.-thick layer was removed from each edge to eliminate edge effects. The specimens were then cut to approximately ¼-in.-thick parallel slices (Fig. 9), weighed and dried in an oven maintained at 60°C over a period of three days. The moisture distribution in each material is summarized in Figure 10.

The second group of specimens was placed in a pressure-cooker type container. They were kept submerged by a ¼-in. perforated Masonite board held in place by retaining clips fastened to the side of the chamber. The water level was maintained at 2 in. above the specimens. An air pressure of 15 psi was applied and maintained for 7 days. A mercury manometer attached to the container provided an accurate check on the pressure.

Table V. Materials used in pressure soaking test.

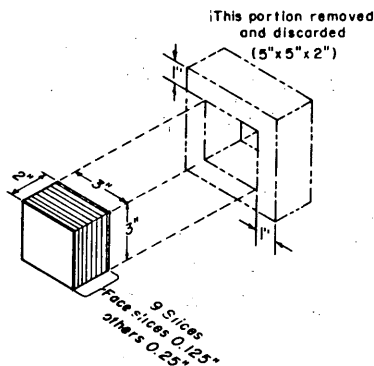| Material	Density (lb/ft³)
Armalite	0.89
Cellular glass	8.66
PU 1	1.64
Perlite	10.70
Roofmate brand	2.48
Scorbord brand	2.51
Styrofoam CB brand	1.94
Styrofoam FR brand	1.90
Styrofoam HD-1 brand	2.91
Styrofoam HD-2 brand	4.42
Thurane FR brand	1.90
PU 3	2.24

Figure 9. Sketch of sectioning procedure for 5 × 5 × 2-inch specimens.

Upon completion of testing, each 5 × 5 × 2-in. specimen was drained for two minutes on absorbent paper and the wet weight was recorded. One inch of material was trimmed off and the specimens were sliced parallel to the flat walls. The moisture content was determined for each slice. The internal distribution of moisture is summarized in Figure 11 for the 12 materials tested.

Results and discussion. The pressure test at 15 psi is roughly equivalent to a 34-ft head of water. The test results revealed high resistance to moisture penetration by most of the foamed plastics. The correlation between long-term and hydrostatic pressure tests appeared good. A number of specimens showed slightly less internal wetting under 15-psi pressure than in shallow submersion for the 7-day period at nominal 0 psi. (The pressure exerted on the material may have caused closure of some of the cells.) The beaded polystyrene Armalite (BPS 1a) and the polyurethane PU 3 continued to show the highest absorption values. Thurane FR exhibited very low absorptivity.

In a number of materials practically no internal penetration of moisture took place during these short-term pressure tests. In several materials the weight loss upon drying was less than that observed in a control specimen not subjected to soaking. The fibrous perlite board (P) showed the highest absorption under pressure, approximately 50% by volume (but considerably less than the 82% absorption in long term soaking tests (Fig. 6). All materials showed high absorption values in the outside slices. The initial weight losses by oven drying of several control specimens not subject to soaking are shown in Figures 10 and 11 for comparison with tested specimens.
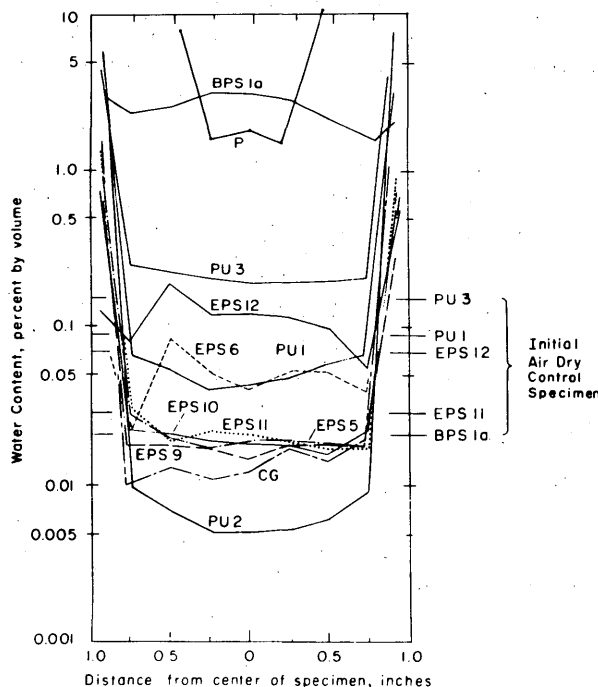

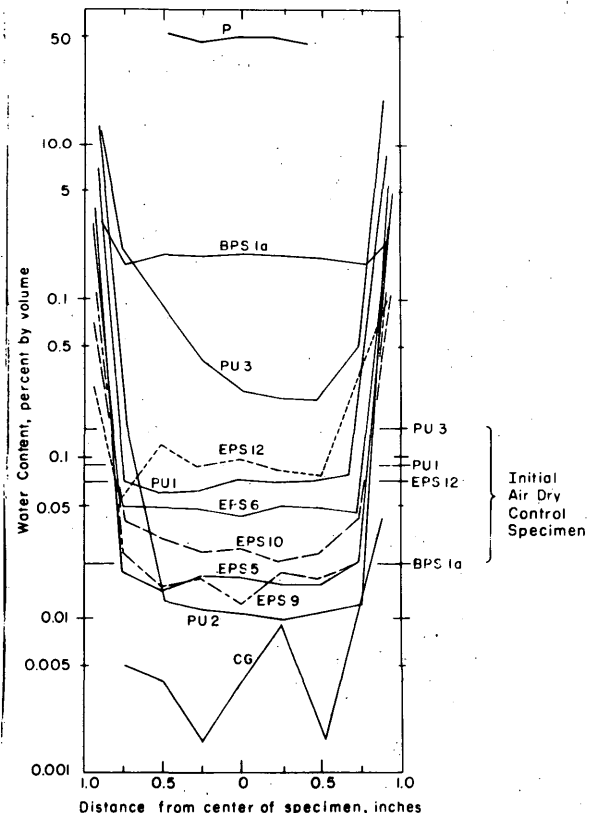Figure 10. Zero head, 7-day soak specimens (except Perlite).

Figure 11. Summary graphs of moisture absorption under 15 psi hydrostatic pressure; 7-day test. (EPS 11 not plotted; results similar to EPS 5 and EPS 9.)

MOISTURE ABSORPTION DURING EMBEDMENT IN MOIST SOIL

Rigid board insulations are frequently used in moist ground as perimeter insulation. More recently they have been used experimentally in highway pavements to retard frost penetration.* Therefore long-term absorption of moisture from the soil and the effect of a number of freeze-thaw cycles on highly wetted insulation board were considered important factors to study.

The moisture absorption characteristics of a number of rigid insulation boards under long-term burial either in a moist glacial till or a wet silt soil are given in this section; freeze-thaw effects are covered in the next section.

Cork board

Two specimens of cork board, E and F, approximately 6 × 6 × 1.6 in., were embedded in a glacial till (East Boston till), compacted to about 90% Proctor density and saturated to 95% or higher. Specimen E was sealed at its ends with asphalt cement of 100-120 penetration grade and given a slight coating of paraffin over the asphalt to keep soil from adhering to the asphalt. Specimen F was not sealed.

Testing of specimen E was discontinued after 40 days when the asphalt seal dripped and peeled off during removal from soil. The results are plotted in Figure 12. Specimen F was removed from the soil and the moisture gain recorded after approximately 20, 40, 80 and 500 days.
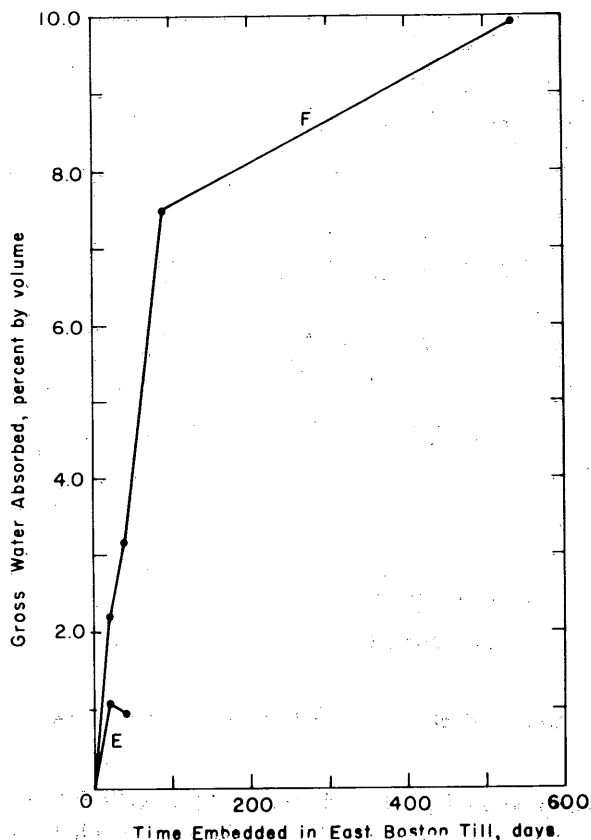
Figure 12. Moisture absorption by cork board in wet glacial till.

Foamed plastics and other cellular materials

A 3-year program was initiated to observe the effect of moisture absorption on insulations embedded in a moist silt. The tests were intended to supplement the data obtained from 90-day soaking and hydrostatic pressure tests. Other possible deleterious effects that might occur, such as bacterial, chemical or physical effects, could also be observed.

The rigid board insulations selected for this test were those which previous tests had shown to be most resistant to moisture absorption (those in Table V, with Styrofoam BB replacing perlite). The soil selected was a local silt available in abundance in the Hanover, New Hampshire, area.

A 44 × 32 × 18-in. metal tank was constructed to contain the moist silt. A 2-in. gravel layer was placed on the bottom with a 1-in.-thick coarse filter layer above it and a 1-in. fine filter layer on top. This was designed so that a continuous supply of water would be available at the bottom of the tank in contact with the silt to maintain a moist condition by capillarity. The tank had a 5-gallon water supply which maintained the

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* Ref. 5, 6, 7, 8, 9, 10, 11.
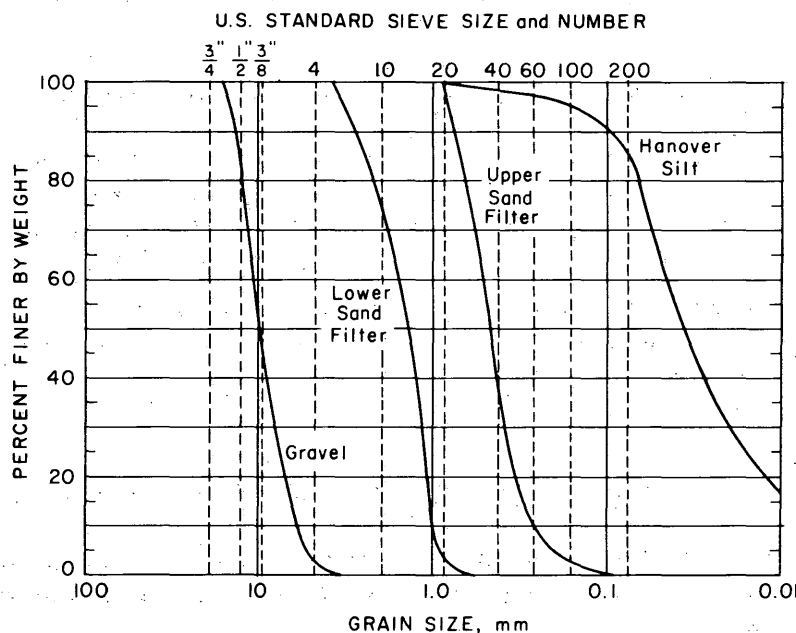
Figure 13. Gradation curves of soil and filters used in soil burial tests.
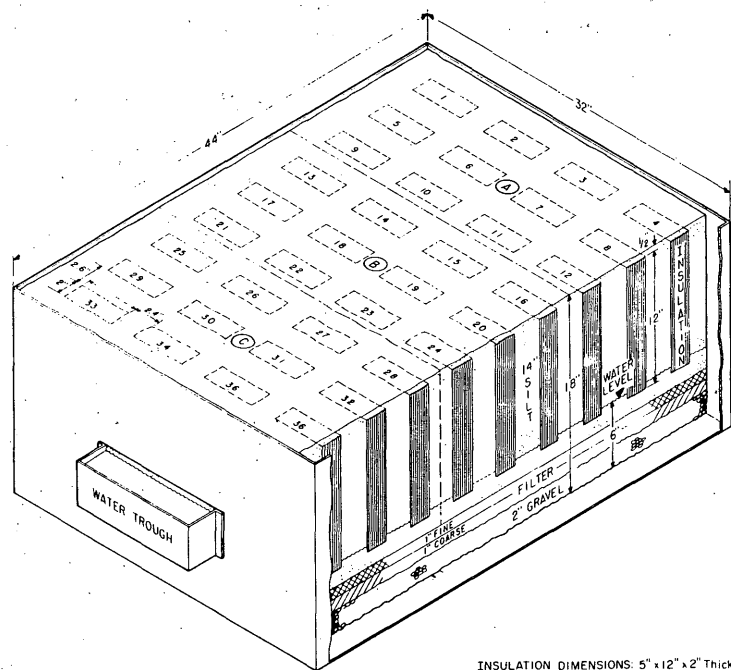
Figure 14. Positions of specimens in soil tank.

water level about 6 in. from the bottom or 2 in. into the silt. Figure 13 shows the gradation curves of the filter soils and the silt.

Samples of each of the insulations were placed in a vertical position in the test box in four rows of nine each, arranged so that one-third of the total number (1 specimen of each type) could be easily removed without disturbing the remainder (Fig. 14). Specimens were wrapped with paper hand towels to prevent soil from adhering to the insulation.

WATER CONTENT, percent dry weight
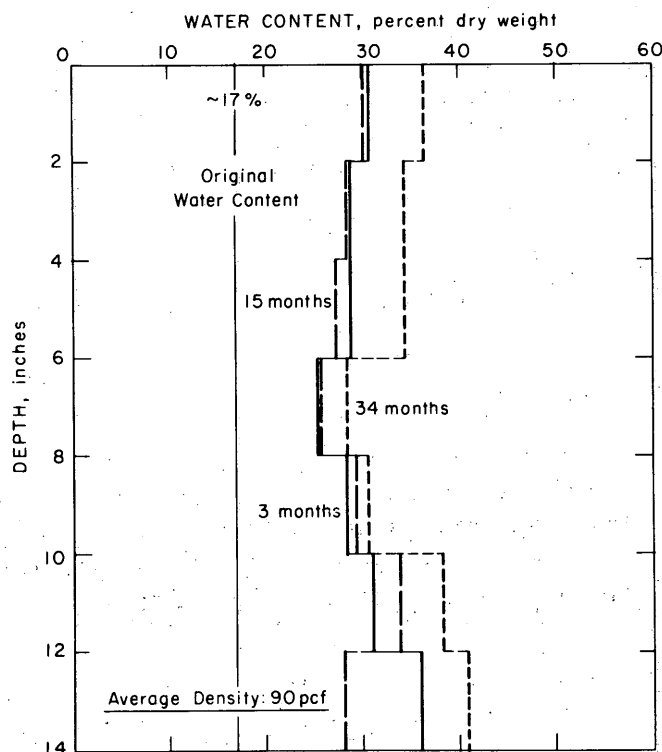
Figure 15. *Water content of soil containing buried insulation.*

The silt was compacted around the insulation at optimum water content to 90% or more of Standard Proctor density. The insulation was covered by at least ½ in. of soil. Water was introduced into the gravel layer in the tank and maintained about 6 in. from the bottom. The silt absorbed moisture by capillarity and thus was kept wet. Density and water content of the silt were sampled initially and each time a group of specimens was removed. The initial water content distribution is shown in Figure 15.

Three 12 × 5 × 2-in. specimens of each of 12 different samples were used in the silt embedment studies, divided into three separate but similar groups of 12 each. The first group of specimens was removed from the silt after 4 months, the second after 15 and the final group after 34 months. From each block a 1-in.-wide section was trimmed off each edge. The remaining 10-in. length was further divided into three equal pieces and labeled top, middle or bottom, according to its position. Each piece was then cut into nine slices, as shown in Figure 9, for water content distribution. The slices were dried in a 160°F (60°C) oven for 24 hours.

Results

The results are given in terms of the ratio of volume of water gained (computed from the weight loss) to the bulk volume of the slice. Since it was not practical to measure the volume of each thin slice the volume was computed from its oven-dry weight using the following relationship:

$$V = \frac{W}{\rho}$$

where: V = volume of slice, cm^3
W = oven dry weight of slice, g
ρ = average bulk unit density of large sample, g/cm^3.

The percentage volume ratio of absorbed moisture in a slice is computed using the following relationship:

$$\text{\% volume moisture} = \frac{w}{\rho_w \, V} \times 100$$

where: w = weight (water) loss
ρ_w = unit weight of water, g/cm^3

The absorption data obtained from the 4-, 15- and 34-month series were plotted on semilog paper with the percent volume moisture gained as ordinate and the position of each slice as abscissa. In general the average moisture content increased with time. In some cases the 4-month absorption was greater than the 15-month. In these cases the percentage volumes were very low, normally less than 0.05; small variations in material structure and/or measuring errors could easily account for the difference.

A summary of the *maximum* amount of moisture absorbed by each type of material (based on examination of three separate vertical segments of each specimen) during the 34-month period is presented in Figure 16. Results on cork board buried in glacial till were presented in Figure 12.
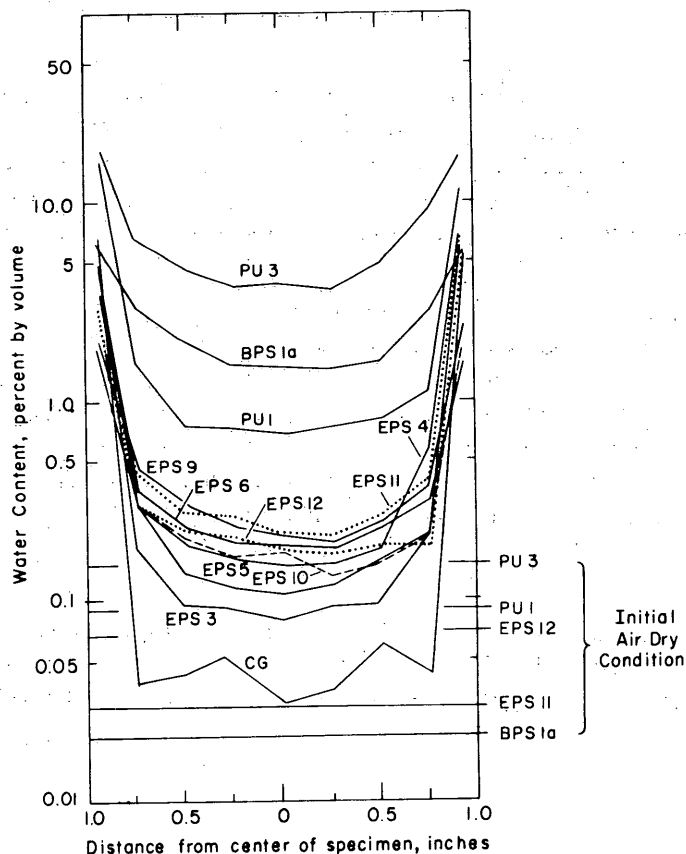

Figure 16. Summary of results of 34-month burial of
insulations.

**Table VI. Comparison of moisture absorption from
34 months soil embedment and 18 months water.**

		Moisture absorption % by volume			
		34 mos. soil embedment		*18 mos. in water*	
		(1)	*(2)*	*(1)*	*(2)*
	Air dry density (lb/ft³)	*Mid-section excluding outer slices*	*Total specimen including outer slices*	*Mid-section*	*Total*
Cellular glass	.8.66	0.07	(1.33)		
Styrofoam BB	1.90	0.09	(0.97)		
Styrofoam FR	1.86	0.15	(0.44)		
Scorbord	2.54	0.16	(0.57)	0.18	(0.42)
Styrofoam FB	1.89	0.19	(1.31)		
Styrofoam HD-2	4.42	0.20	(0.58)		
Styrofoam CB	2.03	0.22	(0.76)		
Styrofoam HD-1	2.91	0.25	(1.5)	0.16	(1.8)
Roofmate	2.46	0.27	(0.66)		
PU 1	1.64	0.79	(3.2)		
Armalite (fused beads)	0.89	1.6	(1.7)	7.8	(7.8)
PU 3	2.24	4.7	(7.0)	3.2	(7.3)

The gross moisture gain by cork board in a wet soil was nearly as large as that gained by cork board specimens C and D (Fig. 1) which were immersed in water.

Discussion

The embedment of any high porosity material in a moist soil for almost three years to observe moisture absorption is considered a severe test condition. However, since the use of foamed plastic insulations in below-ground applications is increasing, evaluation of moisture absorption of these materials exposed to wet soil conditions is important.

A summary tabulation listing the approximate average percentage of moisture, by volume, in the central portion of the specimen after 34 months of burial is presented in Table VI. Total moisture absorption including the outer slices is also tabulated for comparison.

A comparison of the dry unit weights of the insulations and their absorption characteristics indicates that foamed polystyrene insulations with densities below 1.9-2 lb/ft³ absorb more water than those above 2 lb/ft³ (see Fig. 17). Relatively highly absorbent materials like polystyrene beadboard (Armalite) and PU 1 have densities below 2 lb/ft³, while the least absorbent types, i.e. HD-2, Roofmate, FR and FB, have densities of about 2.5 lb/ft³ or higher.

A review of the data from three of the most absorptive insulations in these tests (Fig. 4b, 5 and 16) shows that 34 months of soil embedment resulted in more moisture absorption by the urethane foam than 18 months of submersion in water (Table VI). However, the beadboard absorbed considerably less water under the same conditions. A possible explanation for this may be that the porous structure between the beads is sufficiently large that only small negative (suction) pressures are developed by the air-water menisci formed in the beadboard because of moisture
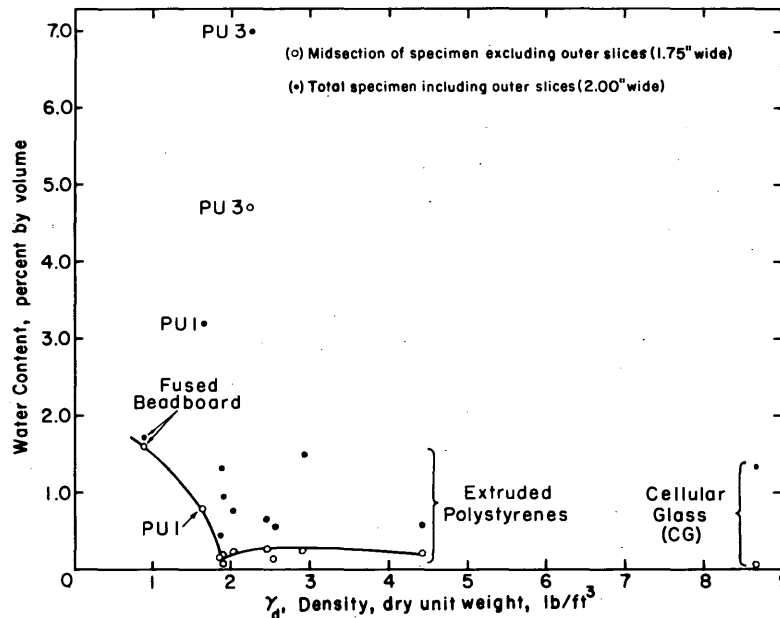
*Figure 17. Summary of water absorption due to 34 months embed-
ment in moist silt.*

Table VII. General observations of specimens after 34-month burial.

Styrofoam FR	Not original dimensions, stained, structure appeared quite good.
Roofmate	Blackish stain lower areas, not original dimensions, structure good, little rust stain.
Armalite	Stained, slightly deformed probably due to emplacement, not very structurally sound, not original dimensions.
Cellular glass	Some rust stain, seemed very weak structurally while being cut compared to original material.
Styrofoam BB	Some stain (rust) in different areas, blackish in lower sections, not original dimensions.
PU 3	Some lower stain, some pinholes in sample, structurally sound, not original dimensions, not cut rectangular originally.
Styrofoam CB	Some stain in all areas, not original dimensions.
Styrofoam HD-2	Appears to be little moisture, very strong structurally, little stain, dimensions different.
Styrofoam HD-1	Some stain (rust and blackish) lower areas, dimensions different, structurally sound.
Styrofoam FB	Some stain (rust type), structurally good, not dimensionally sound.
Scorbord	Some rust stain, blackish lower ½ of sample, internal structure very strong, little moisture, dimensions different.
PU 1	Some rust stain, very wet on surface, some deformation may be due to emplacement and compaction of soil, dimensionally different.

absorption. This would be similar to a layer of very coarse sand buried in a silt material. The coarse sand would lose moisture to the fine-grained silt soil until suction equilibrium pressure was established between the two. The urethane foam in these studies consisted of very fine cells which undoubtedly exerted a greater suction, when wetted, than the soil and therefore attracted water from the soil.

For most of the other thermal insulations in the test series (excluding those discussed above) the amount of absorption resulting from long-term soil embedment was low, on the order of 0.3% by volume or less (in the central part of the specimen, excluding the two outside slices). In nearly all of the materials the two outside slices showed an increase in moisture. This is not surprising since the structure of these sections is disturbed as a result of cutting and slicing operations during manufacture and processing.

In summing up, the studies do indicate that the extruded foamed plastics, in general, are resistant to moisture absorption, especially compared with older fibrous products, organic or inorganic.

Some observations on the appearance of individual materials made at the time of removal from the soil after 34 months of embedment are presented in Table VII.

FREEZE-THAW EFFECTS ON THERMAL INSULATING BOARDS

The use of thermal insulating boards in highway pavements exposes them to a wet environment and numerous freeze-thaw cycles during any given winter. To explore freeze-thaw effects a small program of tests was designed at USA CRREL.

Procedures

The twelve insulation types used in the 7-day soaking and pressure head tests were used in this series. Two additional samples were included: a polystyrene identified as Styrofoam SM,* obtained in two nominal thicknesses, 2 in. and 1½ in.

Two 5-in.-square specimens of each material were used in this exploratory study. One was subjected to 15 freeze-thaw cycles and the other to 30 cycles while just barely covered with water. The freezing was from the surface downward, simulating nature.

The specimens were oven-dried and submerged in water for 7 days prior to the freeze-thaw experiments. After the 7-day soak the 28 specimens (14 different types) were removed and submerged flat in shallow metal trays, nine to a tray (one polystyrene specimen, Styrofoam FR, was eliminated from the 15 freeze-thaw series because of space limitations). The trays generally took 1½ hours to freeze and about 3 hours to thaw.

Results

At the completion of each series the specimens were trimmed and sliced (Fig. 9), and the gain in water content determined. The internal moisture distributions for all materials after 30 freeze-thaw cycles are shown in Figure 18. The data have been plotted in Appendix B for comparison with the zero pressure, 7-day soaking and the 15-psi pressure immersion tests. In all cases the specimens subjected to 30 freeze-thaw cycles absorbed more moisture than those subjected to 15 cycles. The cellular glass disintegrated before it could be properly sectioned and weighed after 30 freeze-thaw cycles, illustrating the severe effects that may be imposed on materials exposed to high moisture and cyclic freezing.

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* This type was used in the pavement insulation tests in the field at the Dow Chemical Co. plant in Midland, Michigan.[6]
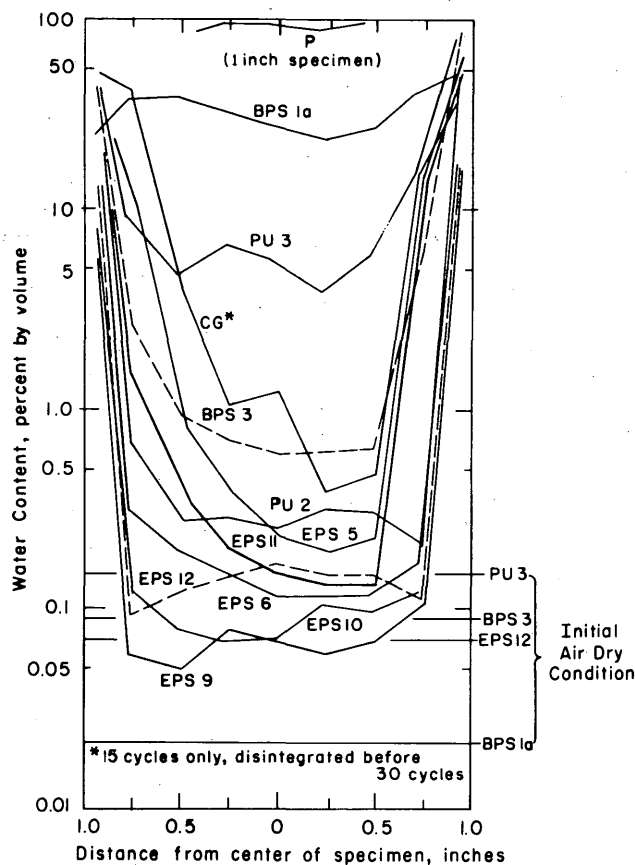
Figure 18. Summary of freeze-thaw test results.
After 30 cycles.

Examination of Appendix B shows freeze-thaw effects to be the most severe of all the tests made. The perlite-fiber material showed the largest water gain, 90% by volume in the freeze-thaw test as against 50% in the submerged pressure test.

Discussion

The freeze-thaw test appeared to be most severe and had destructive results in highly absorbent specimens. The internal water content increased in practically all the specimens after 15 freeze-thaw cycles and increased more after 30 cycles. One notable exception was high density polystyrene Styrofoam HD-2 where 30 cycles began to indicate some adverse reaction. Roofmate also showed good resistance through 15 cycles but revealed signs of adverse reaction at 30 cycles.

The conclusion is reached that under very wet conditions freeze-thaw cycles are likely to cause deterioration of cellular insulation and loss of insulating qualities due to moisture absorption, especially if the voids become saturated to 90% or more before freezing. Where winters are severe, pavement sections may not be subjected to many freeze-thaw cycles per winter. But in more temperate zones there may be several freeze-thaw cycles during a winter and if extreme wetness is present cellular breakdown may occur. Since insulations in the base course or on the subgrade may prevent vertical drainage, water may collect on the insulation. Even if some of this moisture drains downward through the joints, this portion of the insulation is exposed to severely wet conditions and possible deterioration by repetitive freezing. A cellular glass product was severely damaged in a test sequence of this study. From field experience in Greenland spalling

has been observed in cellular glass insulation blocks during freezing when high vapor gradients were present within the joints.

GENERAL CONCLUSIONS

The following conclusions are made from the studies and observations reported:

1. None of the materials was completely resistant to moisture absorption.

2. Many foamed plastics are relatively highly resistant to excessive water absorption, although some are considerably more absorptive than others.

3. Fused polystyrene beadboards absorbed more moisture than expanded, extruded polystyrene boards.

4. The three extruded polyurethanes were generally more absorbent than the polystyrenes.

5. Special surface layer densifications of some of the extruded polystyrene boards appeared to be effective in reducing moisture absorption.

6. Submersion under hydrostatic pressure of approximately 1 atm (15 psi gage) appeared to be less severe than shallow submersion for many of the rigid plastic foams in short-term (7-day) tests.

7. Alternate freezing and thawing of rigid insulations in the presence of free water is more damaging to insulations than submersion and increases water absorption. Although cellular glass has very low moisture absorption in ordinary moisture tests, it deteriorates more rapidly in wet freeze-thaw tests than other insulations.

8. Laboratory absorption and freeze-thaw tests provide a suitable means of distinguishing the least absorbent insulations.

RECOMMENDATIONS

Based on these studies the following recommendations are made:

1. Selection of rigid foamed insulations to be used under wet conditions should be based on the results of long-term moisture absorption tests; a minimum of 30 days (as opposed to the 24-hr ASTM test) is suggested.

2. Selection of rigid insulations for applications under wet conditions with anticipated periodic freezing and thawing temperatures should be based on results of tests with 30 or more freeze-thaw cycles applied.

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Table AI. Summary of physical tests on insulation samples.

Test and applicable test procedures		Cellular glass	No. 22	Styrofoam (expanded polystyrene) No. 33³	HD-1	HD-2	Armalite (expanded polystyrene) Plain	SE³	Fiberglas AE-6	AE-F* (Flooring type)	BPS 3 a. Reg.	b. SE³
Color		Black	White	Blue	White	White	White	White	Black	Black	White	White
Flexural strength (psi) (ASTM C-240, C-203)		110.5	52.9	52.7	168.6	206.0	21.7	17.0	31.4	108.8 (⊥)⁴ 13.7 (∥)⁴	23.5	23.8
Compressive strength (avg. psi at 5% deflection) (ASTM C-240, C-165)		73.1	19.4	22.3	Insufficient material	Insufficient material	7.5	4.8	2.4	11.4	6.8	8.3
Density (pcf) (ASTM C-303)		9.24	1.71	2.09	3.13	3.59	1.01	0.95	9.54	11.29	1.22	1.24
Absorption- percent by vol. (ASTM C-240)	2 hrs	0.075	0.351	0.553	0.065	0.046	1.714	2.114	11.144	–	2.245	1.657
	24 hrs	0.136	1.234	1.227	0.497	0.256	2.399	2.644	19.534	–	2.645	2.712
	14 days	0.520	1.671	2.816	1.496	0.511	4.440	3.449	23.911	–	3.213	3.155
	90 days	1.784	2.653	5.029	2.207	0.652	6.739	5.860	29.736	–	4.913	4.360
	14 days (sat. soil)	0.111	0.310	0.021	–	–	0.196	0.107	–	–	0.008	0.016
Impact¹ (Fed. spec. SS-T-306b)	Indentation, in. (0.143 lb wt. and 4½ in. drop)	0.094	0.093	0.073	0.066	0.038	0.066	0.090	Did not penetrate asphalt coating	Did not penetrate asphalt coating	0.066	0.068
	Indentation, in. (0.350 lb wt. and 6 in. drop)	0.117	0.108	0.080	0.076	0.043	0.073	0.094	Did not penetrate asphalt coating	Did not penetrate asphalt coating	0.075	0.072
Flammability (ASTM D-635-44)		Non-burning	Burning 7.10 in./min	SE³ 1.24 in. of burn	Burning 4.10 in./min	Burning 4.03 in./min	Burning 8.19 in./min	SE³ 0.40 in. of burn	Non-burning	Non-burning	Burning 9.20 in./min	SE³ 0.37 in. of burn

* Manufacture of AE-F Fiberglas board has now been discontinued.

¹ Applicable to asphalt floor tile.

² McBurney indentation test (Fed. Spec. SS-T-306b) as applicable to asphalt floor tile was performed on all above specimens without success. None of the materials were sufficiently strong to withstand the 30 lb point loading.

³ Self extinguishing type.

⁴ Perpendicular (⊥) and parallel (∥) to laminations.

Table AI (cont'd). Summary of physical tests on insulation samples.

	Roofmate	Styrofoam BB	Scorbord	Expanded polystyrene Styrofoam CB	Styrofoam FB	Styrofoam FR	Styrofoam SM	Urethane Thurane FR	PU 3	Thermo-bestos	Perlite	Dylite
Color	Blue	White	Blue	Blue	Blue	Light blue	Light blue	Ivory	Yellow white	Gray	Brown	White
Flexural strength (psi) (ASTM C-240, C-203)	88.5	45.3	106.0	51.8	61.9	91.3	78.7	46.5	34.9	109.8	32.6	46.6
Compressive strength (avg. psi at 5% deflection) (ASTM C-240, C-165)	21.5	35.8	29.9	41.6	33.3	41.4	46.1	32.3	31.3	225.2	21.0	10.73
Density (pcf) (ASTM C-303)	2.46	1.90	2.54	2.03	1.89	1.86	2.35	1.90	2.24	14.83	10.7	1.62
Absorption - percent by vol. (ASTM-C-240) 2 hrs	0.124	0.368	0.085	0.276	0.271	0.230	0.091	0.442	0.514	85.729	0.802	0.106
24 hrs	0.336	1.574	0.359	0.574	0.683	0.651	0.223	0.673	0.650	87.773		
14 days	0.508	2.796	0.614	1.685	1.973	1.367	0.327	1.323	1.626	89.518	8.057	0.719
28 days	0.567	3.551	0.699	2.247	2.987	1.574	0.446	1.634	2.307	89.727		1.868
90 days	0.763	4.028	1.041	2.586	3.427	2.159	0.558	2.083	3.047	89.811	39.933	
Impact (Fed. spec. SS-T-306b) Indentation, in. (0.143 lb wt and 4½ in. drop)	0.021	0.070	0.023	0.062	0.085	0.045	0.021	0.019	0.052	0.018	0.037	0.037
Indentation, in. (0.350 lb wt and 6 in. drop)	0.032	0.104	0.034	0.093	0.123	0.081	0.038	0.029	0.083	0.025	0.044	0.052
Flammability (ASTM D-1692-59)	SE 1 in. of burn	Burning 2.85 in./min	SE 1.13 in. of burn	SE 1 in. of burn	SE 1.03 in. of burn	SE 1.05 in. of burn	SE 1.25 in. of burn	Burning 8.18 in./min	SE 1.75 in. of burn	Non-burning	Non-burning	Burning 5.11 in./min

Table AII. Summary comparison of manufacturers data with test results.

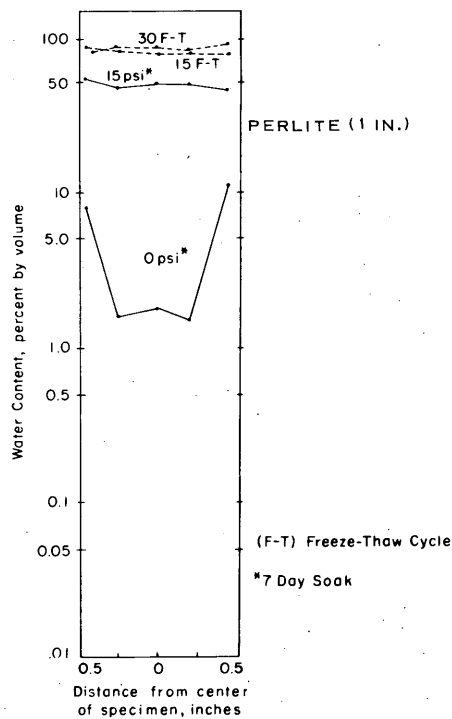|	Flexural strength (psi)	Compressive strength (psi)	Density (pcf)	Absorption (% by volume)	Thermal conductivity, K (Btu/hr/ft²/°F/in.)	Flammability
Cellular glass						
Mfgr. data	75.0	100.0	9.0	0.2 (24 hrs)	0.38 @ mean = 50°F	Non-burning
NED lab test data	110.5	73.1	9.24	0.14 (24 hrs)	0.375 @ mean = 50°F	Non-burning
Styrofoam 22						
Mfgr. data	42-61	16-32	1.6-2.0	<0.15 lb/ft²†	.23-.27 @ mean=40°F	Burning (7-8 in./min)
NED lab test data	52.9	19.4	1.71	0.07 lb/ft²	0.246 @ mean = 40°F	Burning (7.10 in./min)
Styrofoam 33*						
Mfgr. data	48-99	16-38	1.7-2.3	<0.15 lb/ft²†	.23-.27 @ mean=40°F	SE* (Reduced burn.)
NED lab test data	52.7	22.3	2.09	0.12 lb/ft²	0.229 @ mean = 40°F	SE* (1.24 in. of burn)
Styrofoam HD-1						
Mfgr. data	70-90	50-80	2.8-3.2	Nil	Less than 0.25 @ mean = 40°F	Burning (6 in./min)
NED lab test data	168.6	Insuff. mat'l	3.13	1.50 (14 days)	Insuff. mat'l	Burning (4.1 in./min)
Styrofoam HD-2						
Mfgr. data	150-170	120-140	4.3-4.7	Nil	Less than 0.25 @ mean = 40°F	Burning (2.5 in./min)
NED lab test data	206.0	Insuff. mat'l	3.59	0.51 (14 days)	Insuff. mat'l	Burning (4.03 in./min)
Armalite (plain)						
Mfgr. data	26.0	–	1.25	4.0 (Ult. by vol)	0.24 @ mean=60°F	Combustible
NED lab test data	21.7	7.5	1.01	4.44 (14 days)	.170 @ mean = 60°F	Burning (8.19 in./min)
Armalite (SE*)						
Mfgr. data	–	–	1.25	4.0 (Ult. by vol)	0.24 @ mean=60°F	SE*
NED lab test data	17.0	4.5	0.95	3.45 (14 days)	.233 @ mean=60°F	SE* (0.4 in. of burn)
BPS 3 (plain)						
Mfgr. data	21.0	10.5	0.9-1.2	<2.0	0.25 @ mean=40°F	Combustible
NED lab test data	23.5	6.8	1.22	3.21 (14 days)	0.123 @ mean=45°F	Burning (9.2 in./min)
BPS 3 (SE*)						
Mfgr. data	–	–	–	<2.0	0.25 @ mean=40°F	SE*
NED lab test data	23.8	8.3	1.24	3.16 (14 days)	0.20 @ mean=45°F	SE* (0.37 in. of burn)

* Self extinguishing type.
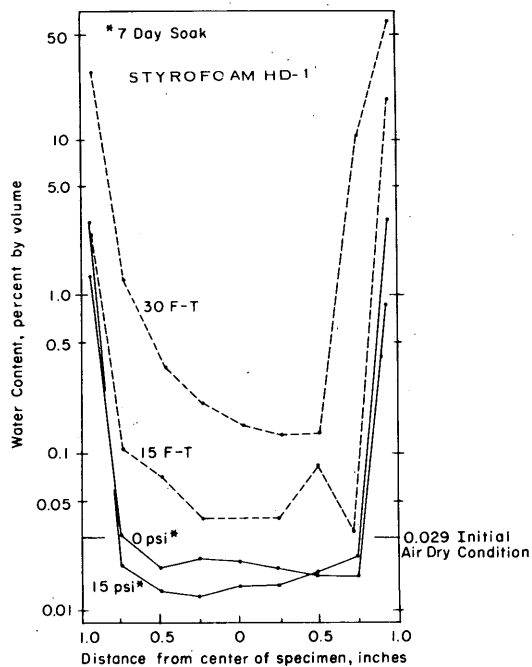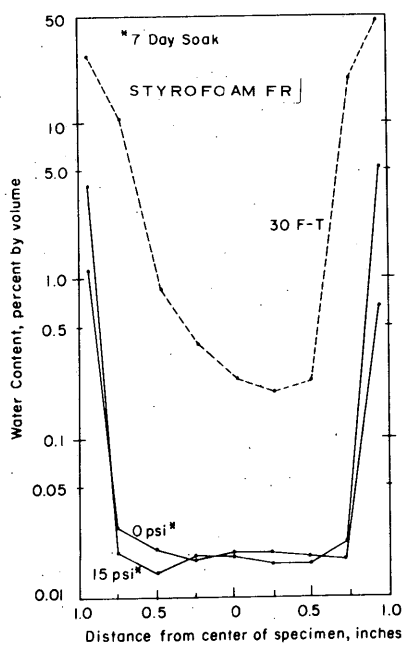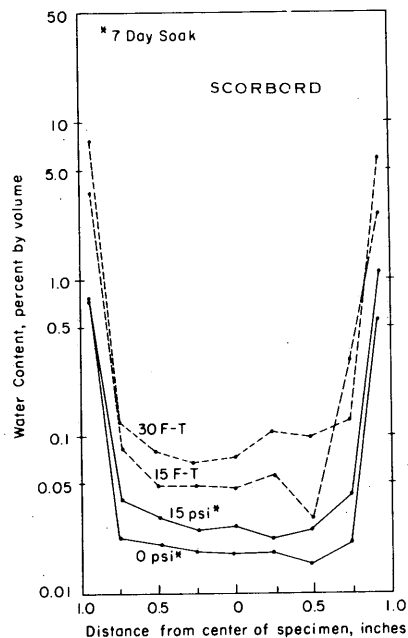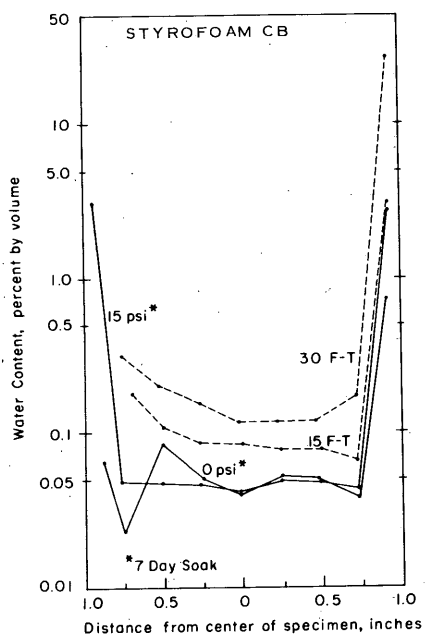† <0.15 lb/ft² of surface area (7 days).

APPENDIX A

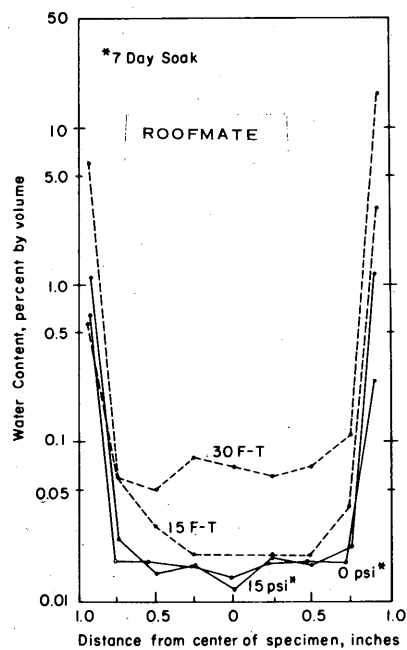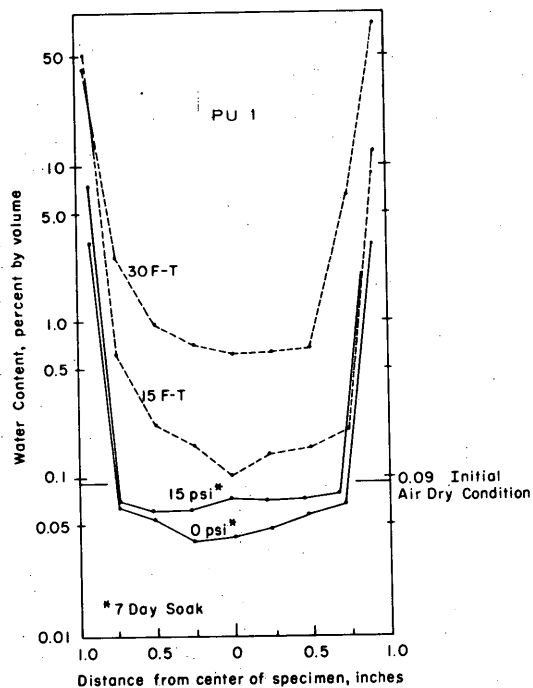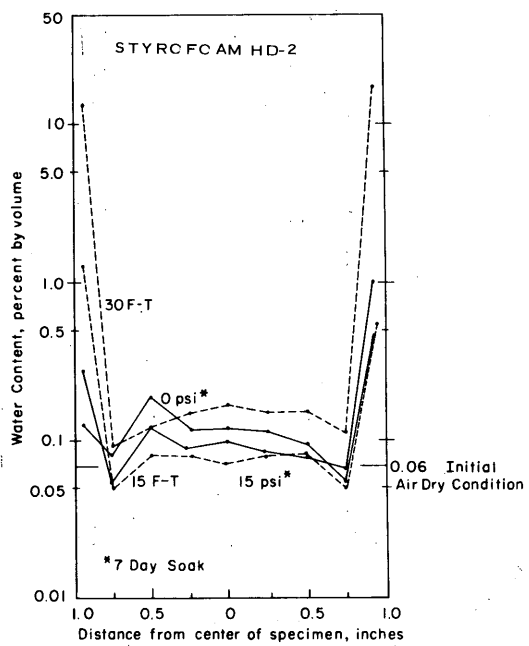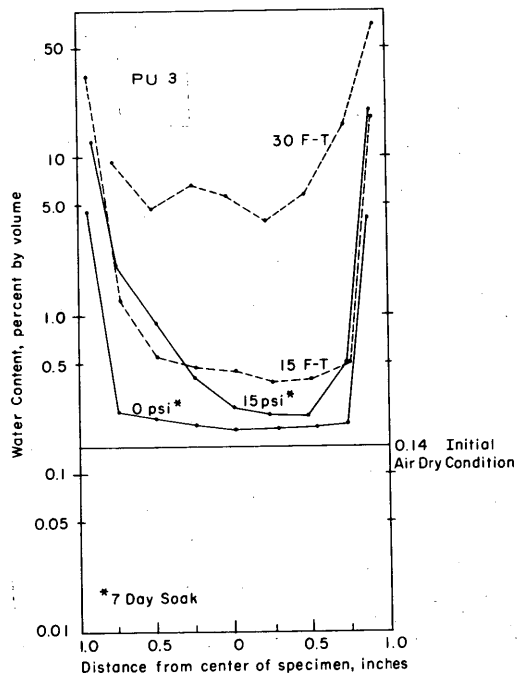Table AII (cont'd). Summary comparison of manufacturers data with test results.

	Flexural strength (psi)	Compressive strength (psi)	Density (pcf)	Absorption (% by volume)	Thermal conductivity, K (Btu/hr/ft²/°F/in.)	Flammability
Roofmate						
Mfgr. data	–	25.0	3.0	0.25 (24 hrs)	0.23 @ 75°F	SE*
CRREL data	88.5	21.5	2.5	0.34 (24 hrs)	–	SE*
Styrofoam BB						
Mfgr. data	44.0	18.0	1.8	0.5	0.35 @ 75°F	Burning
CRREL data	45.3	36.0	1.9	1.6 (24 hrs)	–	2.85 in. of burn
Scorbord						
Mgfr. data	–	30.0	2.5	0.25	0.23	SE*
CRREL data	106.0	30.0	2.5	0.36 (24 hrs)	–	SE*
Styrofoam CB						
Mgfr. data	70.0	30.0	1.9	0.12	0.30 @ 70°F	SE*
CRREL data	52.0	42.0	2.0	0.57 (24 hrs)		SE*
Styrofoam FB						
Mfgr. data	44.0	25.0	1.8	0.5	0.30 @ 75°F	SE*
CRREL data	62.0	33.3	1.89	0.68		SE*
Styrofoam FR						
Mfgr. data	70.0	30.0	1.9	0.25	0.26 @ 75°F	SE*
CRREL data	56.3	41.4	1.86	0.65 (24 hrs)	–	SE*
Styrofoam SM						
Mfgr. data	–	30.0	2.5	0.25	0.23 @ 75°F	SE*
CRREL data	78.7	46.0	2.35	0.22 (24 hrs)	–	SE*
Thurane FR						
Mfgr. data	–	26.0	2.0	0.75	0.15 @ 40°F	SE*
CRREL data	46.5	32.3	1.9	0.67 (24 hrs)	–	8.18 in. of burn
PU 3						
Mfgr. data	50.0	37.0	2.3	2.0 (5 days)	0.14 @ 70°F	Non-burning
CRREL data	34.9	31.3	2 24	1.63 (14 days)	–	Non-burning
Thermobestos						
Mfgr. data	95.0	165.0	11.0	None given	0.33 @ 100°F	Non-burning
CRREL data	109.8	225.0	14.8	87.8 (24 hrs)	–	Non-burning
Perlite						
Mfgr. data	–	–	10 20	1.5 (2 hrs)	–	Non-burning
CRREL data	32.6	21.0	10.70	0.80 (2 hrs)		Non-burning
Dylite						
Mfgr. data	60.0	24.0	1.6	–	0.25 @ 75°F	–
CRREL data	46.6	10.7	1.6	0.72 (24 hrs)	–	5.11 in. of burn

* Self extinguishing type.

PERLITE (1 IN.)

(F-T) Freeze-Thaw Cycle

*7 Day Soak

THURANE FR

*7 Day Soak

ARMALITE

*7 Day Soak

0.02   Initial
Air Dry Condition

CELLULAR GLASS

*7 Day Soak
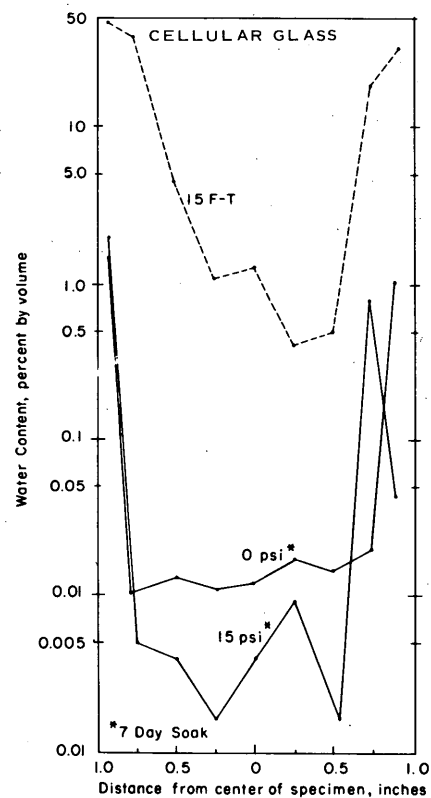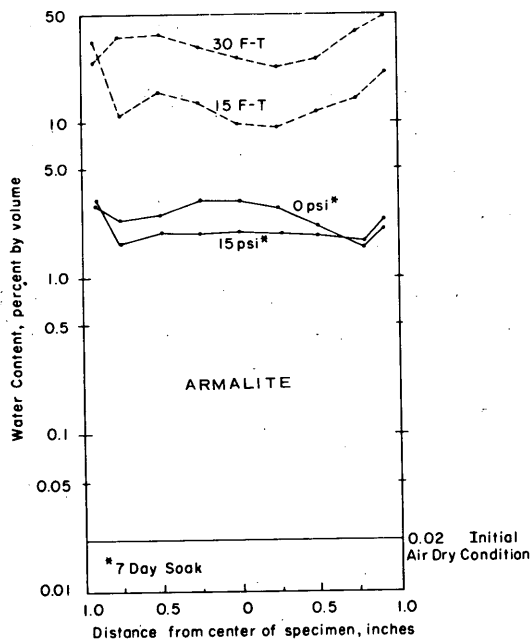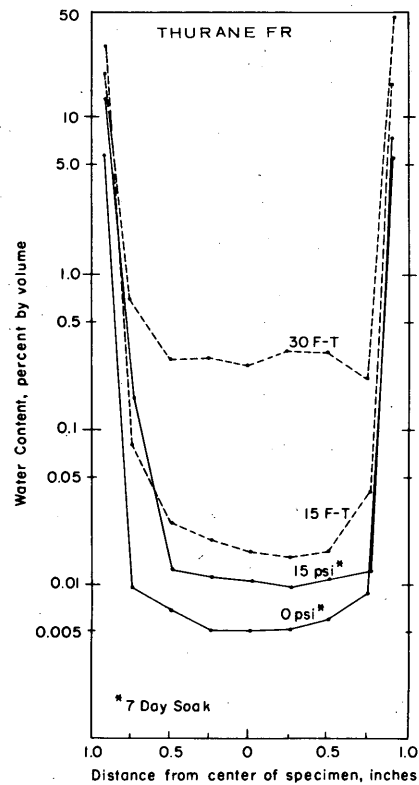
NCTE: CELLULAR GLASS DISINTEGRATED
BETWEEN 15-30 FREEZE-THAW CYCLES.

PU 3

30 F-T

15 F-T

0 psi*

15 psi*

0.14 Initial Air Dry Condition

*7 Day Soak

Water Content, percent by volume

Distance from center of specimen, inches

STYROFOAM HD-2

30 F-T

0 psi*

15 F-T

15 psi*

0.06 Initial Air Dry Condition

*7 Day Soak

Water Content, percent by volume

Distance from center of specimen, inches

PU 1

30 F-T

15 F-T

15 psi*

0 psi*

0.09 Initial Air Dry Condition

*7 Day Soak

Water Content, percent by volume

Distance from center of specimen, inches

*7 Day Soak

ROOFMATE

30 F-T

15 F-T

15 psi*

0 psi*

Water Content, percent by volume

Distance from center of specimen, inches

APPENDIX B

STYROFOAM SM (1½ IN.)

Distance from center
of specimen, inches

STYROFOAM SM (2 IN.)

Distance from center of specimen, inches

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13. ABSTRACT

This report presents data from a limited investigation of some physical properties of predominantly rigid foamed plastic thermal insulations of various types. Included in the study were boards of mineral wool, cork, perlite, calcium silicate, urethane, extruded polystyrene and polystyrene beadboard. Long term moisture absorption tests were conducted both in water and after burial in moist soil. Simulated deep submersion tests (1 atmospheric pressure) were made and wetted insulations were subjected to 30 freeze-thaw cycles to observe the effect of these parameters. Strength and flammability characteristics were also evaluated. The results of these studies indicated the following: 1) None of the insulating boards were completely moisture resistant. 2) Many foamed plastics were relatively resistant to excessive water absorption. 3) Fused polystyrene beadboards were more absorbent than extruded polystyrene. 4) The two extruded polyurethanes in these tests were generally more absorbent than the polystyrenes. 5) Special surface densification treatment on some of the extruded polystyrene boards appeared effective in reducing moisture absorption.

14. KEY WORDS

Cold weather construction	Insulation
Cold weather tests	Insulating boards
Foundations	Thermal insulation
Frost action	

DD FORM 1473 NOV 66 REPLACES DD FORM 1473, 1 JAN 64, WHICH IS OBSOLETE FOR ARMY USE.

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