Foam Plastics in Building Construction

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Using foam plastics safely in building construction is a frequently misunderstood subject. This presentation will address many of the questions concerning fire safety of foam plastics and show how these materials can be used safely in building construction. This overview will cover what foam plastics are, associated fire losses, concerns associated with their fire-safe use, how they have been and are used in building construction, applicable code requirements, and fire testing, as well as their advantages and disadvantages.
Structure of Talk

- Recent fire incidents
- Introduction: typical foam plastic insulations
- Building applications of foam plastic insulation
- Early fire tests
- Early fire incidents
- 1970s Federal Trade Commission decision
- Code revisions
- Modern fire testing
- Recent code proposals
- Summary and conclusions
Recent Fire Incidents
Why do we care?
Notable Losses

- Kiss Night Club, Brazil, January 2013
  - 242 fatalities
- Station Night Club, RI, February 2003
  - 100 fatalities
- Argentine Night Club fire, Dec. 2004
  - 194 fatalities
- Monte Carlo Exterior Facade
  - January 2008
- Palace Station Exterior Facade
  - July 1998
- Eldorado Hotel, Reno, NV
  - September 1997
2003 The Station Nightclub
West Warwick, Rhode Island
(100 fatalities)
2003 The Station Nightclub
Buenos Aires, Argentina
Nightclub fire, 2004
194 fatalities
Un grupo de jóvenes encendió fuegos artificiales que comenzaron a quemar parte de la decoración de techo que empezó a caer sobre los jóvenes.

La banda comenzó a tocar el primer tema y el cante del grupo, les advirtió a sus fans, que no tiraran bengalas.

Esta es la salida que estaba bloqueada por un candado.

Los jóvenes intentaron salir, pero la principal puerta de emergencia estaba cerrada con candado y recién fue abierta con la llegada de los bomberos.

Ambulancias del SAME, personal de bomberos y policial, más la ayuda de vecinos y los mismos jóvenes sobrevivientes, participaron en el rescate de las víctimas de este terrible suceso.

**Datos importantes:**

- **177 muertos**
  - La mayoría por inhalación de monóxido de carbono.

- **Más de 700 heridos**

**“República Cromagnon”**

- Ubicado en Bartolomé Mitre 3066
- Superficie de 1.500 m² (mide 40 x 30 m)
- Dueño: Omar Chabán

**Fernando Vinella**

**Infografía**

**Telam**

**4.000 espectadores**

(habilitado para 1.300)
Kiss Night Club Fire
Brazil – 2013 – 242 fatalities
Kiss Night Club Fire
Brazil – 2013 – 242 fatalities
The Monte Carlo Façade Fire

January 25, 2008
Palace Station
Las Vegas
July 20, 1998
12-21-99 "Don Belles" Letter to CCBD
Eldorado Hotel
Reno, Nevada
September 30, 1997

Flames leap from a wall of the Eldorado Hotel-Casino on Tuesday as firefighters prepare to attack the blaze in Reno.

Fire erupts at hotel
Fire incidents & Codes

- In every major fire incident in recent times, involving foam plastics, there was a code compliance failure
- Code compliant construction has had an excellent fire safety record recently
- Result of combination of code safeguards
Introduction
Definition of Foam Plastic Insulation

A plastic that is intentionally expanded by the use of a foaming agent to produce a reduced-density plastic containing voids consisting of open or closed cells distributed throughout the plastic for thermal insulating or acoustic purposes and that has a density less than 20 pounds per cubic foot (320 kg/m³).
Typical Foam Insulations

- Expanded polystyrene foam (EPS)
- Extruded polystyrene foam (XPS)
- Rigid polyurethane foam (RPU)
- Polyisocyanurate foam (PIR)
- Others
EPS sheets are produced from solid polystyrene beads. The beads are expanded by injecting and dissolving a small amount of pentane gas into the base material during production.
Under heat, the gas expands the beads to form closed cells. These cells are roughly 40 times the volume of the original bead, and can be molded to form insulation boards, blocks, or shapes. It has a lower density and a lower R value than XPS foam and is usually white.
XPS foam is produced from solid polystyrene crystals, which, together with additives, are fed into an extruder. Within the extruder, high heat and pressure form the mixture into a plastic fluid.
This thick liquid plastic is forced into a die where it emerges and expands to a foam. This foam is then shaped, cooled, and cut. It has a higher density and a higher R value than EPS foam and is usually not white.
Polyurethanes are produced by a controlled reaction between a polyol and an isocyanate. Special recipes (with the polyol, isocyanate and other additives) are needed for each type of product.
The amount of polyol and isocyanate is matched according to a chemical equivalent weight. Typically the isocyanate used is 105% of the chemical equivalent of the polyol. Then the foam is said to have an index of 105.
Polyisocyanurates can be produced without polyol, using only isocyanate and additives. Instead of reacting with the polyol, the isocyanate reacts with itself to form a highly crosslinked thermosetting polymer with a ring-like structure.
For commercial PIR foam, the polyurethane is modified with polyisocyanurate. PIR foam has a typical index about 250 (i.e. the isocyanate is 250% of the chemical equivalent of the polyol)
Closed & Open Cell PU Foam

- Both are spray applied
- Open cell foams have < density (and < R value) and expand more easily to cover hard to reach locations.
- Closed cell foams are more resistant to moisture and bacterial growth.
Other Foam Insulations

- Phenolic foam (Phen)
- Polyimide foam (PI)
- Polyolefin foam (Polef)
- Melamine foam (Mel)
- Flexible polymeric foam (Flex Pol)
- Reflective insulation/foam interior (Rfl)
Foam Insulation R Factor

Based on Data from Manufacturers

- EPS: R/inch ≈ 4
- XPS: R/inch ≈ 5
- PU spray closed cell: R/inch: 5.8 – 6.4
- PU spray open cell: R/inch ≈ 3.8
- PIR: R/inch: 5.0 - 5.6
Some Other Insulations
Based on Data from Manufacturers

- Foam plastics: R/inch ≈ 3.7 – 6.4
- Fiberglass batt: R/inch: 3.1 – 3.7
- Fiberglass blown: R/inch: 2.2 – 4.3
- Cellulose loose-fill: R/inch: 3.0 – 3.3
- Mineral Wool batt: R/inch: 4.2
- Mineral Wool blown: R/inch: 3.3 – 3.8
- Straw bale: R/inch: 0.9 – 1.5
- Recycled Denim: R/inch: 3.7 – 4.0
Foam Plastic Applications

- Cavity Insulation (Walls/Ceilings)
- Roofing Systems
- Coolers - Freezers – Doors
- Floor Insulation
- Backing for Siding
- Exterior Systems
- Insulation for Attics & Crawl Spaces
Early Major Fire
Livonia, MI, Fire, 8/12/1953 – General Motors

Largest Industrial Loss on Record at That Time
$50 - $55 M in Property Damage
$750 M in Business Interruption
32,000 Employees Laid Off
Livonia Roofing Fire

- Welder’s torch sparks cause the fire
- Roof covering burns and melts
- Roof covering asphalt and layers
- 45 min fire engulfs 34.5 acre facility
- Resulted in “White House Roof” fire test (100 ft. long) (1955-1957)
- Then ended up in FM 4450 test
Fire Testing
Early Fire Testing

- ASTM D1692, Standard Method of Test for Flammability of Plastic Sheeting and Cellular Plastics (First issued 1959)
- Test: Horizontal Bunsen burner flame, for 60 s
- Test specimen sits on a metallic grid
Early Fire Testing (2)

- Specimen passed test if no ignition or flame does not spread to end or flame spread rate is low
- If materials “passed” the test they were labeled “self-extinguishing”
- Many foam plastics passed the test
- Standard withdrawn in 1976
Early Fire Testing (3)

- Test: Horizontal massive burner flame, for 10 min
Early Fire Testing (4)

- Test specimen under tunnel ceiling
- No “pass” in the test
- Test measures flame spread index and smoke developed index
- Categories: A, B and C
ASTM E84 Categories

- **A**: 25 FSI; 450 SDI
- **B**: 75 FSI; 450 SDI
- **C**: 200 FSI; 450 SDI

- Categories/Requirements are not in the standard
ASTM E 84 Test
Foam Fire Childress

- Missouri polyurethane foam insulation fire killed 2 children of the Childress family
- Foam manufacturer had labeled the foam as “non burning and self extinguishing”, as a result of ASTM D1692 test results
- Lawsuit found manufacture liable
- Manufacturer and testing lab were found to be negligent because test was inadequate to assess the severe fire problem with the foam
FTC Investigation (1972)

- Investigated fires involving cellular plastics
- Same as foam plastics
- FTC Determined there was “misuse” of small scale test data in promotional materials
- “Small scale tests are neither reliable nor accurate tests for determining, evaluating, predicting or describing the burning characteristics of plastic products under actual fire conditions.”
FTC Consent Order

- Determined that cellular (foam) plastics burn different than conventional materials
- Thermoplastics (like polystyrene) tend to melt and drip and contribute to fire spread
- FTC Consent Order Issued 11/4/1974
- Cease using “non-burning”, “Self-extinguishing” or non-combustible” when describing foam plastics
- Any reference to numerical flame spread ratings based on small scale tests, such as ASTM E84, must contain a disclaimer
FTC Consent Order Terms

- Plastics manufacturers must conduct $5 million fire research program on safe means of using foams
- Develop guidelines for safe and effective use
- Develop appropriate fire test methods, including large scale test methods, to provide accurate and reliable means to assess burning characteristics under actual fire conditions
- Manufacturers must report to FTC for 5 years
- FTC Consent Order withdrawn in 1980
FTC Consequences

- Industry conducted research with NBS (now NIST)
- Developed large scale wall tests
- Developed large scale corner tests
- Developed correlations with ASTM E84
- Developed validation studies
- Developed combustion toxicity studies
- This resulted in modern fire test requirements
- Incorporated into codes in 1970s
- Have been slightly modified since then
Code Requirements Now

- International Building Code (IBC): Chapter 26 and section 2603
- NFPA 5000: Chapter 48 and section 48.4
- Very similar in both
Code Fire Testing Now

- Either: Testing Foam Plastic to NFPA 286
- Or: Testing Foam Plastic to ASTM E84
- If tested to ASTM E84 Foam Plastic Must be Covered by Thermal Barrier for all Occupiable Spaces
- Foam Plastic Also Always Needs to Meet ASTM E84 Class B (75/450)
NFPA 286
Basic Test Apparatus
Fire Requirements for NFPA 286

- Requirements are not in the standard
- No Flashover
- Peak HRR $\leq 800$ kW
- Peak TSR $\leq 1000$ m²
Interior Wall & Ceiling Finish
Fire Requirements (2015)

- Foam Plastic Finish Permitted Only If:
  - (a) Meets NFPA 286-based requirements
  - (b) Meets FM 4880/UL 1715/UL 1040 (all large scale tests)
  - (c) Covered by Thermal Barrier
  - and meets ASTM E84 75/450
FM 4880 25 ft. Corner Test
Thermal Barrier
Thermal Barrier

- Must meet NFPA 275, which has NFPA 286 & ASTM E119 tests
- Also thermal barriers named as:
  - Alternative: ½” gypsum board
  - New alternative: ¾” plywood
  - (Plywood in IRC only, for now)
NFPA 275:
ASTM E119
(smaller scale)
and
NFPA 286
Exceptions to Thermal Barrier Requirements (1)

- Behind 1 inch of masonry or concrete
- Cooler & freezer walls
- Walk-in coolers
- Exterior walls in one-story buildings
- Roofing
- Attics & crawl spaces (non occupiable)
- Doors not required to have fire protection rating
Exceptions to Thermal Barrier Requirements (2)

- Exterior doors in Group R-2/R-3 buildings
- Garage doors
- Siding backer board
- Interior trim
- Interior signs
- Type V (combustible) construction
- Walking surfaces of structural floors
Non Occupiable Spaces
Attics & Crawl Spaces

- Foam Plastic Needs to Meet ASTM E84 Class B (75/450)
- Normally Spray Foam
- Foam Plastic Must be Covered by an Ignition Barrier
- Ignition Barrier: Named Products
Ignition Barrier
Ignition Barrier

- 1.5” Mineral Fiber Insulation
- 0.25” Wood Structural Panel
- 3/8” Gypsum Wallboard
- 0.25” Hardboard
- 0.016” Corrosion Resistant Steel
- 1.5” Cellulose Insulation
- Another Approved Material
Exterior Walls
Exterior Walls: 1 story

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 25/450 &
  - Maximum 4 inches thick &
  - Al (0.032”) or steel (0.016”) covering &
  - Building fully sprinklered
Exterior Walls: > 1 story
Type I-IV Construction

- Fire resistance rating
- Thermal barrier over foam
- Foam must meet NFPA 259 Pot. Heat
- ASTM E84 25/450
- Pass NFPA 285 multistory test
- Pass NFPA 268 ignition test
Thermocouples here cannot reach 1,000 deg F

1st: burn room burner is ignited
2nd: after 5 min, window burner is ignited
3rd: after 30 minutes, both burners are shut off.
4th: residual burning is monitored until complete

Test Wall

18'

10'

Window burner

Burn room burner

7' 6” min.

7' 6” min.
NFPA 268 Test

Requirements: No ignition @ 12.5 kW/m²
Exterior Walls: > 1 story
Type I-IV Construction

- Tested to NFPA 268 (ignition)
- Exceptions:
  - Thermal Barrier
  - 1” Concrete
  - 3/8” Glass Fiber Reinfor. Concrete
  - Steel or Aluminum Panels
  - 7/8” Stucco
Exterior Walls: > 1 story
Type V Construction

- Thermal barrier over foam
- ASTM E84: 75/450
Cooler/Freezer Walls
Cooler/Freezer Walls

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 25/450 &
  - Maximum 10 inches thick &
  - Al (0.032”) or steel (0.016”) covering &
  - Ignition temperature 600/800F (flash/self) &
  - Building fully sprinklered
Walk-in Coolers
Walk-in Coolers

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 75/450 &
  - Maximum 4 inches thick &
  - Al (0.032”) or steel (0.016”) covering &
  - Aggregate floor area \( \leq 400 \text{ ft}^2 \)
Roofing
Roofing

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 75/450 &
  - Wood structural panel 0.47” & exterior glue
  - Roof assembly meets FM 4450 or UL 1256 (including foam)
- Foam plastic with thermal barrier, roof assembly (with foam) must meet ASTM E108 Class A, B or C
FM 4450
Heat Release Roofing Test

Heptane & propane burners – 30 minute test
Structural Floors
Structural Floors

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 75/450 &
  - Wood structural panel 0.5” &
  - Thermal barrier on underside if the underside is exposed to building interior
Siding Backer Board
Siding Backer Board

- Foam plastic without thermal barrier if it complies with all the following:
  - ASTM E84 75/450 &
  - NFPA 259 \( \leq 2000 \) BTU/ft\(^2\) &
  - Maximum thickness 0.5” &
  - Separated from building interior by 2” of mineral fiber insulation or equivalent
  - Does not include “insulated vinyl siding”
Interior Trim
Interior Trim

- Needs to comply with all the following to avoid thermal barrier:
  - ASTM E84 75 (no SDI) &
  - Surface $\leq 10\%$ of wall or ceiling &
  - Density $\geq 20$ lb./ft$^3$
  - Thickness $\leq 0.5$"
  - Width $\leq 8$"
Interior Signs
Interior Signs in Covered Malls

- Needs to comply with all the following to avoid thermal barrier:
  - UL 1975 or NFPA 289, 20 kW source, HRR $\leq 150$ kW &
  - Height $\leq 36$” (or 96” x 36” if vertical) &
  - Surface $\leq 20\%$ of wall
  - No ASTM E84 requirements
Plenums
Foam Plastic In Plenums

- Foam Plastic Interior Finish Must Have Thermal Barrier or NFPA 286
- Also: ASTM E84 75/50
- Or NFPA 286 (as above)
- Or Al or Steel coverings
Plenum Pipe/Duct Insulation

- ASTM E84 with FSI 25/SDI 50
- Mounting by ASTM E2231
- Included in IMC (& IBC)
- Included in UMC
- Included in NFPA 5000 and 90A
Recent Developments
Code Proposals
International Residential Code

- RB 163: Allows foam plastic without fire test in wall cavities
- RB 164: Allows foam plastic without fire test under floors
- Both proposals were disapproved
- RB 167: Allows 3/4” plywood as thermal barrier: proposal approved
Code Proposals
International Green Code

• GG 221: Requires foam plastic to disclose contents or comply with GreenScreen label
• GG 222: Allows foam plastic without fire test under floors
• GG 242: Requires 50% of foam plastic insulation to have no halogens
California Law
CA AB 127

- Requires California State Fire Marshal to develop new fire test or options for using foam plastic insulation without meeting a fire test
- Working group formed in California
- Much debate centers on allegations of toxicity of flame retardants
Flame Retardants in Foams

- Typical foams do not pass needed fire tests as such (polyurethane, polystyrene, polyisocyanurate)
- Need FR to meet fire test requirements
- New flame retardants are being used
- Many other insulation materials also need flame retardants
Toxicity of Flame Retardants (1)

- Issue is “measurable vs meaningful”
- Decomposition products of flame retardants are found in fire effluents
- Studies have shown that toxicity of normal smoke effluents (such as CO and polynuclear aromatics) are 1,000 times more toxic than FR derivatives
Toxicity of Flame Retardants (2)

- More fire safe materials lower emissions
- Firefighters have higher cancer rates
- All fire effluents affect firefighters, both during fires and during overhaul
- SCBA use is essential for firefighters
- Rapid cleaning of fire gear is essential
- The key issue is personal protection
Conclusions

- Foam plastic insulation materials are needed for energy efficiency
- They have high insulation (R values)
- They can be used safely
- Fire incidents have involved code non compliance
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