Can foam plastic insulation without flame retardants be used safely below grade?

Avery Lindeman [1] and Donald Lucas [1, 2], with contributions from David Rich [3]

[1]Green Science Policy Institute, Berkeley, CA 94709; [2]Lawrence Berkeley National Laboratory, Berkeley, CA 94720; [3]Reax Engineering Inc., Berkeley, CA 94703

INTRODUCTION

In part as a result of feedback from the International Building Code Fire Safety Code Committee about proposals FS 170-15 and FS 171-15 at Committee Action Hearings in April 2015, we have compiled this whitepaper to summarize some of the existing codes and regulations for labeling, site storage, and site installation of foam plastic insulation materials. In addition, we conducted preliminary fire tests to investigate some of the concerns raised about fire performance.

These tests examined fire performance of insulation with and without added flame retardants (FRs) in use (installed below grade) and when exposed (e.g. on a construction site). This testing, described below, demonstrates comparable performance of both materials with respect to fire risk. The results will be submitted to a peer-reviewed journal for publication in the future.

As participants in the Assembly Bill 127 (AB 127) Working Group convened by the California Office of the State Fire Marshal, we hope this information is also helpful to the State of California as it moves forward with recommendations from the AB127 Working Group, including the research needs identified by the State Fire Marshall:

> *"The informal recommendation was for the State Fire Marshal to consider a California code change proposal to allow the use of non-flame retarded foam insulation in foundation and under slab/subgrade applications (under specific conditions)…*
> *The informal proposal is under consideration for the 2016 Supplemental Code Cycle (effective July 2018). In order to move this proposal forward, the State Fire Marshal will need to address* ***the labeling, site storage, and site installation of the product within the adopted codes. Some fire testing will be required****."*
> - Message from State Fire Marshal Tonya L. Hoover, excerpted from *Flammability Standards for Building Insulation Materials - Working Group Report and Recommendations (Aug., 2015)*

INSTALLED USE

The California Building Code addresses fire performance requirements for foam plastic insulation in **Chapter 26 Plastic**. The requirements of that chapter are outlined in the AB 127 Working Group report. They include Section **2603.4 Thermal barrier**, which requires a thermal barrier of ½-inch (12.7 mm) gypsum wallboard or similar material to separate foam plastic insulation from the building interior. **Section 2603.4.1.1 Masonry or concrete construction** allows for removal of the thermal barrier for foam plastic installed in a masonry or concrete wall, floor, or roof system where the foam plastic insulation is covered on each face by a minimum of 1-inch (25 mm) thickness of masonry or concrete.

The rational for this exception is based on the fact that foam plastic insulation protected by a minimum of 1-inch thick cement does not pose a fire hazard – it does not have access to oxygen or to an ignition source, and the cement will protect insulation from the heat of the fire.

LABELING

Chapter 26 of the 2013 California Building Code (CBC) includes requirements for clear labelling of foam plastic insulation materials. Section **2603.2 Labeling and identification** (and Section 316.2 of the California Residential Code) requires sufficient identification and labeling of packages and containers of foam plastic insulation and foam plastic insulation components delivered to the job site to ensure that the end use will comply with the code requirements. Installation of foams would typically be handled by contractors with good familiarity with these building products, their limitations and proper installation requirements. There are standard methodologies to document delivery, storage, and installation of the many hundreds of building products needed for a single construction project.

SITE STORAGE AND SITE INSTALLATION

Fire safety during construction is covered in numerous regulatory and industry guidance documents. Site storage and worksite installation of combustible solids is covered directly or indirectly in the 2013 California Fire Code (CFC), primarily **Chapter 33 Fire Safety During Construction and Demolition**, and **Chapter 35 Welding and Other Hot Work** (also covered in NFPA 51B).

CFC Chapter 33 identifies flammable and combustible liquids (Section 3305) as an area of concern during construction but provides less attention to combustible solids. Broadly, as soon as combustible materials arrive on a site, **Section 3312.1 Water supply for fire protection** requires an approved water supply for fire protection, and **Section 3313 Standpipes** requires a wet or dry standpipe when construction reaches 40 feet in height.

Construction site fires, particularly those involving ignition of solid combustibles, are frequently associated with "hot work" activities involving welding, cutting, brazing, grinding, etc. where hot surfaces or flame impingement results in a smolder period that breaks into open flaming after workers have left the job site for the day. Chapter 35 sets detailed requirements for fire watch to address this issue where **Section 3501.3 Restricted areas** prohibits hot work in areas with readily ignitable materials without approval from the fire official.

Where indicated, **Section 3504.2.1** requires that a fire watch be provided during hot work activities and continue for a minimum of 30 minutes after the conclusion of the work. The fire code official, or the responsible manager under a hot work program, is authorized to extend the fire watch based on the hazards or work being performed. Recent construction site fires (e.g. the San Francisco Mission Bay Fire – in which sub-grade foam plastic insulation was not implicated – and other construction site fires) have led to calls for stricter observance of fire watch and hot work requirements and possible extension of the mandatory fire watch period.

In addition to a fire watch, Section **3504.1.1 Combustibles** requires that hot work areas not contain combustibles, or that combustibles are appropriately shielded to protect them from ignition from sparks, slag, or heat. Section **3504.1.8 Sprinkler protection** requires that automatic sprinkler protection remain active while hot work is performed.

Occupational Safety and Health Administration (OSHA) regulations currently require adherence to NFPA 51B for hot work on construction sites. The provisions of NFPA 51B help prevent injury, loss of life, and loss of property from fire or explosion as a result of hot work projects such as welding, heat treating, grinding, and similar applications producing or using sparks, flames, or heat. Adherence to these provisions will reduce fires during construction of residences using flammable products, including wood and foam plastic insulation.

Foam plastic insulation is flammable whether or not it contains flame retardants, and NFPA 51B should be followed and other fire protections should be in place around these and other flammable materials.

In spite of these code provisions for fire safety on construction sites, construction site fires account for a significant portion of yearly fire losses. Arson is the leading cause of construction site fires. Open flames and hot work are other contributing causes of fires on construction sites. A variety of materials and debris are likely to be present on construction sites, including building materials, waste, sawdust, and other combustibles. The authors are not aware of data regarding the most common items of first ignition on construction sites. However, the flame retardants currently added to foam plastic insulation materials for use below grade will provide a minimal delay in ignition for only a small range of ignition sources. The presence of some types of foam plastic insulation without flame retardants is not expected to significantly increase the fire hazard represented by foam plastic insulation in storage or during installation on a construction site.

TRANSPORTATION

Transportation of foam plastics is covered by U.S. Department of Transportation rules. Currently, there are no restrictions or special regulations regarding the transportation of foam plastic materials, regardless of flame retardant content.

FIRE TESTING

During the AB 127 Working Group discussions in 2014, then-Deputy State Fire Marshal Kevin Reinertson stated that foam plastic insulation sandwiched between concrete and soil is clearly not a fire hazard.

There is no recognized fire test for assemblies of this type, since it is difficult to envision a realistic scenario where below-grade foam plastic would be a major factor in a residential fire. However, in response to requests for fire test data, we conducted a series of fire tests relevant to foam plastic insulation in below-grade uses.

Based on these requests and the risk areas identified in code sections above, we sought to answer the following questions:

(1) If exposed to an ignition source, will insulation installed below grade (between a concrete slab and sub-grade material) ignite? Will a flame propagate under the slab?
(2) What happens if insulation below a cement slab is exposed to heat from a post-flashover fire and ignited?
(3) If exposed near reasonably foreseeable worksite hazards (e.g. welding slag or brazing), does insulation with flame retardants provide a meaningful increase in fire safety?

Rigid foam plastic building insulation without flame retardants was obtained from Sweden (EPS: Cellplast JP 80, 7 cm thick, Beijer Byggmaterial; XPS Ecoprim 7 cm thick, Beijer Byggmaterial), where approximately 97% of all polystyrene foam insulation is manufactured without flame retardants. X-Ray fluorescence (XRF) results confirmed that insulation did not contain chlorine or bromine.

Similar EPS insulation with flame retardants was purchased locally at The Home Depot (R-Tech Insulfoam, 7/8" thick). XRF results indicated a bromine content of approximately 6000 ppm, indicating presence of added brominated flame retardants.

Both types of insulation were manufactured for use in building applications, but the Swedish insulation was not expected to meet the flammability requirements of California Building Code Section **2603.3 Surface burning characteristics** or California Residential Code Section **R316.3 Surface burning characteristics**. There was a slight variation in density between the foams tested which should not meaningfully impact the results.

Insulation from Sweden was tested in stacks of two to achieve a thickness equivalent to the U.S. insulation.

DESCRIPTION OF FIRE TESTS:

TEST 1:

Insulation was placed on a flat dirt surface and covered with 2" thick concrete pavers. A charcoal fire was ignited in the center of the pavers, and allowed to burn for an hour to simulate flash-over conditions in a residence above the concrete floor with limited oxygen access to the foam plastic insulation.

Results: Both foams melted directly under the charcoal fire, but there was no evidence of any combustion. Foams with and without flame retardants showed no significant differences.

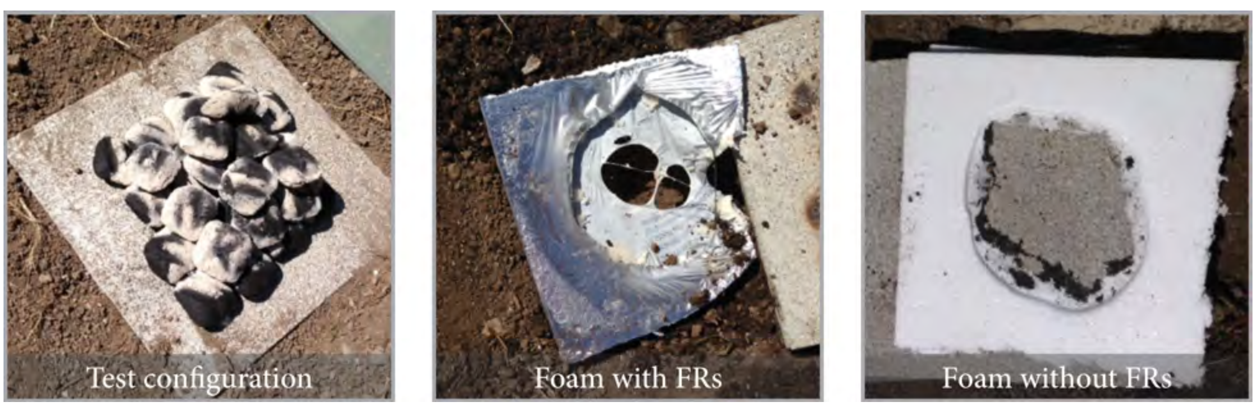


Figure 1. Concrete paver supports a charcoal fire above a sample of foam plastic insulation. After termination of the test, foam without FRs (left) and foam with FRs (right) displayed similar melting.

TEST 2:

Insulation was placed on a flat dirt surface and covered with 2" thick concrete pavers. A 4"x4" square opening was created to simulate an unprotected pipe or other opening in a cement slab which allowed for oxygen access to the foam. A handheld butane torch, simulating a significant direct ignition source, was applied to the exposed foam for approximately 1 minute; the assembly was then cooled before removing the concrete pavers.

Results: Both foams melted and burned where they were directly exposed to the torch. However, foam under the concrete did not sustain combustion, and no significant difference was observed between foams with and without flame retardants.

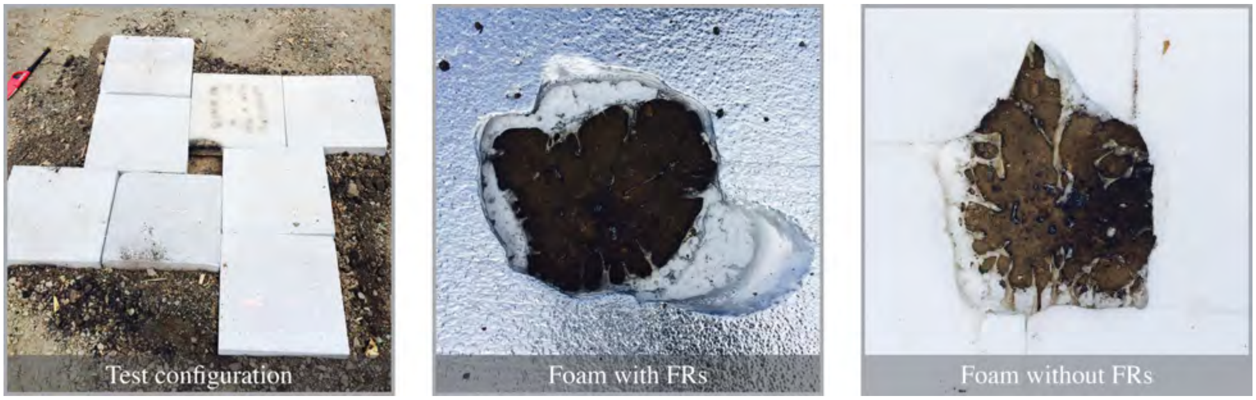


Figure 2. Concrete pavers cover foam plastic with a 4” x 4” opening where small butane torch was applied (left). Center image shows foam with FRs after the test; image on the right shows comparable melting of foam without FRs after the test.

TEST 3:

Foam plastic insulation was placed in a steel pan and covered by 2” thick concrete pavers. Pavers were spaced to create a 2.5” gap running the width of the pan to simulate an opening or an unprotected gap at the slab edge presenting greater oxygen access than the penetration condition above. Steel spacers were used to support pavers in the event of melting.

A small flame (butane lighter) was applied to exposed foam at the gap in the pavers until the foam ignited. Flames were allowed to propagate below the slab until they self-extinguished.

Results: Foam without FRs ignited, and the flame propagated approximately 7 inches before self-extinguishing. Foam with FRs melted but did not ignite when exposed to the butane lighter.

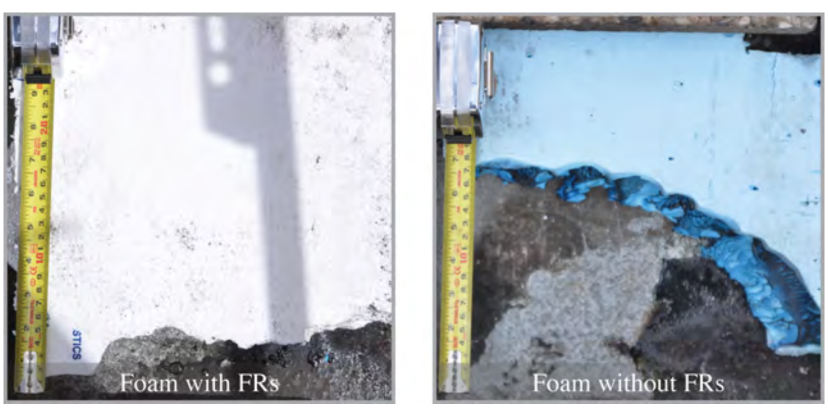


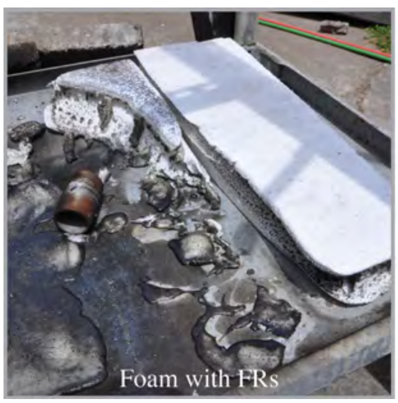
Figure 3 (images shown to scale). Flame propagation below the slab for small flame ignition without external heat flux. Small flame ignition of the foam with FRs (left) was not successful. Foam without FRs (right) propagated approximately 7” from the slab edge before self-extinguishing. Pavers were removed after test to show extent of burning.

TEST 4:

Using the same setup described in Test 3, an experiment was performed to evaluate exposure of insulation below a cement slab to heat from a post-flashover fire. A radiant ceramic heater (15" x 12") was suspended above the gap in the surface of the pavers to provide a heat flux comparable to that at the floor during a post-flashover fire. Heat was applied for one hour until un-melted foam had recessed approximately 8 inches back from the gap in the pavers.

The resulting pool of melted foam below the pavers was ignited by a large flame source (an oxy-acetylene brazing torch) underneath the pavers and directed at the wall of un-melted foam for 15 – 20 seconds. Flames were allowed to propagate 12 inches away from the gap and then extinguished. It is important to note that this test simulated an extreme fire scenario where the floor assembly is exposed to an hour of post-flashover fire and the heated/melted foam has access to a continuous source of oxygen after ignition, conditions that would virtually ensure that the residence above the concrete was destroyed.

Results: For both the foam with and without flame retardants, the flames were self-sustaining and spread at a slow rate (approximately 2 inches per minute). There was not a marked difference in ignition time or regression rate for the foam with or without FRs.



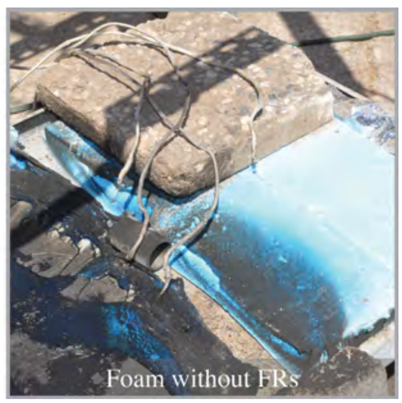


Figure 4. Flame spread testing with an external radiant flux above 2" concrete pavers resulted in similar flame spread rates for foam with FRs (left) and foam without FRs (right).

TEST 5:

A copper pipe was inserted into each sample of foam and heated with an oxy-acetylene brazing torch for 5 minutes at a point 3" form the foam surface. Brazing solder was applied to the pipe at the point of flame contact and allowed to drip down to the foam surface.

Results: Neither hot pipe contact with the foam nor falling droplets of brazing solder resulted in ignition of foams with or without FRs.

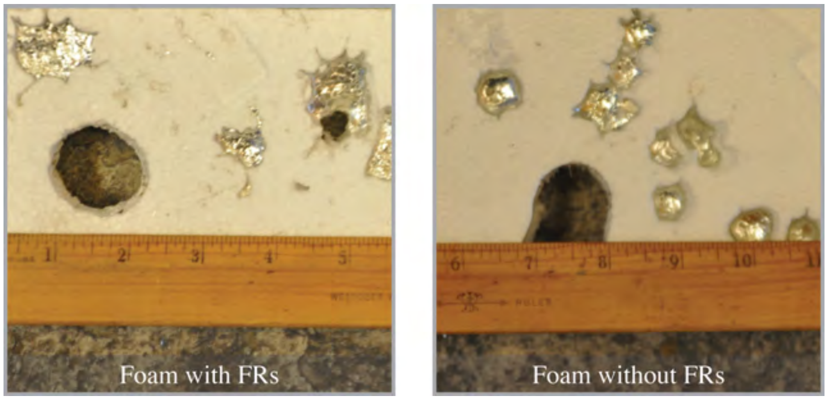


Figure 5. Brazing solder drips onto foam with FRs (left) and foam without FRs (right). Neither showed ignition.

TEST 6:

Drops of molten steel from oxy-acetylene cutting were allowed to fall on foam plastic insulation with and without FRs from a height of 3 feet. In total, at least 10 droplets of slag fell on each sample.

Results: Neither sample of foam plastic sustained flame propagation away from the point of contact of molten slag. One sample of foam without flame retardants sustained a small flame near the point of contact with slag, but this flame self-extinguished in approximately 2.5 seconds as the slag cooled.

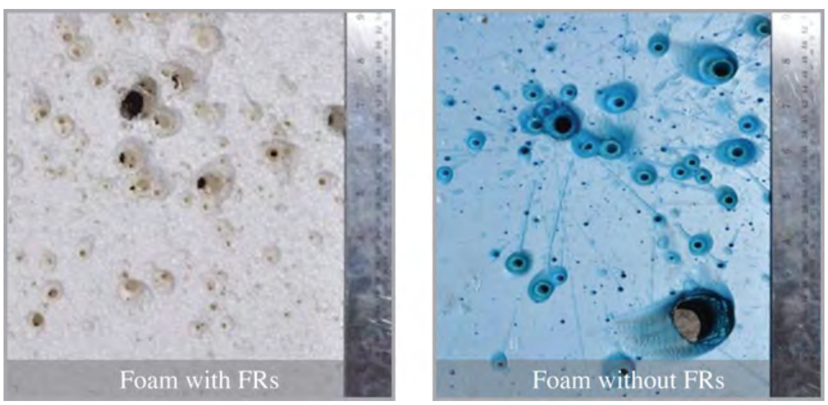


Figure 6. Steel welding slag dropped from approximately 4 feet onto foam with (left) and without (right) FRs. The larger hole in the sample on the right burned briefly before self-extinguishing.

PRELIMINARY CONCLUSIONS

In these tests, Swedish foam plastic insulation without FRs exhibited similar fire behavior to the conventional U.S. foam plastic insulation containing FRs.

While the presence of FRs in the U.S. foam provided a slight increase in time to ignition in tests using a small open flame, overall fire behavior was comparable

Despite the lack of flame retardants in Swedish insulation samples, initial brazing and welding tests did not indicate an increased hazard from this material if improperly exposed to such operations on the job site. Foam plastic insulation should not be exposed during hot work regardless of the presence of added flame retardants.