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Urea-Formaldehyde Foam Insulations: A Review of Their Properties and Performance

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The conditions for which shrinkage measurements are made are often not recorded.

Standards for foam insulation have requirements that under test conditions a freshly prepared specimen should not undergo shrinkage in excess of a specified percent in a given period of time (table 1). In North America, the Canadian standard [13] and the HUD bulletin [19] specified that the shrinkage should not exceed 4 percent in 28 days. The ASTM standard [17] specified that the shrinkage should not exceed 4 percent over the period of time required for the foam to dry to constant weight. These requirements are considered applicable to quality control only, since foams have been shown to undergo shrinkage greater than 4 percent in service. A methodology has not been developed to predict on the basis of laboratory tests the extent of shrinkage which a foam will undergo in service.

3.13.2 The Effect of Shrinkage on Thermal Performance

The extent to which shrinkage of foam insulation reduces the thermal efficiency of insulated walls depends upon the amount of shrinkage which occurs and the orientation of the cracks and gaps which result [31, 44]. Shirtliffe has indicated that the vertical shrinkage gaps along the studs are more important in reducing thermal efficiency than the horizontal gaps which occur in the foam [44]. The Canadian standard [13], DOE standard [18] and HUD bulletin [19] provided guidelines as to the effect of shrinkage on the efficiency of foam-insulated walls (table 1). In this regard, these standards used the term "effective thermal resistance" to indicate the calculated reduction of the laboratory measured value of the thermal resistance of the foam which is determined by a thermal conductivity test. This recognizes that the thermal efficiency of an insulation is based on simulated in-use conditions and not thermal conductivity alone. The Canadian standard indicated that foams in typical wood frame construction would be expected to shrink in service about 7 percent, resulting in an effective thermal resistance of the foam of 40 percent less than the thermal resistance determined by the thermal conductivity test [13]. The HUD bulletin [19] stated that 6 percent shrinkage would be expected in service and would result in an effective thermal resistance of the foam of 28 percent less than that based on the laboratory measured thermal conductivity value. The HUD Bulletin [19] also presented a plot estimating the effective thermal resistance of the installed foam as a function of the percent shrinkage. The DOE interim standard [18] indicated that the effective thermal resistance of foam should be taken as 30 percent less than that of the laboratory determined thermal conductivity value without considering the extent of shrinkage. The effective thermal resistances given in the HUD and DOE documents were also for wood frame construction. It is noted that the effective thermal resistance of 3.5 in. (90 mm) of foam, having a thermal resistance (R-value) of about 4.1 units per inch and subjected to a derating of 30 percent, would be about 10. This is about 15 percent less than the thermal resistance of a fibrous glass batt having an R-value of about 11.5.

The guideline concerning the effective thermal resistance of foams in service given in the Canadian standard was based on a summary of existing literature information [40]. For the HUD bulletin, the guideline on effective thermal resistance was based on a calculation for predicting the effect of air gaps on reducing the thermal efficiency of insulated walls [77, 78]. In spite of these guidelines for effective thermal resistance in standards, there is not general agreement in the literature that shrinkage reduces the insulating ability of foams. Timm and Smith [75] have made reference to calculations by Barker indicating that shrinkage has little effect on insulating ability of foams.

Since the publication of the Canadian [13] and DOE standards [18] and HUD bulletin [19], studies have been conducted which provide data supporting the guidelines for effective thermal resistance given in these documents. Reliable determinations of heat flow through building envelope components such as walls are made using calibrated or guarded hot box tests. Two of the studies on effective thermal resistance used hot box techniques. In one, the National Research Council, Canada, conducted a study of full scale walls filled with foam [79]. The foam was allowed to shrink in the walls and their thermal resistance was determined. The results indicated that, for example, if the foam shrunk 6 percent, the reduction in the thermal resistance was about 29 percent. In the second study, Tye and Desjarlais [80] measured the resistance of wood-frame cavity walls containing polystyrene boards of varying dimensions (to simulate shrinkage) and found a direct relationship between thermal performance of the wall and air gap around the polystyrene boards. For each 1 percent shrinkage, the reduction in thermal resistance of the insulation was about 5 percent which was comparable to the NRC results. In a related study, McFadden et al. [81] conducted a field test using a small structure having walls insulated with urea-formaldehyde foam. The foam underwent a shrinkage of about 6 percent, which resulted in a measured thermal resistance of the wall which was about 20 percent less than that predicted without shrinkage. The effective thermal resistance of the foam was calculated to be about 29 percent less than the R-value measured in the laboratory.

The U.S. Federal Trade Commission (FTC) reviewed available information concerning shrinkage and its effect on thermal efficiency in 1978 [82]. This review was undertaken by FTC because of concerns over misleading statements in advertisements regarding the R-values of foam insulation. Based on the review, the FTC considered that shrinkage is an inherent characteristic of urea-formaldehyde foam insulation which can significantly reduce the R-value of the insulated area. Consequently, the FTC's insulation advertisement rule requires a disclosure statement on shrinkage or a reduction in the claimed R-value to account for shrinkage, whenever ads for the product mention its R-value [83]. The required disclosure statement is as follows:

> "Foam insulation shrinks after it is installed. This shrinkage may significantly reduce the R-value you get."

This statement need not be made if a manufacturer's literature claims a lower R-value than that measured in the laboratory. However, the claimed lower R-value must be based on "reliable scientific proof of the extent of shrinkage and of its effect on R-value [83]."

rain depending upon the type of masonry. An exception is where the outer leaf has adequate rain protection through rendering or cladding.

3.13 SHRINKAGE

3.13.1 The Extent of Shrinkage

Urea-formaldehyde foam insulations shrink after installation during drying, and often for some period of time after drying. As the foam shrinks, gaps, cracks, and other voids are created between wall components and the foam, or within the foam, providing unwanted paths for increased heat flow and thus lowering the insulating properties of the foamed wall [38]. Variables impacting on foam shrinkage after application under typical ambient temperature and humidity conditions have not generally been investigated. In general, a better understanding of shrinkage processes of aqueous-based foams is needed. It has been shown that reversible expansion and contraction of about 3 percent occurs when humidity changes take place [40]. Timm [75] and Wulken [48] have listed possible factors affecting shrinkage including the chemical formulation, ratio of resin to foaming agent during application, the foaming equipment used, workmanship during application, the rate of drying of wet foam after application and the temperature during drying. Some urea-formaldehyde foams, upon exposure to combined elevated temperature and humidity conditions, undergo shrinkage through a mechanism involving reticulation of the cells [28]. Reticulation was not observed to have occurred during shrinkage of foams at ambient laboratory conditions.

The extent to which foams undergo shrinkage has been a controversial subject [5]. Early literature indicated that manufacturers claimed the extent of shrinkage to be about 1-3 percent, but limited field observations at that time produced evidence that shrinkage was generally greater, in some cases approaching values of 8-10 percent. For example, Burch and Hunt [55] reported shrinkage of a foam sample in a test house to be about 8 percent, occurring over a period of 2 years. Since the mid-1970s, data have been developed from field surveys to support the earlier observations that foams generally shrink in service more than 1-3 percent. Bowles and Shirtliffe [40] reported that field observations in Canada found shrinkage to be generally between 3 and 8 percent, but as high as 11.5 percent. In one study Spinney and Weidt [43] found that foam shrinkage in 12 homes ranged from 2.5 to 9 percent, averaging 4.5 percent. In another study, Weidt et al. [42] reported the average shrinkage in 17 homes to be 6 percent with a range of 4 to 9 percent. In this study, foam in 4 other homes had split and cracked to such an extent that the percent shrinkage could not be determined. In another study of foam in more than 30 homes, Tsongas et al. [41] found the average shrinkage was about 8-10 percent, depending upon the foam dimension. Firstman [76] found that for 26 homes the values of foam shrinkage ranged from less than 1 to over 7 percent. In these field studies noted above, the foam samples were in general older than 2 years when the shrinkage measurements were made. Additionally Wulkan [48] has measured an average shrinkage of 7.8 percent for 39 specimens, but the ages and moisture contents were not given. In the case of all studies mentioned above, it is noted that comparisons of absolute shrinkage values should be made with caution, since foam may reversibly shrink and expand depending upon humidity conditions.