

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 Shirliffe [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.