2.3.1 Expected distribution

A number of possible scenarios exist that may lead to variations in water:cement ratio. According to the American Concrete Institute (ACI), the tolerance for total water content is 3 % and the tolerance for cementitious materials ranges from 1 % to 4 % depending on the scale limits ["*Standard Specifications for Tolerances (ACI 117-90)*," in Part 2 of Ref. [7]]. Therefore, the water:cement ratio variability should be in the range 3 % to 5 %. At these percentages, it would seem plausible to characterize the water:cement ratio by a normal distribution.

The shortest service lifetimes will likely coincide with the largest possible values for water:cement ratio. These larger values lead to greater porosities, larger permeabilities and lower compressive strengths, and more rapid transport of aggressive ionic species.

2.3.2 Direct measurement

Direct measurement of water:cement ratio of a fully hydrated concrete specimen is a difficult process. It typically requires a scanning electron microscope (SEM) analysis of the hydrated paste within the concrete. In addition, certain assumptions must be made. Fortunately, an easier way to characterize the variability in the water:cement ratio, and also the overall quality, is to make compressive strength measurements. Compressive strength measurements can be obtained from a straightforward test procedure and are the default means of quality control at the time of construction. Moreover, for a nuclear structure, the compressive strength measurements at the time of construction should have been recorded, and can serve as an indirect measurement to complement compressive strength testing at the time of entombment.

2.3.3 Indirect estimation

It is difficult to estimate the water:cement ratio without either the original specified mixture design or strength tests. The water:cement ratio could be inferred from permeability measurements, but the relationship is not as reliable as for compressive strength.

2.4 Permeability

The permeability of the intact portion of the concrete is probably the single most important parameter for assessing the future performance of an engineered barrier system. Typically, the permeability of concrete is on the order of 10^{-17} m^2 to 10^{-18} m^2. Although the measurement of concrete permeability has been reported in the concrete materials literature, measurements on specimens with low water:cement ratios having exceedingly low permeabilities might have to rely on novel dynamic techniques developed for geological research [8, 9].

The permeability of concrete is a strong function of the water:cement ratio (w/c). Unfortunately, even at a fixed value of w/c, the measured permeability of various concretes can still vary over orders of magnitude [10]. Therefore, although knowing the w/c