Discussion of the paper "Air permeability of concrete containing fly ash" by Ainim Xu, Nordic concrete research 1/1994

Permeability to gas is a very useful material property in order to predict durability aspects or material composition. I would like to make two comments on the paper, one regarding the influence of the pressure gradient and a second concerning the moisture content on permeability.

Influence of the pressure gradient on permeability:
The decrease of permeability with increasing pressure gradient is a well known phenomena, which was discovered by Kundt & Warburg (1875). Klinkenberg (1941) used this phenomena to explain the apparent difference between the permeability to gases and the permeability to liquids of rocks. Jacobs (1994) showed for cementitious materials the importance of this phenomena on permeability to gas. The decrease in permeability can be explained with the following thaughts:
Consider a straight tube with a diameter >> as the mean free path of the gas molecules. According to the law of Hagen Poiseuille for the gas flow in the tube the gas molecules at the wall of the capillary do not contribute to the gas flow. Their velocity is zero. According to Kundt & Warburg this is not correct. These molecules have a velocity > 0. Hence the gas flow is larger than calculated by the law of Hagen-Poiseuille. The contribution of this additional transport decreases with increasing mean free path of the gas molecules and therefore decreasing pressure. This phenomena can be seen experimentally when the permeability through dried porous materials is determined, especially when permeability is relatively low (e.g. less than 10^{-15} m^2). It was suggested by Klinkenberg that the material property permeability to gas is obtained by plotting the reciprocal mean gas pressure versus the permeability. A straight line is obtained and extrapolating this relationship to infinite pressure (intersection with y-axis) gives the material property permeability. In general the slope of the line decreases with increasing permeability. In the following figure this was tried for the permeability values presented by Xu in figure 2. In the table the data for the linear regression are given.

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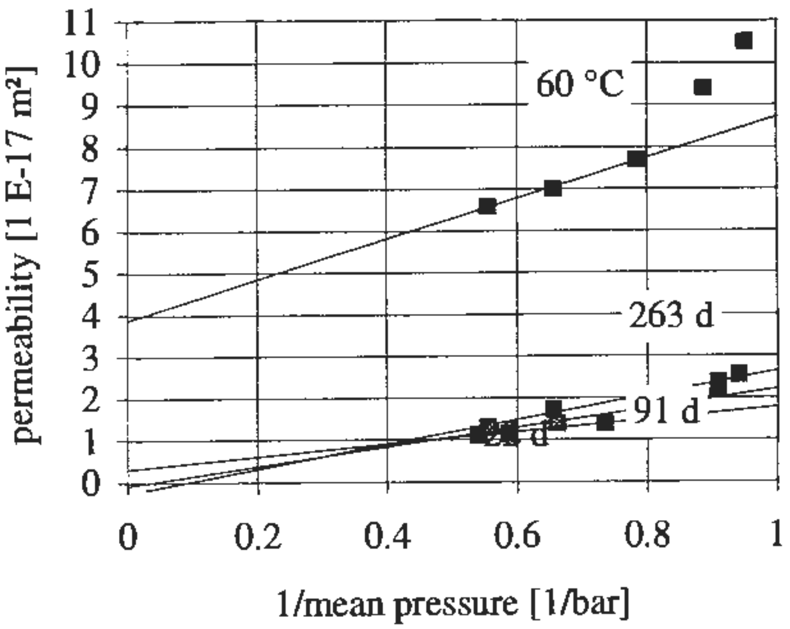

Figure: Permeability as function of the reciprocal mean gas pressure.

For the sample dried at 60 °C a good correlation is obtained when the two lowest pressure points were neglected. In Jacobs (1994) it was found typically for wet conditions that the coefficient of correlation is low and/or the intersection with the y-axis is at negative numbers. For dry conditions and well working equipment high coefficients of correlation were obtained (in general > 0.99). The deviation of the correlation with the permeabilities determined at low inlet pressures can be probably caused by no steady state measurement or/and an inaccuracy when determining permeability at low pressures. E.g. it could be shown that right at the beginning of a permeability test permeability was influenced by the different viscosities of the measuring fluid and that in the pores. Permeability should be measured for a wide set of inlet pressures (e.g. 0.5 to 5 bars). If this is not done a relatively good correlation can be obtained for rather similar inlet pressures and sometimes wet conditions (see 22 d measurement).

Table: Data obtained by a linear regression between the reciprocal mean gas pressure and the permeability.

storage conditions	coeff. correlation	slope	y-intersection
60 °C	0.993	4.838	3.882
22 d	0.981	1.455	0.317
91 d	0.794	2.288	-0.079
263 d	0.917	2.908	-0.266

Influence of the moisture content on permeability

As Xu showed the very strong influence of the moisture on the permeability is the greatest disadvantage. It was stated that moisture conditions obtained due to drying at elevated temperatures lead to no natural moisture conditions. The advantage of this drying process is the determination of the material property permeability. Saturation-permeability relationships are shown in Jacobs (1994) and indicate that for normal concretes differing only in the w/c ratio the dependency of the permeability to gas from the saturation is similar. These relationships are not always known and it should kept in mind that it takes several months or years to reach a certain predefined moisture equlibrium for cementitious materials with a typical thickness of 5 cm. Therefore a comparison between different materials is only possible when the material property permeability is determined. This can be achieved within short time by drying at elevated temperatures.

References:

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