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# Project Summary

# Laboratory Assessment of the Permeability and Diffusion Characteristics of Florida Concretes: Phase I. Methods Development and Testing

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**The ability of concrete to permit air flow under pressure (permeability) and to permit the passage of radon without any pressure difference (diffusivity) has not been well determined. To establish a standard concrete mix and its maximum radon-resistant placement, these parameters needed to be quantified and their relationship to concrete's physical properties evaluated. The concrete testing consisted of separate permeability and diffusivity measurements and a set of preliminary measurements to determine the size, weight, and porosity of each sample. Ten concrete samples were tested. Cylinders represented one of the four general types of concretes manufactured in Florida. Permeability was measured with a device developed for the project using custom software. The diffusion coefficient was determined with a system developed by and purchased from Rogers and Associates Engineering Corporation. Two of the samples had measured permeabilities 100 times greater than the other samples due to defects in the concrete. All of the correlations of the various physical parameters were investigated, but there were insufficient data to confidently determine any correlations. The most significant fault in this phase of the research was the lack of unbiased, representative concrete slab samples.**

***This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).***

## Introduction

Much of Florida's natural soil and the sand recovered from the phosphate mining/beneficiation process there contain significant quantities of radium. Buildings constructed on these high-radium soils have been found to contain elevated radon levels.

To decrease elevated radon levels, Florida's legislature instructed its Department of Community Affairs (DCA) to develop new construction standards for radon-resistant buildings, primarily slab-on-grade constructions.

It is well known that concrete slab is the primary barrier to radon entry. But the extent of its ability to permit air flow under pressure (permeability) and to permit the passage of radon without any pressure difference (diffusivity) has not been well determined. To establish a standard concrete mix and its maximum radon-resistant placement, these parameters needed to be quantified, and their relationship to concrete's physical properties evaluated.

Concrete testing consists of separate permeability and diffusivity measurements and a set of preliminary measurements to determine the size, weight, and porosity of each sample. After preliminary tests are completed, each sample is mounted in a 4-in.* long section of 4-in. schedule 80 wrought steel pipe. The concrete remains in this pipe for both tests.

Ten concrete samples were tested and divided into two groups. The first group

* 1 in. = 2.54 cm.

consisted of two Rogers and Associates Engineering Corporation (RAECORP) samples that were cored from two different compression test cylinders. The remaining eight samples (the second group) were cored from four compression test cylinders (two samples from each cylinder) from the Florida Concrete and Products Association (FC&PA). Each compression test cylinder represented one of the four general types of concretes manufactured in Florida. The four compression test cylinders were made in Jacksonville, Tampa, Orlando, and Miami.

After the cylinders were received, they were logged in on a sample custody form. Entries included identifying marks. The RAECORP samples had already been reduced to the nominal testing size, 4-in. diameter by 2-in. thick. The three, larger, FC&PA cylinders required coring and slicing to produce the nominal sample size; the smaller, 4- by 8-in. cylinder only required slicing. Two of the cylinders were cored on site. The remainder of the coring and slicing was performed by Lipscomb Concrete Cutting Company of Raleigh, NC.

Sample permeability was measured with a device developed for this project. The sample holder's open end was sealed airtight into the permeability test fixture using Mortite, a non-hardening, clay-type sealant. A top plate kept the sample holder sealed to the fixture. Compressed air at 25 psi* (nominal) pressurized the space enclosed by the test fixture and the bottom side of the concrete. The pressurizing valve was closed, and a pressure-sending unit measured the pressure in the sealed volume. As the air escaped through the concrete, the pressure decreased.

The diffusion coefficient was determined with a system developed by and purchased from RAECORP. The method uses uranium mill tailings as a strong emitter of radon gas. The tailings are in a 30-gal.** drum with a fitting built into the lid, which accommodates the sample holder. The sample holder is mounted in the fitting, and the detector assembly is mounted on top of the holder. After the background count rate is measured, the valve is opened between the drum of radon gas and the bottom surface of the concrete sample. The scalar ratemeter counts and produces a paper record of the number of counts per interval. When the count rate stops increasing, the radon in the drum and in the space above the concrete has reached equilibrium. The valve is closed, and the sample holder and detector apparatus are disassembled.

The permeability time-versus-pressure data were analyzed by software written for this permeability determination method. The software also provided the automatic data collection system. Usually, data were collected from the pressure sender every 10 sec. Then, six of the data points were averaged to produce a raw data point every 1 min. This could be varied; for some of the high permeability concrete samples, raw data points were saved each second with no averaging. The sampling technique allowed more data to be collected and improved the standard deviation.

The physical parameters of the test (air temperature, sample thickness, sample diameter, and volume under pressure) were used to calculate the permeability coefficient. The software requested the data as measured, then converted them to the appropriate units. The errors in each parameter were used to determine an estimated standard deviation for the calculated permeability coefficient. The results were written to a data file in a format suitable for printing.

RAECORP software was used to determine the diffusion coefficient. The software uses 10 pairs of data points from the breakthrough region of the alpha activity data. For this work, 10% offsets from the baseline and the equilibrium level were used to determine the breakthrough region.

Within this region, 10 data points, evenly spaced in log time, were selected. The next highest adjacent data point was used as the second data point of the pair. The first data point of the pair was used to calculate the diffusion coefficient. The second data point was used to estimate the standard deviation of the diffusion coefficient.

The permeability and diffusion coefficients are graphically illustrated in Figures 1 and 2. The permeability coefficients for Samples 2a and 2b are very high because of defects in the concrete.

The air seemed to flow primarily from a set of pores near the center. It is possible that only a few through-connected pores were responsible for the increased permeability, and the remainder of the sample had a much lower permeability. Even if that were the case, a distribution of such pores in a slab would significantly alter the slab's overall effective permeability.

But Sample 2 does not deviate from the range of the other samples in the diffusivity graphs. Sample 4, however, is higher in both the pore space and bulk coefficients.

The data quality for this project met all the data quality objectives listed in an EPA-approved Quality Assurance Project Plan (QAPP). All 10 samples were collected and analyzed (except for the density on samples C000 and C001); the results are acceptable, within the limitations of this project. The limitations of this research were that these measurements of concrete had not been performed before on this scale, and that the permeability

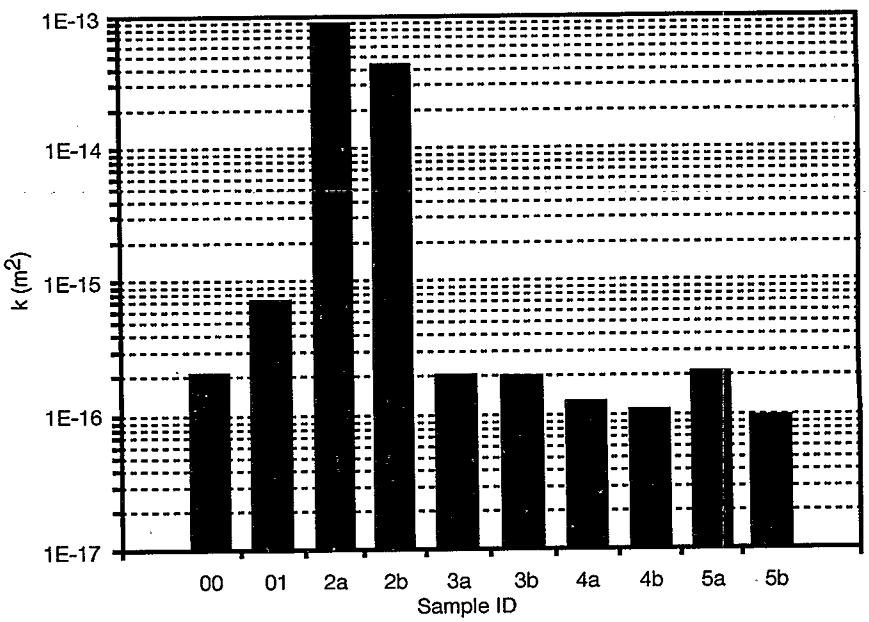


***Figure 1.** Permeability coefficients.*

* 1 psi = 6.89 kPa.

** 1 gal. = 0.0038 m³.

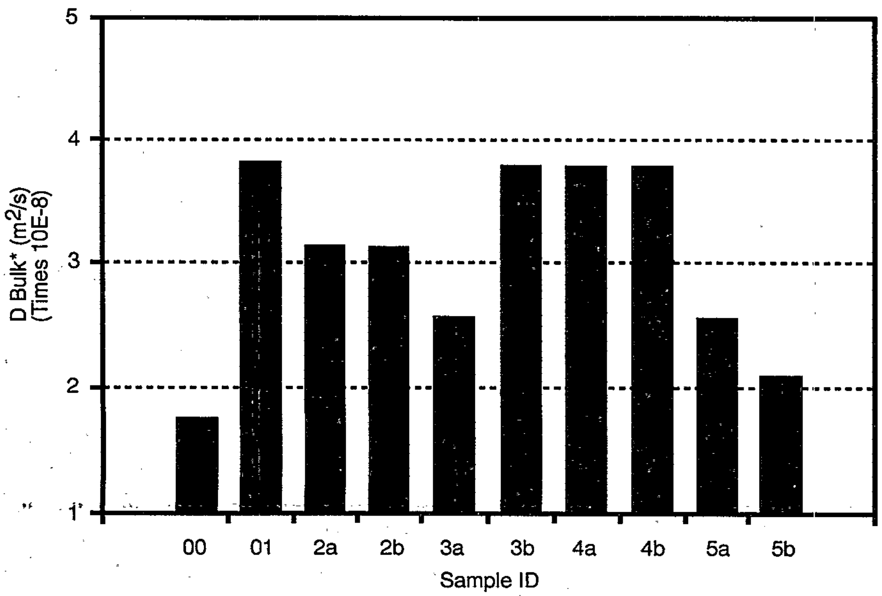


***Figure 2.*** *Bulk diffusion coefficients.*

test system was a new method developed for this project.

Because the permeability test was a new method (there were no available data on the permeability of concrete, and there was no test standard for calibration purposes), it is not possible to calculate the percent difference between the actual and measured permeability values. The data collected in these tests compare favorably (order of magnitude) with the expected permeability coefficients. The limiting factor in the permeability test is the system leak rate. This leak rate imposes a minimum detectable limit of $10^{-20} m^2$, which is a factor of 10,000 lower than the concrete samples measured.

The objectives of Phase I of this project have been met. The permeability and diffusion coefficients of concrete can now be measured. Compression test cylinders of concrete from the four representative areas of Florida have been processed and analyzed. The correlations of the various physical parameters were investigated, although there were insufficient data to confidently determine any correlations.

The most significant fault in this phase of the research was the lack of unbiased, representative concrete slab samples. Although the compression test cylinders were intended to represent the actual concrete mix from which the sample was drawn (in accordance with the applicable ASTM standard), a compression test cylinder will never accurately represent an as-poured slab because it does not include the effects of on-site water addition, finishing and curing practices, and other procedures.

The Phase I method of slicing cores into 2-in. thick sections further removed the samples from representing typical slab concrete. The correlation plots do indicate some trends in the data, but the lack of reliability and representativeness of the concrete cylinders does not allow definitive correlations to be determined. That the various physical parameters should correlate to the coefficients is evident and reasonable, but not significantly so, based on these data. The cause and meaning of the Sample 2 and 4 outliers have not been determined.

Further analysis of unsliced concrete cores from real slabs would help to obtain reliable data on the mix design. Mixing design data and on-site practice data should help meet the ultimate goals of this project.

A larger number of samples also would provide better, more significant data. The recommended minimum sample is two cores from four slabs, from each of the four major areas in Florida with the mix design data and, if possible, the on-site treatment. Additionally, one old concrete core from each of the four areas could be collected and included in the data base as historical data. Nationwide samples could be considered for additional support for the data base.



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*The complete report, entitled "Laboratory Assessment of the Permeability and Diffusion Characteristics of Florida Concretes: Phase I. Methods Development and Testing," (Order No. PB94-162781; Cost: $27.00, subject to change) will be available only from:*
*National Technical Information Service*
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