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PRECONDITIONING IN SITU CONCRETE FOR PERMEATION TESTING

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ABSTRACT

This paper investigates the application of a vacuum technique for preconditioning concrete in-situ prior to permeation tests. Cover Concrete Absorption Test (CAT) and Figg Air Permeation Index Test (API) were applied after vacuum drying of concrete. The application of vacuum using ISAT cap did not lead to satisfactory results with these tests. However, direct application of vacuum to CAT and API heads prior to testing resulted in improvement of the reproducibility of the permeation indices obtained from these tests.

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INTRODUCTION

The damage to cover concrete in existing structures usually involves movement of aggressive fluids from the surrounding environment into the concrete followed by physical and/or chemical actions leading to irreversible deterioration [1]. Therefore the in-situ assessment of permeation characteristics of cover concrete is important from the durability point of view.

A great number of permeation tests are available in the literature (e.g. ISAT [2]; Figg permeation methods [3] and CAT [4]). These tests can be used for quality control and compliance testing, during and immediately after construction, or to check the residual durability of existing structures [5] and [6]. However, the major problem which limits the application of these tests in-situ is their sensitivity to the moisture condition of the test concrete. Therefore, the moisture condition has to be determined or set to a predefined standard prior to testing.

A new technique for preconditioning concrete, both in-situ and in the laboratory prior to testing, was developed [7]. It is based on applying vacuum to a modified ISAT cap, monitoring the progress of drying using silica gel indicator, and was successfully reproducible when tested with ISAT.

This paper reports the results of further investigation of the application of the vacuum drying system with CAT and Figg air permeation test. The ultimate aim was to improve the application of these tests in-situ (i.e. the reliability and reproducibility of results).

BACKGROUND TO THE COVERCRETE PERMEATION TESTS

Figg Air Permeation Index (API)

Figg [3] developed a test for air and water permeability which involved a hole drilled into the concrete surface. Figg's air permeability test method is based on applying low pressure to the drilled hole in the concrete through a hypodermic needle using a hand generated vacuum. In order to improve the repeatability, Cather et al [8] modified the dimensions of the hole. Further modifications of the test cavity dimensions and applied pressure level were made by Dhir et al [4], which resulted in a reduction of variation from 27% to 11%. This version was used in the investigation and is described below.

A hole of ϕ 13 x 50 mm is drilled into the concrete. After thorough cleaning, the hole is plugged to a depth of 20 mm from the outside surface by polyether foam and then sealed with a catalysed silicon

rubber. When the rubber had hardened, a hypodermic needle is pushed through the silicon rubber plug (Figure 1). Connections are then made to the hypodermic needle, to introduce air under vacuum using a hand-held digital electronic manometer. The vacuum applied was 55 kPa below atmospheric pressure and the purmeation index is taken as the inverse of the time elapsed in seconds for the decay of the applied pressure from 55 to 45 kPa below atmosphere [9].

Covercrete Absorption Test (CAT)

In an effort to improve the reliability and the repeatability of the Figg water permeability test [3], Dhir et al [4] developed the Covercrete Absorption Test. The test assesses the absorption characteristics over the full depth of a 50 mm hole drilled in the cover concrete. The CAT method has the advantage of not being influenced by localized surface effects such as carbonation of the outer few millimetres of the concrete (Dhir et al, 4). A hole of ϕ 13 x 50 mm is drilled on one of the surfaces and a gasketted cap with an internal diameter of 13 mm clamped to the test specimen with the end of the inlet tubing (ϕ 3 x 20 mm) about 2 mm above the bottom of the hole (Figure 2). De-ionized, de-aired water is fed into the hole from a reservoir, then through the outlet of the cap into a capillary tube. The water pressure is maintained at 200 mm head above the centre of the hole. The covercrete absorption is defined as the volume of water absorbed by concrete unit area in one minute after the tap is shut off ten minutes from starting the test.

PROCESS OF VACUUM DRYING

The process operates by removing moisture under vacuum from the surface of concrete, with equilibrium being defined by a suitable humidity indicator. A Full description of the method and its application to ISAT is detailed elsewhere [7]. It was found that vacuum up to 10 mbar is suitable for drying in a reasonable time period, and 3 gm of silica gel is sufficient as a drying indicator [10].

Pilot trials were conducted in order to test the vacuum system prior to CAT and API. The vacuum technique was used for preconditioning test concrete (100 mm cubes) by drilling holes ϕ 13 x 50 mm depth and subjecting the test specimens to different moisture conditions. The vacuum was applied as described by Dhir et al [7] and the preconditioned concrete specimens were tested using both CAT and API tests immediately after the silica gel colour turned blue. The results obtained from both CAT and API test were not reproducible (i.e. the vacuum preconditioning method failed to give similar results regardless the moisture history of the test concrete).

Reproducibility was improved by applying the vacuum directly to the hypodermic needle prior to the API test and to the CAT cap prior to CAT measurements. This is probably because of the concentration of vacuum on the immediate test area in contrast with the larger area under the ISAT cap. This leads to reduction in the leakage around the cap. Splitting cubes after preconditioning by vacuum showed that the drying front shape (see Figure 3) is similar to the wetting front shape obtained by applying the absorption test [10]. Therefore, preconditioning the test area using CAT cap or the hypodermic needle in CAT and API tests respectively leads to a drying of the concrete volume which will be tested by the specific permeation test.

APPLICATION OF THE VACUUM SYSTEM PRIOR TO PERMEATION TESTS

Further Development of the Test Apparatus

A separate perspex silica gel chamber was developed for placing in the vacuum line in order to monitor the progress of drying since it was not possible to use the same arrangement as with the larger ISAT cap (see Figure 4 (a)). Figure 4 (b) shows the application of the vacuum through a hypodermic needle to precondition concrete prior to API test.

Preparation of Test Samples

Two concrete mixes with design strengths of 35 and 60 N/mm^2 were used (mix proportions are detailed else where [7]). The test specimens, 100 mm cubes, were cast and kept under wet hessian for 1 day before demoulding. Subsequently, two curing conditions were used: water curing at 20°C; and air curing at 20°C, 55% RH, until testing at 28 days.

Experimental Design

It was suggested [7] that the effective preconditioning method should produce similar permeation results from similar samples (i.e. samples with equal mix proportions and curing regimes) regardless of the initial moisture content of these samples. The test program was therefore carried out on sets of samples taken from a mix which had been cured in an identical manner and then brought to different moisture contents

before preconditioning. The effectiveness of the vacuum drying technique in giving similar results from each set was then compared with BS 1881 [11] drying methods (2 days drying in the laboratory and drying in oven at 105°C to constant weight) using the variance ratio test known as F test. The methods used to bring samples to different moisture contents were as follows:

1. Vacuum saturation for 2 hours at 10-15 mbar (typical weight gain from air curing = 2%).
2. Six hours in water (typical weight gain from air curing = 1%).
3. Drying in laboratory air for 28 days.

For each grade, curing condition, moisture content and drying method, two samples were tested giving a total of 72 samples for each test.

RESULTS AND DISCUSSION

The results for CAT and API test are shown in Tables 1, 2 and Figures 5, 6, respectively. The coefficient of variation (V = the standard deviation divided by the mean) has been calculated from the CAT_{10} and permeation index results from each moisture condition, i.e. a total of 6 samples in each case.

The statistical F test is used to compare the variability in the set preconditioned by vacuum with that in the sets preconditioned in the oven or in the laboratory for 2 days. Because the means of the sets were not equal, the coefficient of variation is used to calculate the variance ratio (F ratio) [12]. The two sided F test was applied on the null hypothesis that the variation in results caused by the different moisture contents was the same for the different preconditioning methods. The critical value for the variance ratio is called the F statistic. The F statistic for 95% confidence limits is 7.15 (both degrees of freedom being 5).

Generally, the variation of the results was higher than that for the ISAT results reported previously [7]. This is probably because of the nature of the tests. CAT and API are carried out in drilled holes in concrete, and therefore are less sensitive to variations in pore structure due to the heterogeneous nature of the test cavities (locations of big aggregates in a small test hole, microcracking due to drilling, etc., [13]).

The F ratios are shown in Tables 1 and 2 for each of the four mix/curing combinations. It can be seen that the coefficients of variation of the vacuum dried samples were significantly less than those for the two day room dried samples except for water cured concrete (60 N/mm^2), i.e. the null hypothesis can not be rejected for concrete of design strength 60 N/mm² (cured in water). It can be argued that the sensitivity of CAT and API test to changes in concrete decreases with the increase of concrete design strength.

Figures 5 and 6 show that the oven drying method produces highest permeation results. The oven drying method gave lowest coefficient of variations for CAT. However, coefficient of variations for API values obtained after oven drying were comparable to those obtained after vacuum preconditioning. It is clear from Figures 5 and 6 that the error bars, represent the mean ± standard deviation, are overlapped for water cured concrete of design strength 35 N/mm² and air cured concrete of design strength 60 N/mm² regardless the preconditioning method used. This again can be attributed to the nature of the tests themselves not to the method of preconditioning.

CONCLUSIONS

1. The vacuum technique can be applied successfully prior to CAT and API test with slight modification to the apparatus in order to give reproducible results.

2. The sensitivity of the technique with the CAT and API test is less than that with ISAT. This is because of the nature of these tests.

REFERENCES

1. BASHEER P A M, MONTGOMERY F R and LONG A E. The "Autoclam Permeability System" for Measuring the In-situ Permeation Properties of Concrete. Conference Proceedings of the British Institute of Non-Destructive Testing, 14-16 April 1993, the University of Liverpool, pp. 235-259.

2. LEVITT M. Non-Destructive Testing of Concrete by the Initial Surface Absorption Method. Proceedings of Symposium on Non-Destructive Testing of Concrete and Timber, Institute of Civil Engineers, London, 1969, pp. 23-36.

3. FIGG J W. Methods of Measuring Air and Water Permeability of Concrete. Magazine of Concrete Research, Vol. 25, No. 85, 1973, pp. 213-219.

4. DHIR R K, HEWLETT P C and CHAN Y N. Near Surface Characteristics of Concrete: assessment and development of in-situ test methods. Magazine of Concrete Research, Vol. 39, No. 141, 1987, pp. 183-195.

5. BUNGEY J H. The Testing of Concrete in Structures. Surrey University Press, London, 1989, pp. 137-161.

6. SCHONLIN K and HILSDORF H. Permeability as a Measure of Potential Durability. ACI SP 108, 1988, pp 99-115.

7. DHIR R K, SHAABAN I G, CLAISSE P A and BYARS E A. Preconditioning In- Situ Concrete for Permeation Testing, Part 1: initial surface absorption. Magazine of Concrete Research, Vol. 45, No. 163, 1993, pp. 113-118.

8. CATHER R, FIGG J W, MARSDEN A F and O'BRIEN T P. Improvements to the Figg Method for Determining the Air Permeability of Concrete. Magazine of Concrete Research, Vol. 36, No. 129, 1984, pp. 241-245.

9. DHIR R K. and BYARS E A. PFA Concrete: Permeation Properties of Cover to Steel Reinforcement. Cement and Concrete Research, Vol. 23, 1993, pp. 554-566.

10. SHAABAN I G. Fluid Transfer and Related Durability Aspects in Structural Concrete. Internal Report, University of Dundee, IGS/1, 1993.

11. BS 1881: Part 5 (1970) Methods of Testing Hardened Concrete for Other than Strength.

12. KENNEDY J B. and NEVILLE A M. Basic Statistical Methods for Engineers and Scientists, 3rd Edition, Harper & Row, New York, 1986.

13. PIHLAJAVAARA S E and PAROLL H. On The Correlation Between Permeability Properties and Strength of Concrete. Cement and Concrete Research, Vol. 5, No. 4, 1975, pp. 321-328.

Table 1 API results for different preconditioning methods

CONCRETE GRADE: N/mm^2	CURING	PRE-CONDITIONING	MEAN API, 1000/s	V of API, %	F-STATISTIC
35	Air	Vacuum dry	125	14.0	1.0
		2 day air	71	63.0	20.3
		Oven dry	143	12.0	1.4
35	Water	Vacuum dry	16	20.5	1.0
		2 day air	8	60.0	7.2
		Oven dry	26	8.0	6.6
60	Air	Vacuum dry	17.5	19.0	1.0
		2 day air	9	56.0	10.0
		Oven dry	33.3	8.4	5.1
60	Water	Vacuum dry	4.4	23.0	1.0
		2 day air	2.5	43.0	3.5
		Oven dry	6.7	9.5	5.9

Table 2 CAT results for different preconditioning methods

CONCRETE GRADE: N/mm^2	CURING	PRE-CONDITIONING	MEAN CAT_{10} x 10^{-2} ml/m^2/s	V of CAT_{10}, %	F-STATISTIC
35	Air	Vacuum dry	121.4	19.5	1.0
		2 day air	106.5	59.5	9.3
		Oven dry	185.0	12.5	2.4
35	Water	Vacuum dry	58.3	15.0	1.0
		2 day air	38.0	51.0	11.6
		Oven dry	110.0	11.0	1.9
60	Air	Vacuum dry	63.5	12.0	1.0
		2 day air	41.5	39.0	10.6
		Oven dry	115.0	8.0	2.3
60	Water	Vacuum dry	16.0	10.0	1.0
		2 day air	14.0	24.0	5.8
		Oven dry	85.0	5.0	4.0

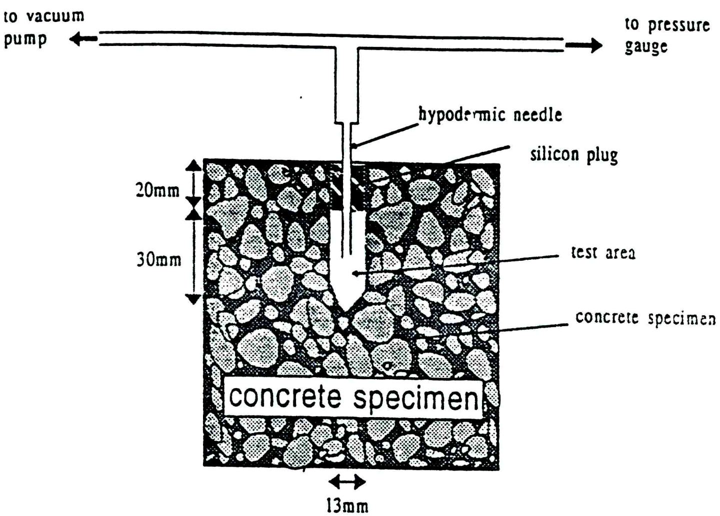
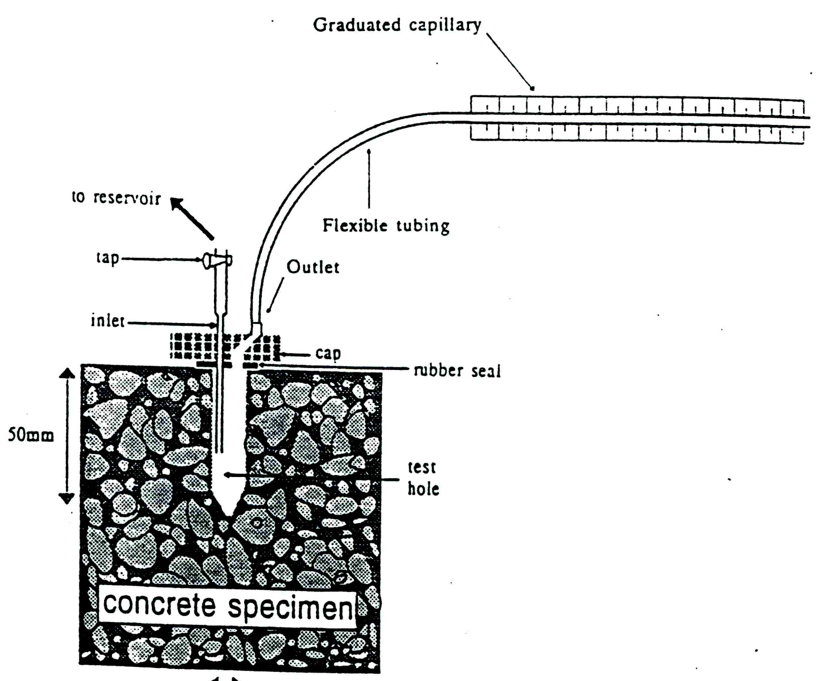


Figure 1 Schematic arrangement of API test



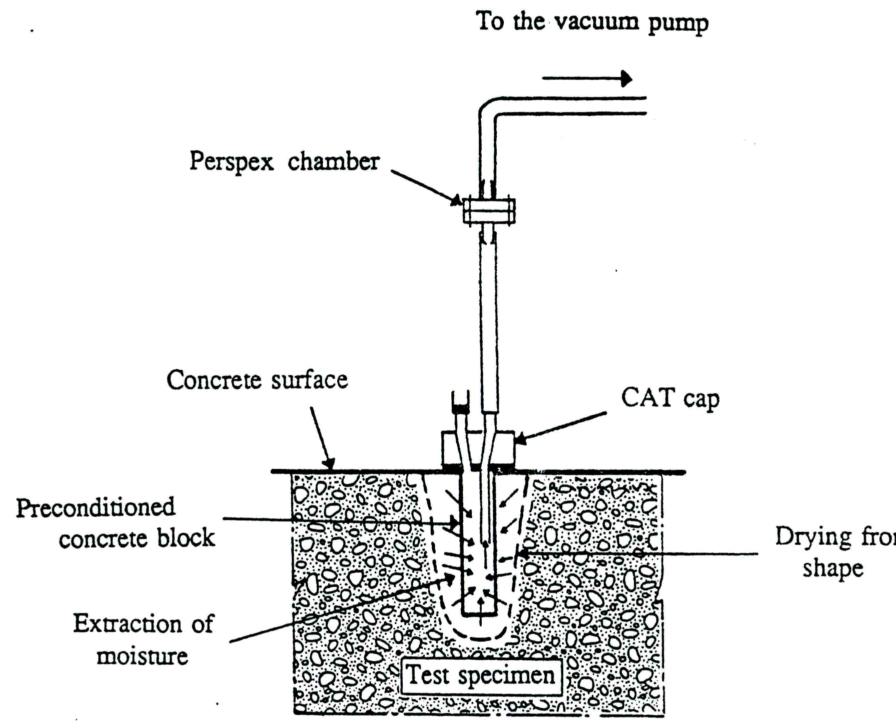
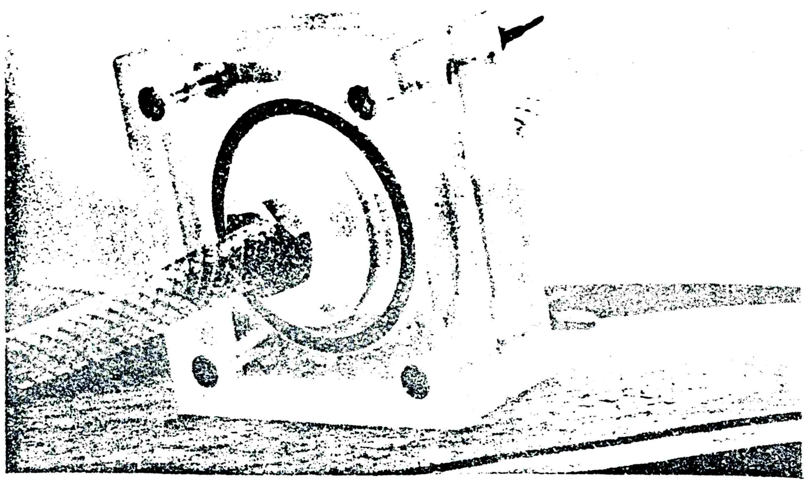
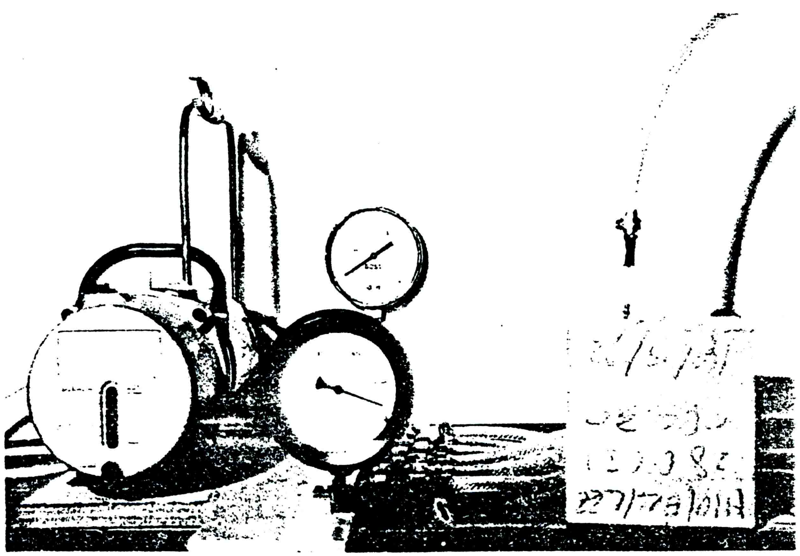


Figure 3 Vacum drying front shape for CAT



(a) General view of the vacuum chamber



(b) Preconditioning concrete prior to API test

Figure 4 Application of vacuum system for concrete permeation tests

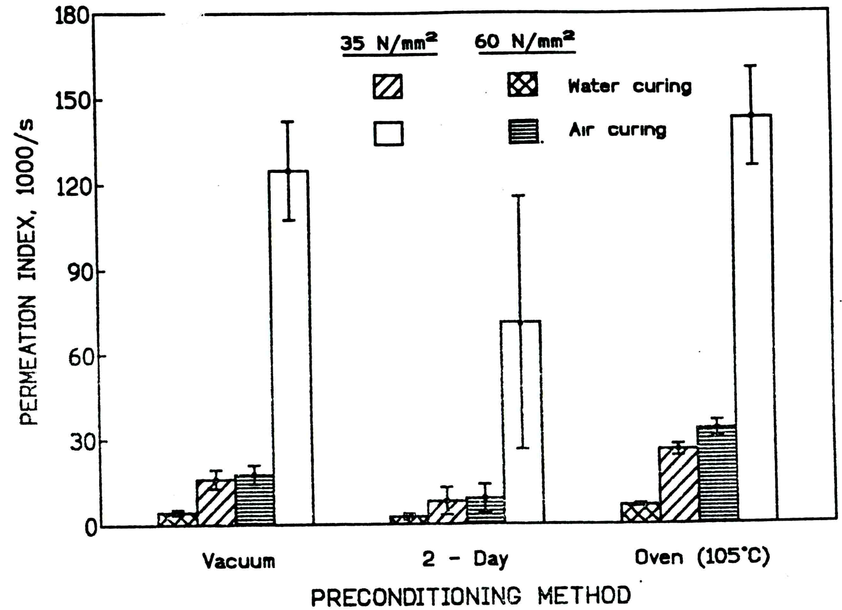


Figure 5 Effect of preconditioning method on API results.

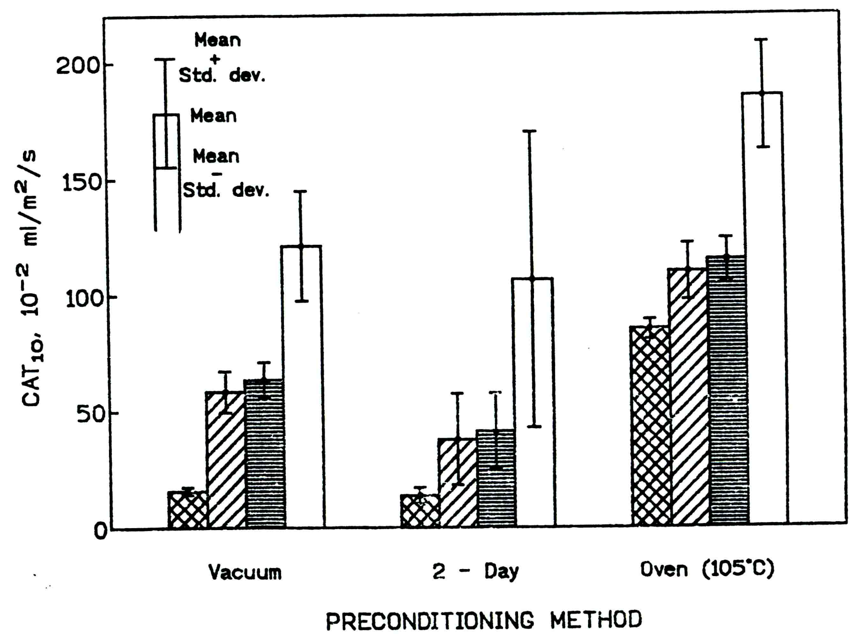


Figure 6 Effect of preconditioning method on CAT results.