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Leakage of Gas through Cracked Concrete Walls

Fuite de gaz à travers une paroi en béton fissuré

Gasaustritt aus gerissenen Betonwänden

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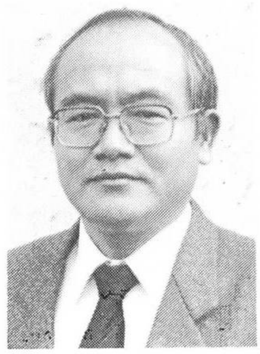
Toshiro Suzuki, born 1936, received his doctor's degree from the University of Tokyo in 1963. He was awarded the Prize of the Architectural Institute of Japan for his studies on steel structures in 1981.



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SUMMARY
Basic experiments were carried out on gas leakage through a cracked concrete wall. The leakage rate of gas through a crack in a concrete wall was formulated as a function of the crack width, the differential pressure and the wall thickness.

RÉSUMÉ
Des essais fondamentaux ont été faits concernant la fuite de gaz à travers une paroi en béton fissuré. Le taux de fuite du gaz a été formulé en fonction de la largeur de la fissure, de la pression différentielle et de l'épaisseur de la paroi.

ZUSAMMENFASSUNG
Es wurden grundlegende Versuche über den Gastransport durch gerissene Betonwände durchgeführt. Der Gasaustritt aus einem Riss wird als Funktion der Rissbreite, des Differentialdruckes und der Wandstärke dargestellt.

1. INTRODUCTION

The air-tightness of concrete walls is important for nuclear-related facilities. A concrete wall has very high probabilities of developing cracks due to shrinkage, seismic forces or other factors. It is therefore essential to be able to predict the amount of gas which will leak through a cracked concrete. This paper discusses the degree of gas leakage through a cracked concrete wall. Basic experiments were carried out on gas leakage through a cracked concrete wall. The experiment was conducted using oxygen gas as the gaseous body, and was based on parameters consisting of the width of the crack, the thickness of the wall, the pressure differential across the wall, and the material of concrete. In this experiment, a single tensile crack was produced in an experimental wall. This paper discusses slower gas flow than that discussed in the references 1 and 2 .

2. EXPERIMENT

Eleven specimens listed in Table 1 were fabricated and tested. The specimen named 15G was made for leakage test of an idealized crack. The idealized crack was made by using two parallel glass plates.

Table 1 List of specimens

Name	Wall Thickness	Concrete	Fine Aggregate	Coarse aggregate
60-A-1	60 (cm)	A	Sand 5 (mm)	Crushed Gravel 10 20 (mm)
60-A-2	60 (cm)			
30-A-1	30 (cm)			
30-A-2	30 (cm)			
15-A-1	15 (cm)			
15-A-2	15 (cm)			
30-B	30 (cm)	B	Sand 2.5 (mm)	Crushed Gravel: 10 25 (mm)
30-C	30 (cm)	C		Crushed Gravel: 2.5 15(mm)
15-D	15 (cm)	D		Spherical Aluminum: D=24.8(mm)
15-E	15 (cm)	E		Cubical Aluminum: 20×20×20(mm)
15G	15 (cm)	Specimen for leakage test of idealized crack. Idealized crack was made of two parallel glass plates.		

Table 2 Mix proportion of the concrete A

W/C (%)	Mix Proportion (kg/m^3)					Slump (cm)
	Water	Cement	Fine Agg	Coarse Agg	Admixture	
39.0	163	418	718	1023	1.045	8

Table 3 Mix proportion of the concrete B and the concrete C

W/C (%)	Mix Proportion (kg/m^3)					Slump(cm)	
	Water	Cement	Fine Agg	Coarse Agg	Admixture	30-B	30-C
41.4	170	411	883	938	——	20	15

Table 4 Mix proportion of the concrete D and the concrete E

W/C (%)	Mix Proportion (kg/m^3)					Slump(cm)	
	Water	Cement	Fine Agg	Coarse Agg	Admixture	15-D	15-E
39.1	156	400	1100	788	——	15	20

The mix proportion of the concrete A is shown in Table 2, the concrete B Table 3, the concrete C Table 3, the concrete D Table 4, and the concrete E Table 4. The sieve analysis curves of the aggregates used in the concrete A and the concrete B and C are shown in Fig.1. Two types of aluminum model gravel were used in the concrete D and E, spherical aluminum of 24.8 mm diameter in the concrete D, and cubical aluminum of 20x20x20 mm in the concrete E.

The specimen and the testing set up are illustrated in Fig.3. The specimen was notched so that a single crack would occur along the notch. Each specimen was prestressed with four PC bars at four corners of the specimen not to be cracked before testing. PC bars were also used to control the crack width during the leakage test.

Both notched sides of the specimen were gas proofed with gum, and two pressure boxes were set on the flat sides.

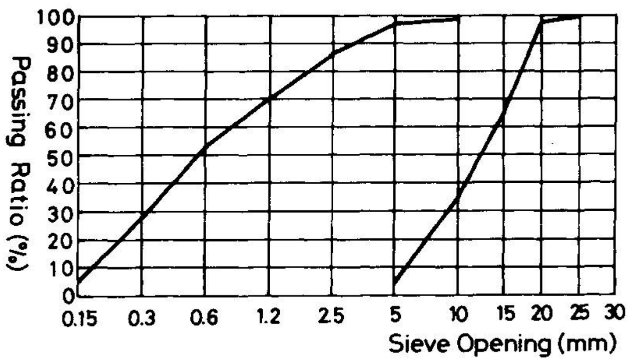


Fig.1 Sieve analysis curve of the concrete A

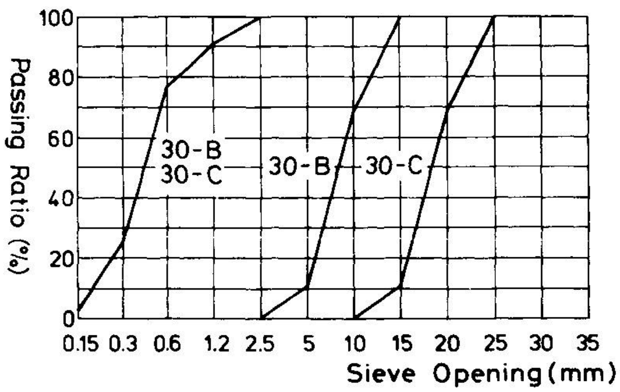


Fig.2 Sieve analysis curve of the concrete B and the concrete C

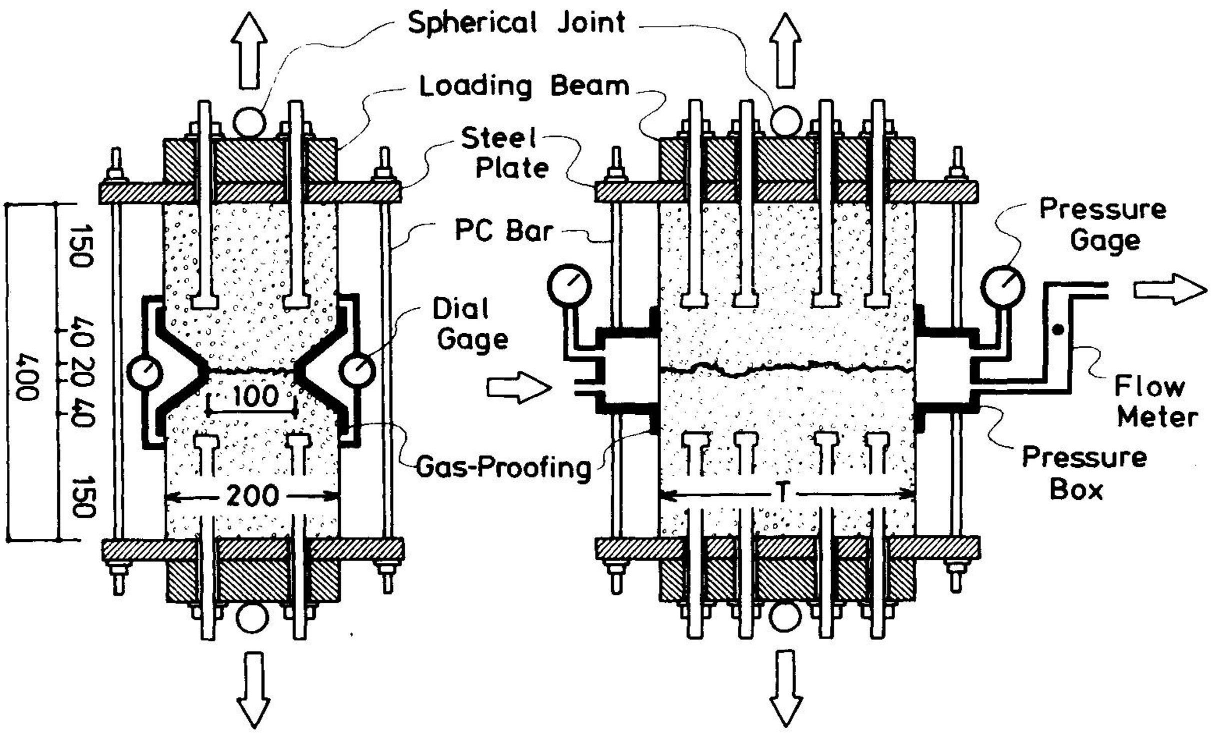
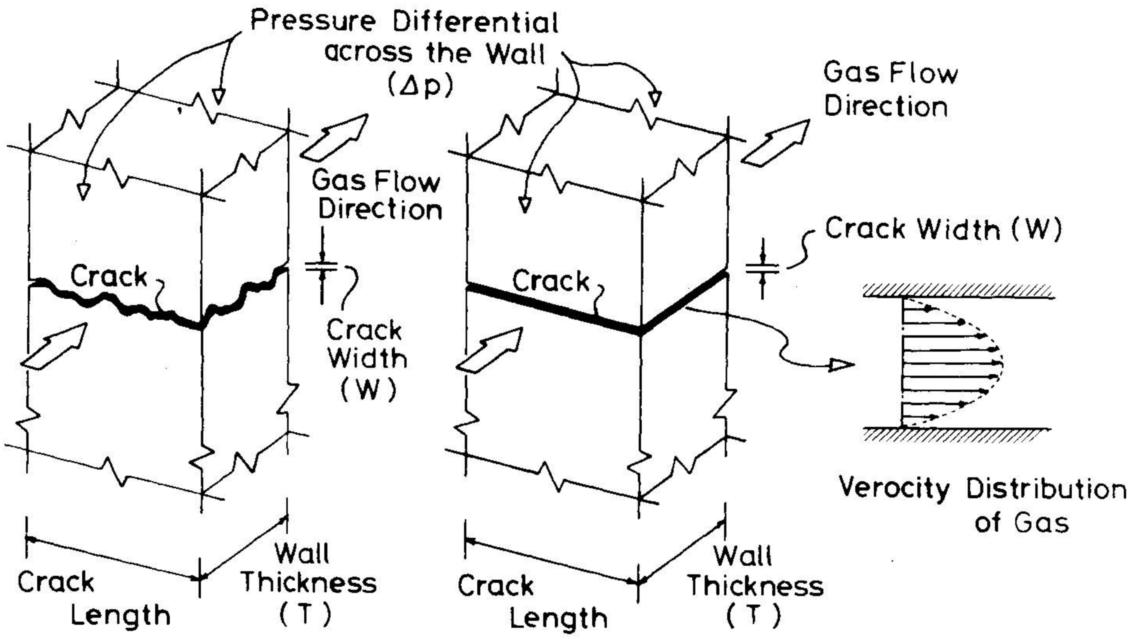


Fig.3 Specimen and testing set up



(a) Actual crack (b) Idealization of crack and gas flow

Fig.4 Idealization of crack and gas flow

Crack width was measured with four dial gages attached to four corners of the specimen. By fastening or loosing of PC bars, crack width was controlled till the values of four dial gages were almost equal.

After gas proofing was confirmed, the gas leakage test was carried out. The leakage rate Q was measured with the flow meters connected to the out flow pressure box.

3. EXPERIMENTAL RESULTS

Assuming that the crack surfaces are parallel plates and gas flow is slow as illustrated in Fig.4, the gas leakage rate can be expressed by equation (1) as two dimensional Poiseuille's flow

(1) $$Q = (1/12)W^3\Delta p/(\mu T)$$

where
- Q is leakage rate
- W is crack width
- Δp is pressure differential
- T is wall thickness
- μ is viscosity of gas

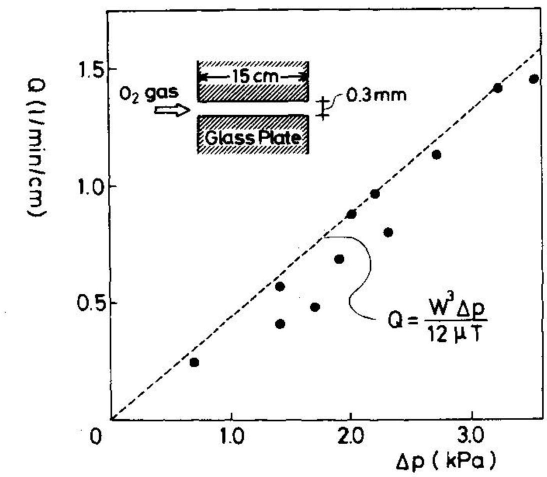


Fig.5 Relationship between Q(leakage rate) and Δp(pressure differential) of the specimen 15G

Leakage test of an idealized crack was carried out using the specimen 15G under the condition that W(crack width) was 0.3 mm and T(wall thickness) was 15 cm. The leakage test results of the specimen 15G are plotted in Fig.5. The experimental results coincided with equation (1) indicated by a dotted line.

Actual crack surfaces of the concrete are shown in Figs.6 - 10 and are far different from idealized one. The leakage test results of the concrete specimens, however, were arranged to the form of equation (2).

(2) $$Q = \alpha W^3 \Delta p/(\mu T)$$

Finally, the experimental results of all the concrete specimens could be described by equation (3).

(3)
$$\begin{aligned}
\alpha &= 2.04\times10^{-1}\ W + 3.06\times10^{-3} && \text{(concrete A)}\\
\alpha &= 1.16\times10^{-2} && \text{(concrete B)}\\
\alpha &= 1.46\times10^{-1}\ W + 0.34\times10^{-3} && \text{(concrete C)}\\
\alpha &= 4.18\times10^{-1}\ W + 5.44\times10^{-3} && \text{(concrete D)}\\
\alpha &= 3.50\times10^{-1}\ W + 2.04\times10^{-3} && \text{(concrete E)}
\end{aligned}$$
unit of W: cm

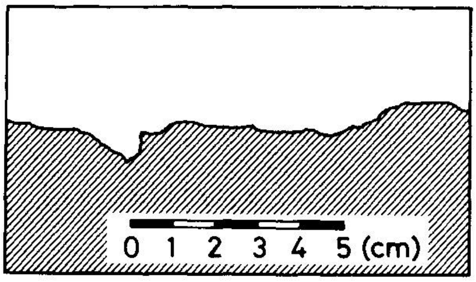


Fig.6 The crack surface of the concrete A

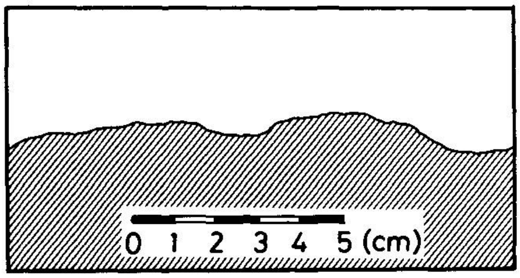


Fig.7 The crack surface of the concrete B

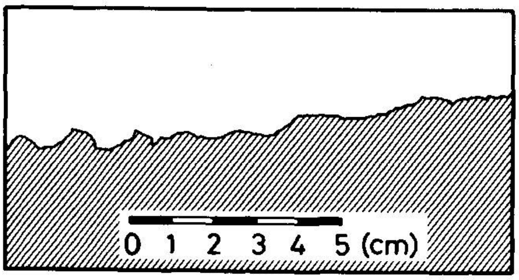


Fig.8 The crack surface of the concrete C

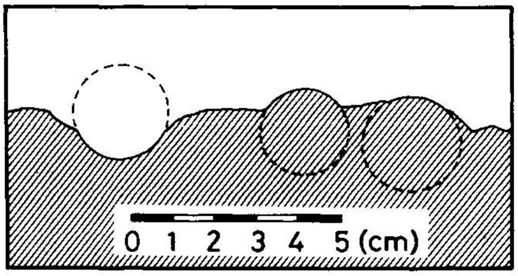


Fig.9 The crack surface of the concrete D

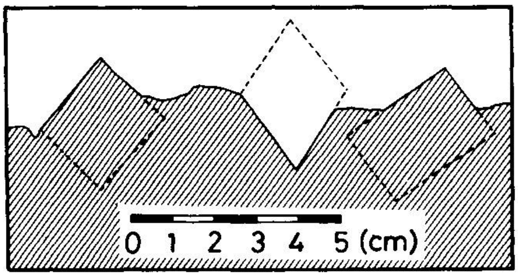


Fig.10 The crack surface of the concrete E

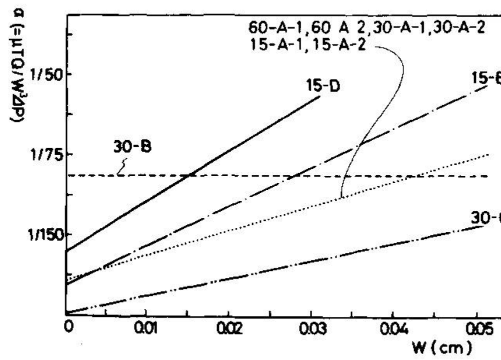


Fig.11 Relationship between α(=μTQ/WΔp) and W

The equation (3) is graphically represented in Fig.11. With regard to the concrete A(specimens 60-A-1,60-A-2,30-A-1,30-A-2,15-A-1, and 15-A-2), comparison of leakage rate calculated by equations (2) and (3) and measured values is shown in Figs.12 and 13. It can be concluded that the equations (2) and (3) are satisfactorily accurate.

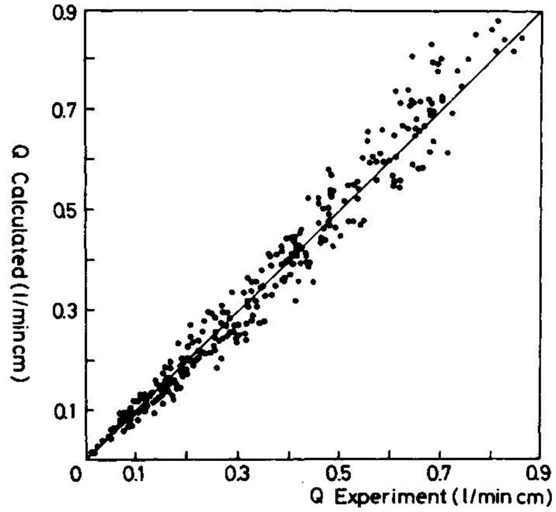


Fig.12 Relationship between Q calculated by eq.(2) and Q measured (60-A-1,60-A-2,30-A-1,30-A-2, 15-A-1,15-A-2)

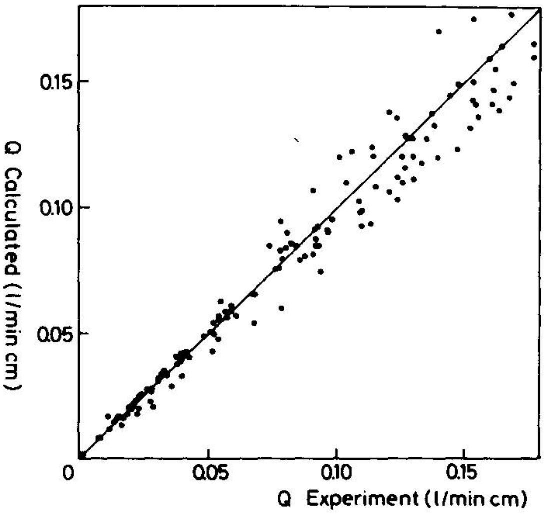


Fig.13 Relationship between Q calculated by eq.(2) and Q measured (60-A-1,60-A-2,30-A-1,30-A-2, 15-A-1,15-A-2)

4. CONCLUSIONS

1) Gas leakage rate through a crack of the concrete wall can be estimated by equation (2), when the gas flow is relatively slow.
2) To say the least, in the range of 0.8×10^5 Pa $\leqq$ p(absolute pressure) $\leqq 1.2 \times 10^5$ Pa , of Δp(pressure differential) $\leqq 0.2 \times 10^5$ Pa and of Re (apparent Reynolds' number) $\leqq 10^2$Pa, equation (2) is applicable. $Re=2\rho Q/\mu$, where ρ is the density.
3) The coefficient α in the equation (2) can be defined as a function of W. The coefficient function α depends on the irregularities of the crack and the roughness of the surface. The different function α should be defined for the different concrete.
4) The coefficient function α could be defined by the equation (3) for each concrete used in this experiment.

REFERENCES

1. Rizkalla,S.H.,Lau,B.L., and Simmonds,S.H., Air Leakage Characteristics in Reinforced Concrete. ASCE Journal of Structural Engineering Vol.110, No.5, May, 1984, pp. 1145-1165.
2. Tinker,J.,Del Frate,R., and Rizkalla,S.H., The Prediction of Air Leakage Rate through Cracks in Pressurized Reinforced Concrete Containment Vessels. Transactions of the 8th International Conference on Structural Mechanics in Reactor Technology, Vol.J(J1/7), 1985, pp. 25-30.
3. SUZUKI, T., and TAKIGUCHI, K., Leakage of Gas through Cracked Concrete Walls. The 9th International Conference on Structural Mechanics in Reactor Technology, 1987.
4. SUZUKI, T., and TAKIGUCHI, K., Fundamental Experiments on the Leakage of Gas through Cracked Concrete Walls. Transactions of Architectural Institute of Japan No.373, March, 1987 (in Japanese).