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Water Penetration of Cladding Components –
Results from Laboratory Tests on Simulated Sealed Vertical Joints of Wall Cladding

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Sealed Joint Water penetration Crack
Rainfall Test method Wall cladding

1. Introduction

The approach taken in this study provides some fundamental information on the nature of water entry at vertical joints for a simulated wall system when subjected to water penetration tests in which test conditions emulate heightened wind-driven rain loads.

2. Approach and Description of Water Penetration Test

2.1 Test parameters

An overview of possible test parameters is provided in Table 1; Fig.1 illustrates the joint configuration. Not all parameters given in Table 1 were tested in this study; only those directly influencing rates of water leakage were considered, specifically, crack opening size (function of joint strain; crack length) in relation to wind driven rain loads.

Table 1 Experimental test parameters

Environmental parameters		
Water deposition rate	1.6, 3.4, 4.0, 6.0L/ m^2·min	
Wind velocity pressure	Static pressure (0, 75, 150, 500, 1000, 2000 Pa)	
Façade conditions		
Joint type	Cross section	Single joint
	Plane	Linear vertical joint
Sealant	Type	Working joint
	Joint width	20 mm
	Joint depth	15 mm
	Backer rod	Yes
Movement	Joint strain	0%, 2.5%, 5%, 10%
Crack type	Crack condition	Yes or No
	Crack location 1	Linear joint
	Crack location 2	Adhesion failure
	Crack length	2, 4, 8, 16 mm

2.2 Test specimen

The test specimen is shown in Fig.2. The panel had a vertical joint located at the middle of the specimen that was sealed with a 1-part polyurethane sealant. The sealant was applied to a polyethylene backer rod having a diameter of 25-mm and cured in laboratory conditions (23°C) for 2 weeks before initiating the test. The panel assembly, and substrate to which the sealant was applied, was made of transparent acrylic sheathing. The back of the specimen was sealed with an adhesive tape.

2.3 Test apparatus

The water penetration tests were carried out using a recently developed test apparatus in which the quantity of water applied to the surface of the test specimen and the air pressure difference across the assembly can automatically be regulated.

Table 2 Test matrix for water penetration tests

Crack length	Joint displacement	Quantity of water (L/ m^2-min)			
(mm)	(mm)	1.6	3.4	4	6
No crack (0)	0, 0.5, 1, 2	-	-	-	6*
2	0, 0.5, 1, 2	6*	1**	6*	6*
4	0, 0.5, 1, 2	-	1**	6*	-
8	0, 0.5, 1, 2	-	1**	6*	-
16	0, 0.5, 1, 2	6*	1**	6*	6*

*6 tests at : 0, 75, 150, 500, 1000, 2000 Pa, **1 test at : 150 Pa

2.4 Test methods

The water penetration test method was summarized in Fig.3 and the test matrix is given in Table 2. The joint strain to the prescribed displacement was adjusted with a clamp. The rate of water deposition, pressure differential, and rate of water leakage was recorded automatically and the behavior of water leakage was verified by visual observation. Tests were carried out over a period of ten minutes for each test parameter.

3. Results from Laboratory Tests on Sealed Vertical Joints

3.1 Crack width related to joint movement and crack length

The results obtained from joint movement at prescribed displacements and the relation to crack width and crack length is

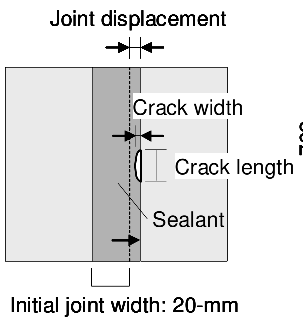

Fig.1 Sealed joint

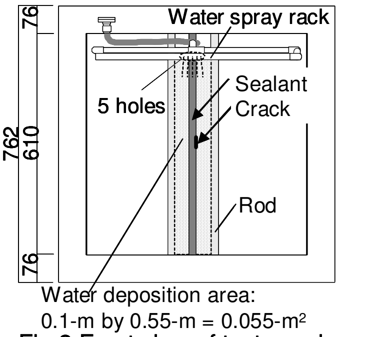

Fig.2 Front view of test specimen

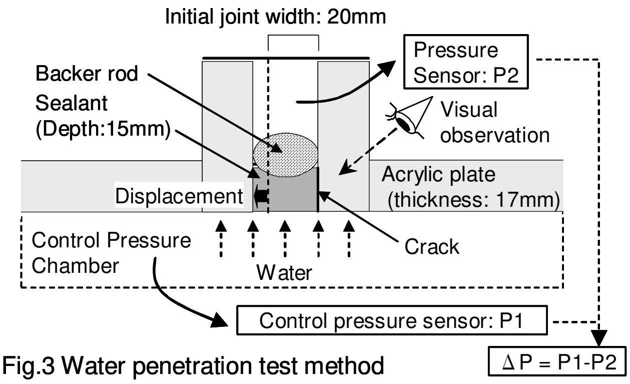

Fig.3 Water penetration test method

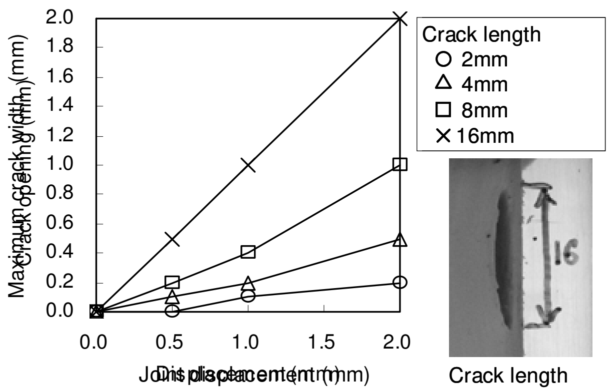

Fig.4 Relationship between crack width and displacement

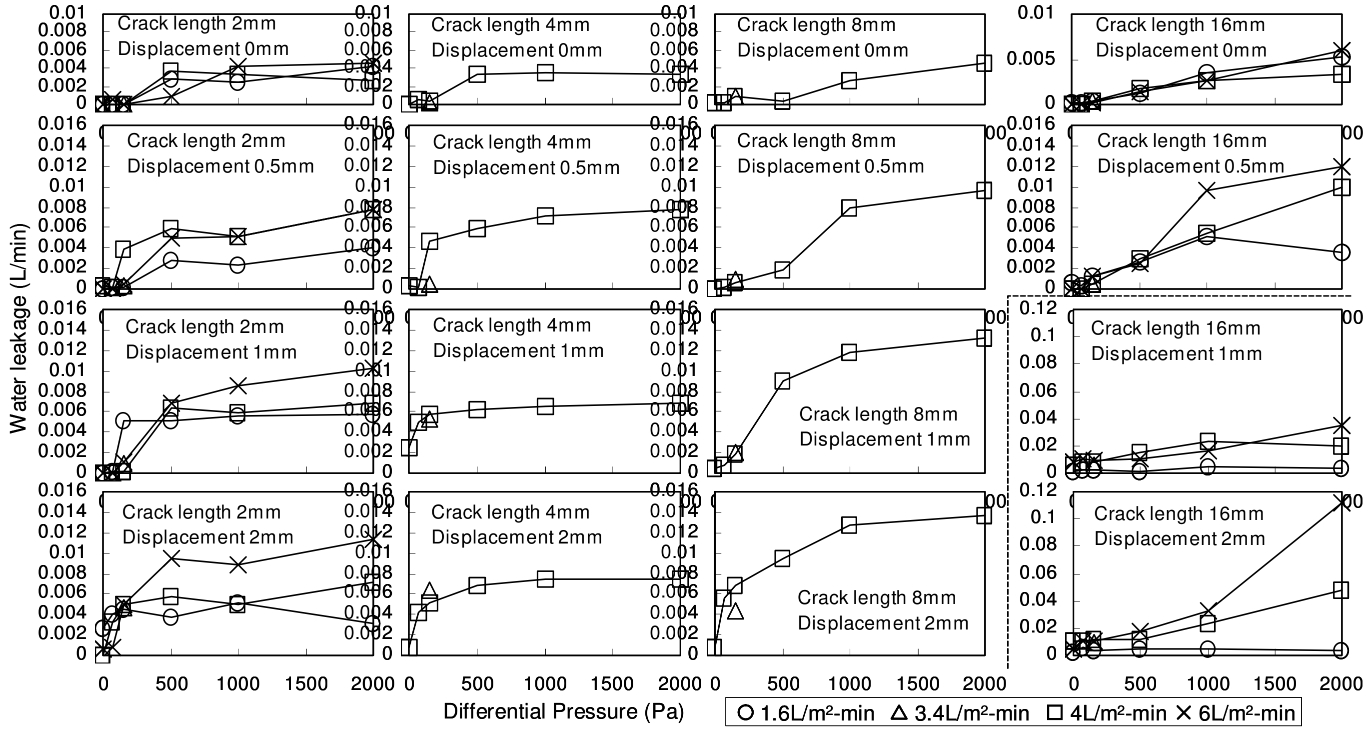

Fig.5 Relationship between differential pressure and water leakage

shown in Fig.4. There is a linear relationship between joint displacement and crack width; as well, the longer the crack length, the broader the crack width.

3.2 Water penetration test results

The relationship between pressure differential and water leakage is shown in Fig.5. The nature of water leakage at the joint is illustrated in Fig.6.

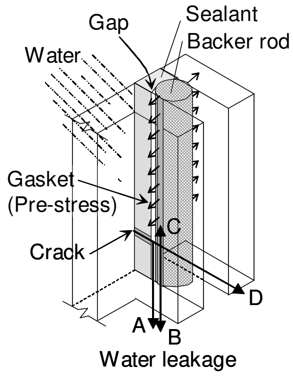

Fig.6 Water leakage type

(1) Quantity and pattern of water leakage

In general, greater rates of water leakage occurred through cracks in the sealed joint, given either higher water deposition rates on the specimen surface or higher pressure differentials across the specimen. In respect to the pattern of water leakage and the effect of the backer rod: when the diameter of the backer rod was greater than the joint width, water flowed downwards along the gap between sealant and backer rod (Fig.6-Type-A); when the rod diameter was smaller than the joint width, water flowed from the opening across the gap at the substrate-backer rod interface, towards the back of the joint (Type B or Type-D). When the rate of water entry exceeded the drainage capacity along the gap, excess water flowed up the gap (Type-C).

(2) Influence of joint displacement and crack length

Given the presence of a crack, at no joint displacement (0-mm), water leakage nonetheless occurred. Excluding results obtained with no joint displacement (0-mm), the longer the crack length and the greater the joint displacement, the higher the water leakage rate. Hence, the crack length and joint displacement provided a multiplicative effect on water leakage rates. When the joint displacement was largest, water readily penetrated the joint even at low pressure conditions.

4. Discussion

a) Effect of backer rod

The backer rod acted as a gasket providing a secondary barrier to water entry at the joint. When leakage occurred at the crack, and given that the backer rod was compressed, water leakage was arrested beyond the position where the backer rod interfaces with the substrate. However, when the joint was extended and the diameter of the backer rod was then smaller than the joint width, the rod no longer acted as a gasket. It is therefore critical to consider the diameter of backer rod and its degree of compression in a joint to help avoid water leakage should a fail safe system be of interest.

b) Influence of gap between sealant and backer rod

In these tests, it was observed that water leakage occurred in the gap between the sealant and the backer rod. In an actual sealed joint system, it would be difficult to ensure a situation in which no gap was present. Therefore, given that the size of this gap influences the flow of water, one might consider the design for a specific gap size between the sealant and the backer rod; in essence this implies the proper choice of backer rod to joint width and depth. It may also imply the use of different profiles of backer rod that would restrict the size of this gap.

5. Conclusions

1) There exists a linear relationship between crack width and joint displacement for cracks introduced in a sealant at the sealant-substrate interface; as well, larger crack lengths induce greater crack widths in extended joints. The crack length and joint displacement provide a multiplicative effect on water leakage.
2) If a crack exists in a sealed jointing system, even if the joint displacement is 0-mm, water may leak from the crack area. The higher the quantity of water deposition on or air pressure differential across the specimen, the larger the rate of water leakage.
3) The size and shape of the backer rod affects the nature of water leakage across the joint.

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