

Evaluating the Performance of a New Polyurethane Sealant for External Joints under Tropical Conditions

An on-site horizontal weathering rack (HWR) was developed to simulate the tropical conditions, combining the simultaneous effects of joint movement, temperature, humidity, rainfall, water retention and sunlight (Fig. 1). The simulated movement of joints was achieved by using the high level of extension and contraction of aluminium under temperature change. The 10m long aluminium rack with concrete slabs bolted on it allows sealants to be tested on concrete surfaces. Test results have shown that the rack is efficient in subjecting test specimens to real level construction joint movements exposed to the tropical environment.

The two main objectives of this study were to test for:

- The effectiveness of HWR as a tool to test the performance of sealants under real site conditions.
- The performance of a self-developed sealant under simulated on-site conditions of HWR.

METHODOLOGY AND RESULTS

Daily joint movement

Three joints were used to take movement readings on different locations of the aluminium bar at different times of the day. The joint widths were adjusted strictly at the same values at the moment of installation. The measurements were made over a period of ten days and the average value was taken as the final result. The results are summarised in Table 1. An average daily movement of the joints on the HWR of 21.5% was recorded.

Daily specimen temperature

As for temperature change of the sealant specimen installed on the HWR, the daily change constitutes the dominant factor for the monthly and even annual change is negligibly small. The data obtained from daily temperature monitoring of the sealant on the HWR are summarised in Table 2. The average daily change in the specimen temperature on the HWR is as high as around 25°C.

Water immersion

One special feature of the HWR test is its ability to simulate the effect of rainfall retention on the

horizontally applied construction sealant in the tropics. The average time for the water on the sealant to evaporate or drain off after raining was 7 hours.

Table 1: Statistical Evaluation of Cyclic Movements on the HWR

	L_l (mm)	L_h (mm)	ΔL (mm)	L_a (mm)	Movement (%)
Day 1	17	26	9	21.5	21
Day 2	17	25	8	21.0	19
Day 3	16	26	10	21.0	24
Day 4	17	25	8	21.0	19
Day 5	18	26	8	22.0	18
Day 6	15	25	10	20.0	25
Day 7	17	26	9	21.5	21
Day 8	17	27	10	22.0	23
Day 9	17	27	10	22.0	23
Day 10	16	25	9	20.5	22
Average					21.5

L_l : the lowest value of the joint-width readings taken throughout the day;

L_h : the highest value of the joint-width readings taken throughout the day;

ΔL : the maximum change of the joint-width readings taken throughout the day, $\Delta L = L_h - L_l$;

L_a : the average value of the gauge readings taken on the day, $L_a = (L_h + L_l)/2$;

Movement of joint = $\Delta L/2L_a \times 100$



Figure 1. Set-up of the Horizontal Weathering Rack (HWR)

Table 2: Statistical Evaluation of Temperature Change of Sealant Specimens on the HWR

	T _{MINIMUM} (°C)	T _{MAXIMUM} (°C)	ΔT (°C)
Day 1	17	48	31
Day 2	18	46	28
Day 3	20	47	27
Day 4	20	44	24
Day 5	22	46	24
Day 6	20	43	23
Day 7	17	49	32
Day 8	19	42	23
Day 9	20	45	25
Day 10	23	42	19
Average	19.6	45.7	25.4

Curing condition

Hardness was used to monitor the curing condition of MZ on the HWR as compared with commercial products: C1, a one-part, and C2, a two-part polyurethane sealant. Comparison of results from HWR and those from the indoor labs was made to underscore the necessity of the HWR test on curing properties. The relevant data are shown in Table 3.

The results show clearly that sealants cure much slower in the indoor than outdoor environment. It is thus important that those who write specifications understand the actual environments the sealants will be exposed to rather than rely on standard international test results. The study has also shown that the curing profile with time shown by the conventional international laboratory standard tests is very different from that exposed to the outdoor tropical conditions. Therefore in order to determine the actual outdoor curing performance, the HWR appears to be an alternative which can provide a more realistic estimation. It takes into account a combination of factors, including heat exposure, rain fall, joint movements, etc.

Quality of cured sealants

The quality of cured sealants is compared according to elastic recovery value. The data of MZ, C1 and C2 are summarised in Table 4.

There was a small difference between the results from the indoor and HWR conditions. The commercial sealants, especially the one-part C1, under tropical conditions, tend to degrade in elastic recovery throughout the whole curing process. The HWR test appears to be effective in showing the effect of the actual tropical conditions on the elastic recovery of the one-part and two-part sealants.

Cohesion against natural weathering

After 28 days' curing, measurements of hardness and elastic recovery were made on the specimens both on the HWR rack and in the indoor labs, representing the cohesion of the tested sealants. The results are summarised in Tables 5 to 8.

Table 3: Shore-A Hardness Data of Sealant Specimens

Day	MZ	C1	C2	MZ	C1	C2
1	12.67	8.33	27.67	5.00	10.33	24.00
2	11.67	8.67	27.67	6.67	9.00	23.00
3	21.67	12.33	28.67	14.33	13.33	25.33
4	20.33	12.33	29.20	16.33	14.33	25.33
5	26.67	18.00	30.00	18.00	12.67	28.67
6	26.00	15.33	29.33	19.67	12.33	29.33
7	28.67	14.33	30.33	21.67	14.33	31.33
8	29.67	15.33	30.33	22.00	14.67	31.33
9	31.67	14.67	31.00	25.33	15.00	31.00
10	31.33	15.67	30.67	25.67	14.00	30.33
11	34.33	14.33	30.67	27.67	14.33	29.33
12	35.00	14.00	30.00	27.67	14.00	29.67
13	34.00	14.67	31.33	30.00	14.67	29.33
14	33.33	14.67	30.67	30.67	13.67	29.67
15	34.33	15.33	30.67	29.67	15.00	29.67
16	34.00	15.67	29.00	30.67	15.00	30.00
17	35.67	16.33	31.33	30.00	15.33	29.00
18	35.67	17.33	29.67	30.33	15.67	29.33
19	36.00	17.00	29.00	30.33	15.33	29.33
20	36.33	16.67	29.67	31.33	16.00	29.67
21	36.33	16.00	30.33	30.33	18.33	30.00
22	36.33	16.67	29.67	29.67	17.33	29.67
23	35.33	15.33	29.00	31.00	17.67	30.33
24	36.33	16.33	29.33	31.67	18.00	31.00
25	36.00	18.33	30.33	31.33	19.00	30.67
26	36.67	18.33	30.67	31.67	19.33	30.00
27	36.67	19.33	30.00	32.00	20.33	30.67
28	36.67	20.33	30.67	32.67	20.00	31.33

Blue columns: Cured on the HWR; Yellow columns: Cured in the Indoor Lab

Table 4: Elastic Recovery after 28-day Curing

Sealant Type	MZ	C1	C2
Indoor condition	98.00	96.00	98.20
HWR condition	99.00	91.67	97.10

Table 5: Shore-A Hardness of Specimens Measured in the Indoor Lab

Number of testing day	MZ	C1	C2
Cured specimen	32.67	20.00	31.33
56	32.70	20.00	31.40
238	32.70	20.00	31.40

Tables 5 and 6 show no change in Shore-A hardness in the indoor lab after 8 months. Table 6 shows that C1 and C2 experienced a decrease of 20% and 7% respectively in Shore-A hardness value after eight months' exposure on the HWR while MZ displays nearly no change.

Table 7 shows that all the three sealants displayed no change in elastic recovery even after 8 months under

Table 6: Shore-A Hardness of the Specimens Installed on the HWR

Number of testing day	MZ	C1	C2
Cured sealant	36.67	20.33	30.67
7	36.60	20.33	30.73
14	36.67	20.30	30.73
28	36.67	20.33	30.67
42	36.67	20.00	30.67
56	36.67	19.83	30.73
70	36.67	19.70	30.67
98	36.60	19.40	30.67
126	36.50	19.00	30.20
154	36.30	17.80	29.83
182	36.50	17.20	29.00
210	36.50	16.50	28.50
238	36.30	16.00	28.00

Table 7: Elastic Recovery of the Specimens Tested in the Indoor Lab

Number of testing day	MZ	C1	C2
Cured specimen	98.07	96.07	98.13
56	98.13	96.20	98.20
238	98.13	96.20	98.17



Figure 2. Setting the installation rack on the expansion beam



Figure 3. Priming of the concrete substrate

indoor conditions. Table 8 shows that there was an obvious decrease in elastic recovery after 8 months' exposure on the HWR for both C1 and C2, whereas MZ showed no appreciable change in elastic recovery. The HWR test appears to be able to show the degradation compared to that of the indoor lab test.

The simulation of the tropical conditions combines the effect of joint movements and weathering conditions like temperature, rainfall, water retention and sunshine. The simulated movement of joints was achieved by using the high level of extension and contraction of aluminium under temperature change. The conception created a self-designed ten-metre-long aluminium rack which can simulate the level of joint movement brought about by much longer concrete slabs so that a real level of construction joint movement was obtained for the performance evaluation.

The results have shown that the horizontal weathering rack is suited to tropical sealant testing. Obvious differences in change with hardness and elastic recovery was observed between the commercial and the self developed products using this method.

Table 8: Elastic Recovery of Specimens Installed on the HWR

Number of testing day	MZ	C1	C2
Cured sealant	99.00	91.67	97.10
7	98.97	91.60	97.13
14	99.10	91.20	97.10
28	99.00	90.87	97.00
42	99.10	90.67	96.80
56	99.00	90.33	96.80
70	99.10	90.10	96.83
98	99.00	89.60	96.77
126	99.00	89.10	96.30
154	99.13	88.87	96.23
182	99.10	87.70	96.00
210	98.90	87.10	95.87
238	98.77	86.60	95.80



Figure 4. Thermometer to take surface temperature of sealant

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