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SIX YEARS NATURAL WEATHERING OF SEALANTS

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Conference Paper 4 **W.R. Sharman, J.I. Fry and R.S. Whitney**

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Keywords:

Comparing; Elastomers; Exposure; Joints; Natural; Sealants; Test procedures; Testing.

Abstract:

A range of elastomeric sealants have been naturally weathered for six years in a CSIRO-designed cyclic movement test rig. Sealants were evaluated in a butt joint between two aluminium surfaces, and a shear joint between glass and aluminium. In the shear joint sealants were in continuous contact with water. The rigs provide a degree of acceleration in producing the types of failures to be expected in practice. Exposure of sealants without cyclic stressing was not sufficient to reliably evaluate sealant durability.

In general, acid-cured silicone sealants performed best; solvent based acrylics performed as well as or better than polysulphides. The performance of polyurethanes was poor. Acrylic-latex sealants are not suitable for exterior use in moving joints.

However, chemical type was not a reliable guide to sealant performance, so that the use of sealants as the sole weather barrier must be avoided.

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INTRODUCTION

Modern building practice, with the use of large, often prefabricated components, has given emphasis to the requirement for an efficient method of sealing the gaps between components. The seal must withstand the rigours of weather and be simultaneously capable of accommodating building movement induced by thermal and/or moisture changes, and wind loads.

Over the past 30 years, a variety of sealing components have evolved. Sealants may be used in conjunction with other sealing methods, or as the sole barrier to weather penetration[1] in glazing as well as in joints between cladding panels. Although guides to sealant selection[2,3,4] and application[5] exist they are general in content rather than spelling out the detailed performance which can be expected from a particular sealant. In particular lack of durability can have a marked effect on building maintenance costs (which may also affect the architect and contractor), hence there has been considerable effort put into the specification of sealants, and control of their initial properties[6,7,8,9]. Other workers have investigated rheological properties[10], or the effects on a sealant of stress, strain, temperature and time with the intention of isolating the critical stage of the sealant's life[11,12,13,14]. The more direct approach of exposing sealants to natural weathering has also been employed[15,16,17,18].

The purpose of the present investigation was to compare the performance of sealants such as polyurethanes or acrylics (that in 1975 were new to the New Zealand market), with the more established materials such as 2-part polysulphides and silicone sealants.

It was felt that investigations of initial sealant properties as outlined above did not necessarily correlate with weathering performance. A test method was sought which more closely parallelled the factors causing degradation, such as exposure to sunlight, moisture, and temperature changes while undergoing cyclic movement[15,17,19,20,21].

The method adopted was that of Brown[15], because of its comparative simplicity and ease of test rig construction.

EXPERIMENTAL

Cyclic movement tester

The cyclic movement tester used was almost identical to that used by the CSIRO[15]. The tester (Fig. 1) comprised a 1.8 m length of black painted 50 x 25 mm aluminium channel placed on top of a 2.2 m length of 65 x 50 mm timber painted white. The aluminium was fixed to the timber at one end. Attachment of the appropriate joint configuration between the free end of the channel and the timber utilises the differential thermal movement between them to stress the joint. Maximum movement was measured by noting the displacement of small nylon discs on a brass rod attached to the aluminium channel and passed through a bracket attached to the timber.

Two joint configurations were attached to the cyclic movement tester; a butt-joint representing a joint between curtain wall cladding panels (Fig. 2a) and a shear joint which simulates a joint in glazing (Fig. 2b). Over the first two years of exposure, the average maximum movement was 2.3 mm (i.e. 19%) for the butt joints. Similarly, an 8% average maximum movement occurred in the shear joints.

Joint Configurations tested

Butt joint: The butt joint samples (Fig. 2a) were made between two mill-finished aluminium faces. Aluminium was selected because the material was a suitable substrate for all the sealants tested and required a minimum amount of preparation. As the recommended movement tolerances for the range of sealants tested varied from 10% to 35%, the width of the joint was set at 12.5 mm at a temperature of 20°C to give an anticipated joint movement midway between 10% and 35%. The joint depths were controlled by using an expanded polyurethane backing to meet the sealant manufacturer's recommendation of width to depth ratio.

Shear joints: The shear joint (Fig. 2b) was made between glass and aluminium, with the glass plate as the upper surface, thereby exposing the sealant to degradation by sunlight through the glass. The distance between the glass and aluminium was set at 6 mm. The sealant was applied along the two sides and at one end of the joint between the glass and aluminium, thereby forming a pocket which was later filled with water. The depth of the sealant in the sides and along the bottom of the pocket was controlled by a PVC former, with a PTFE tape on its edge, sandwiched between the glass and the aluminium. The 6 mm depth gave a 1:1 width-depth ratio. The PVC former and tape were removed when the sealant had cured.

Materials tested

The majority of sealants (14) evaluated were commercially available in New Zealand in 1975, with this range extended by the importation of sealants from the USA (5) and Europe (3). The types and number of each type are given in Table 1.

The samples were supplied directly by each manufacturer (or his New Zealand agent).

Sealant application

The aluminium and glass joint faces were degreased with xylene, washed with water and an anionic detergent, rinsed and dried. Sealants were then applied in accordance with the instructions supplied with them. (Where primers were specified they were applied and cured for the recommended period). All sealants were hand-applied from a cartridge in a sealant gun.

The sealants were cured at $20 \pm 2^{\circ}C$ and $65 \pm 5\%$ RH for between 3 and 14 days, depending on sealant type. Problems of early removal of the plastic formers from the solvent-based acrylic shear rigs meant that these samples (6 and 7) were cured for 10 months.

Weathering programme

The cured sealant, assembled into the cyclic tester, was installed in July 1976 (midwinter) at Judgeford (a rural site 25 km northeast of Wellington, approximate latitude 41°S). One butt joint and one shear joint of each sealant were exposed. The testers were positioned at 45° to the horizontal, facing due north. At the start of the exposure trials, the glass/aluminium pockets in the shear joints were filled with distilled water. Losses due to evaporation were replenished by natural rainfall. Examinations were carried out at three-monthly intervals for the first year, and half-yearly thereafter. Where additional material was available, sealants which failed in the first 12 months were retested.

Detailed climatic data for Wellington is available[22]. U.V. levels approximate those of Melbourne and Sydney[23]. In general the climate is mild (mean summer temperature 16°C, mean winter temperature 8.5°C, annual mean rainfall 1300 mm, mainly in winter).

RESULTS AND DISCUSSION

The results after two years exposure have been previously published[24]. Results after six years natural weathering are summarised in Figs 3 and 4 (butt joints and shear joints respectively).

As has been noted elsewhere[25] chemical type was not a reliable indication of performance, due to wide variations in formulation. As a corollary, sealants should not therefore form the sole weatherproofing in the joint, and a two stage or drained joint should be used[26]. Joint design should also allow for sealant replacement.

Unstressed beads of sealant, where these were exposed, did not reliably give parallel results to those from the cyclic testers. The stresses imposed by the cyclic movement therefore provide valuable additional information on sealant performance.

Acrylic-latex

All five samples (Nos. 1-5) failed very quickly in both butt and shear joint assemblies. Initial failures were in adhesion, followed by hardening and cohesive cracking. In the case of sample 4, contact with water in the shear joint assembly caused its disintegration.

Young[16] reported 10 years satisfactory weathering resistance for acrylic-latex sealants from exposure trials carried out in the northeastern USA. These trials were carried out on non-moving joints, however. Bullman et al[27] reported similar results after 3 years. Durability studies of an acrylic-latex sealant in a moving joint were carried out by Burstrom[17], who reported no failure after seven months exposure in Sweden.

In contrast to the successful exposures outlined above, the Greater London Council[28] found a failure of an acrylic latex sealant in its field study. In general acrylic-latex sealants do not appear to be considered suitable for exterior use in the United Kingdom[2,3,4].

On the basis of the present study the use of acrylic-latex sealants in moving joints is not recommended. The view of Young[16] that their main scope is as an improvement in oil-based and butyl rubber caulks, rather than as a replacement for high performance elastomeric sealants is endorsed. The durability of New Zealand formulated acrylic-latex sealants in non-moving exterior joints under New Zealand weather conditions requires further study.

Solvent based acrylic

Of the two types tested, sample 7 showed adhesive failure in the butt joint after two-and-a-half years, and in the shear joint after four years. Sample 6 showed only slight cohesive cracking and dirt pickup after six years. Solvent-based acrylic sealants are only recommended for joint movements of up to 15%[4,29]

The better performance of sample 7 in the shear joint as opposed to the butt may reflect the lesser movement of the former (7% as against 19%) and/or the more readily resisted shear forces in the glazing joint[4,30].

Brown[15] tested two solvent based acrylics in shear joint test rigs. One failed rapidly by cohesive cracking, the other after 7 months by loss of bond to glass.

Several joints sealed with solvent-based acrylics were included in the GLC survey[28]. All were satisfactory apart from some dirt pickup. Burstrom[17] also obtained satisfactory results in natural exposure tests after seven months testing in a cyclic test rig.

Polysulphide sealants

The only 1-part polysulphide (sample 8) failed after two years in both butt and shear joints. One-part polysulphides are slow curing, and known to be susceptible to mechanical damage while curing[4,31]. They have a lesser movement capability than 2-part polysulphide[2,4]. The 1979 G.L.C. survey[28] included three 1-part polysulphides, all of which performed well. There are two inferences from the present results, either the transition from the curing conditions to exposure may have overstressed the partially cured sealant, or the formulation tested will not withstand a butt joint movement of the order of 20%.

The 2-part polysulphides fared a little better, with only the butt joint of one formulation (sample 10) intact after six years. Most other failures were in adhesion, either to aluminium or glass. In all cases the shear joint failed first.

The susceptibility of polysulphide sealants to sunlight through glass was demonstrated by Brown[15], and has been noted by Kasperski et al[31]. In an earlier description[24] of the present study the then discoloration of one polysulphide sealant under glass was noted as being a likely precursor to failure. The effect of priming appears to have been miminal, with the only sealant where primer was used (sample 11) failing within two years.

Burstrom[17] included two 2-part polysulphides in his weathering study. After seven months both were exhibiting surface cracks and showing signs of adhesive failure. The GLC included one 2-part polysulphide in their survey[28]. It had a satisfactory performance. In a European survey of joints and sealants[32] only "well formulated" polysulphide sealants withstood joint movements of 20%.

Polyurethane sealants

Both the two 1-part (samples 12, 13) and the two 2-part (samples 14, 15) polyurethane sealants failed within two years. Again, the effects of priming appear negligible. Cohesive and adhesive cracking occurred in the butt joints, and also in unstressed beads of sealant, showing that overstressing in the joint was not the cause of failure. The shear joints all failed in adhesion to glass.

Two 1-part polyurethane sealants showed poor durability in the 1979 GLC survey[28]. Burstrom[17] found surface cracking of a 1-part polyurethane sealant after seven months exposure, but no change in a 2-part formulation. Beech[4] has suggested that the slow cure of 1-part polyurethane sealants may make them vulnerable to mechanical damage; no such explanation is available for the 2-part polyurethane failures. It is noteworthy that a high damage rate of polyurethane sealants compared to silicones or polysulphides was found in a European survey of joints[32].

Silicone sealants

Of the seven silicone sealants tested, three (samples 8, 9 and 11) had both butt and shear joints intact after six years exposure. Three others (samples 12, 13 and 14) had failed in the butt joint, but were intact in the shear joint, while one (sample 10) had failed in adhesion in both the butt and shear joints after five years. This latter sample was the only neutral-cure silicone tested, the remainder being acetoxy-cured. Baker et al[33] have noted that neutral-cure silicone sealants do not ahdere as well as acetoxy-cured types to substrates such as aluminium and glass. For the acetoxy-cured sealants, priming gave no discernible advantage.

Brown[15] found that acetoxy-cured silicone sealants in cyclic movement testers did not fail after up to three years exposure with the sealant screened from sunlight, but lasted only 12 to 16 months exposed through the glass of the shear joint. Further work with the CSIRO testers[34] gave good results after four years with silicones exposed through glass. In the final evaluation, after nine years, two of six acetoxy-cured silicone sealants had failed (six years, eight-and-a-half years) while the remaining four were in good condition. In the European survey of building sealants and joints[32], silicone sealants performed well, as did the silicone sealant examined as part of the GLC survey[28]

In general the results obtained in the present study demonstrate the previously noted superior weathering properties of silicones compared to other sealants including polysulphides[19,31].

CONCLUSIONS

The CSIRO cyclic movement testers proved to be a useful tool in illustrating potential performance differences in building sealants. Weathering of an unstressed bead of sealant did not provide a reliable guide to sealant durability.

Sealant chemical type alone was not a reliable guide to durability. Sealants should not therefore be used as the sole joint weatherproofing. Two stage or drained joints are strongly preferred; joint design should include provision for sealant replacement.

In general, the acid-cured silicone sealants showed the best performance. Solvent based acrylics performed as well as or better than polysulphides. The performance of the polyurethane sealants was poor, and acrylic-latex sealants are not suitable for exterior use in moving joints.

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Table 1 : Sealant type/substrate pretreatment/cure type

Sealant type	Sealant Sample	Primer used on aluminium	Primer used on glass	Cure type
acrylic/ latex	1	-	-	solvent loss
	2	-	-	solvent loss
	3	-	-	solvent loss
	4	-	-	solvent loss
	5	-	-	solvent loss
acrylic/ solvent	6	-	-	solvent loss
	7	-	-	solvent loss
polysulphide 1-part	8	-	X	
polysulphide 2-part	9	-	-	
	10	-	-	
	11	X	X	
polyurethane 1-part	12	-	X	
	13	X	-	
polyurethane 2-part	14	-	-	
	15	-	-	
silicone	16	X	-	acetoxy
	17	-	-	acetoxy
	18	-	-	neutral
	19	X	X	acetoxy
	20	X	X	acetoxy
	21	X	X	acetoxy
	22	X	X	acetoxy

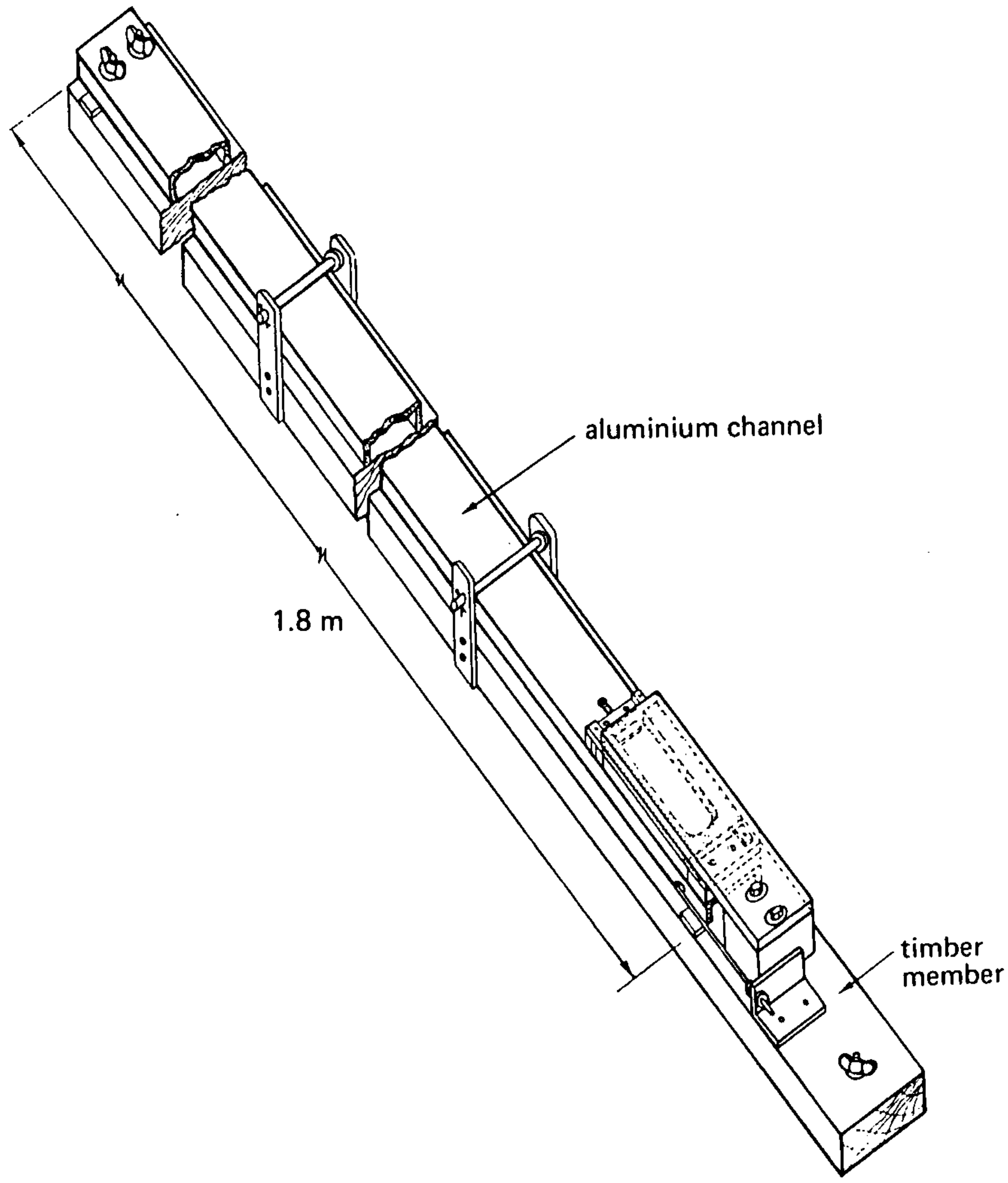

Fig. 1 : Cyclic movement tester

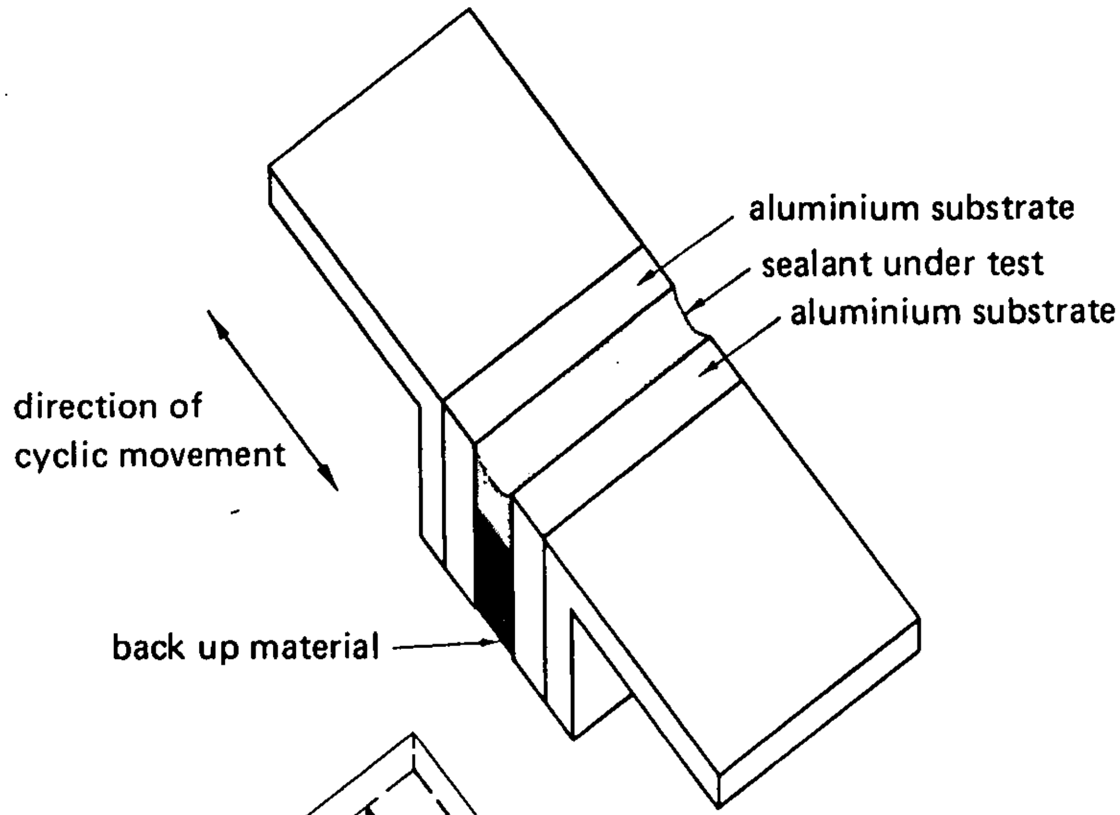

Fig. 2a : Butt joint configuration

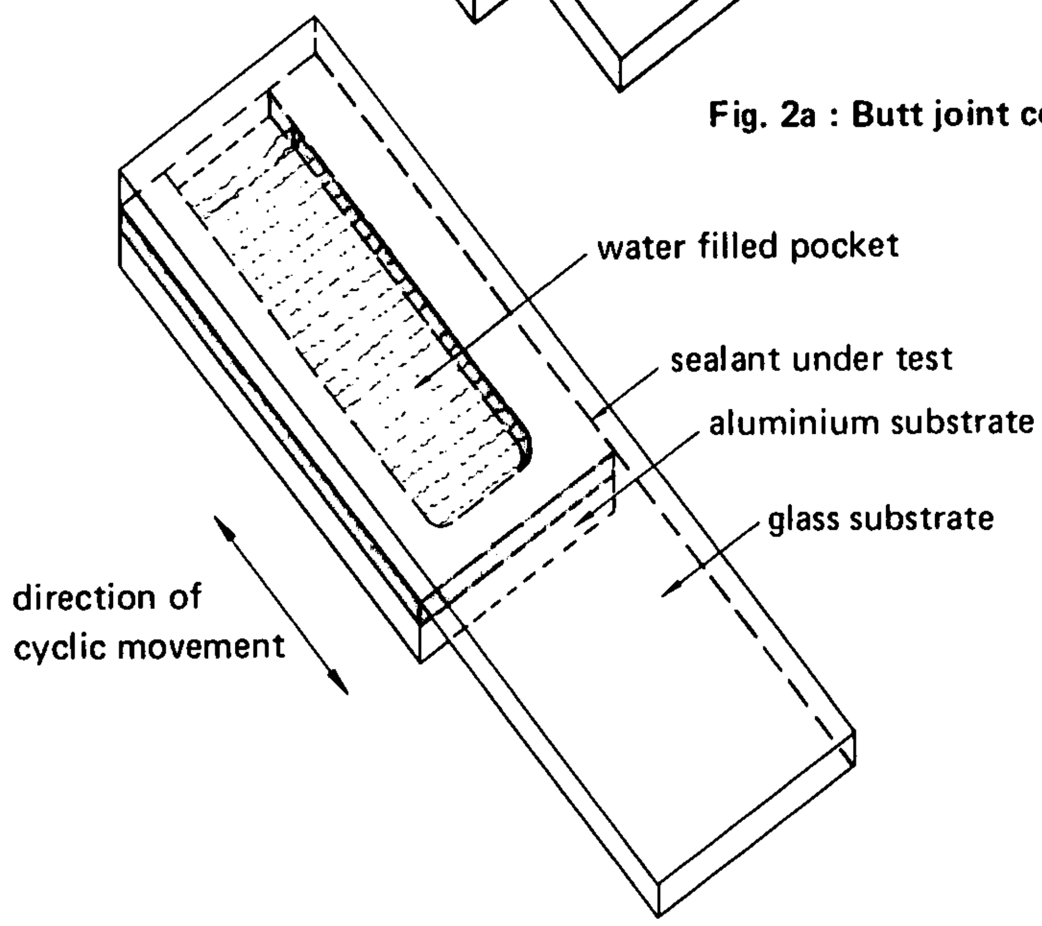

Fig. 2b : Shear joint configuration

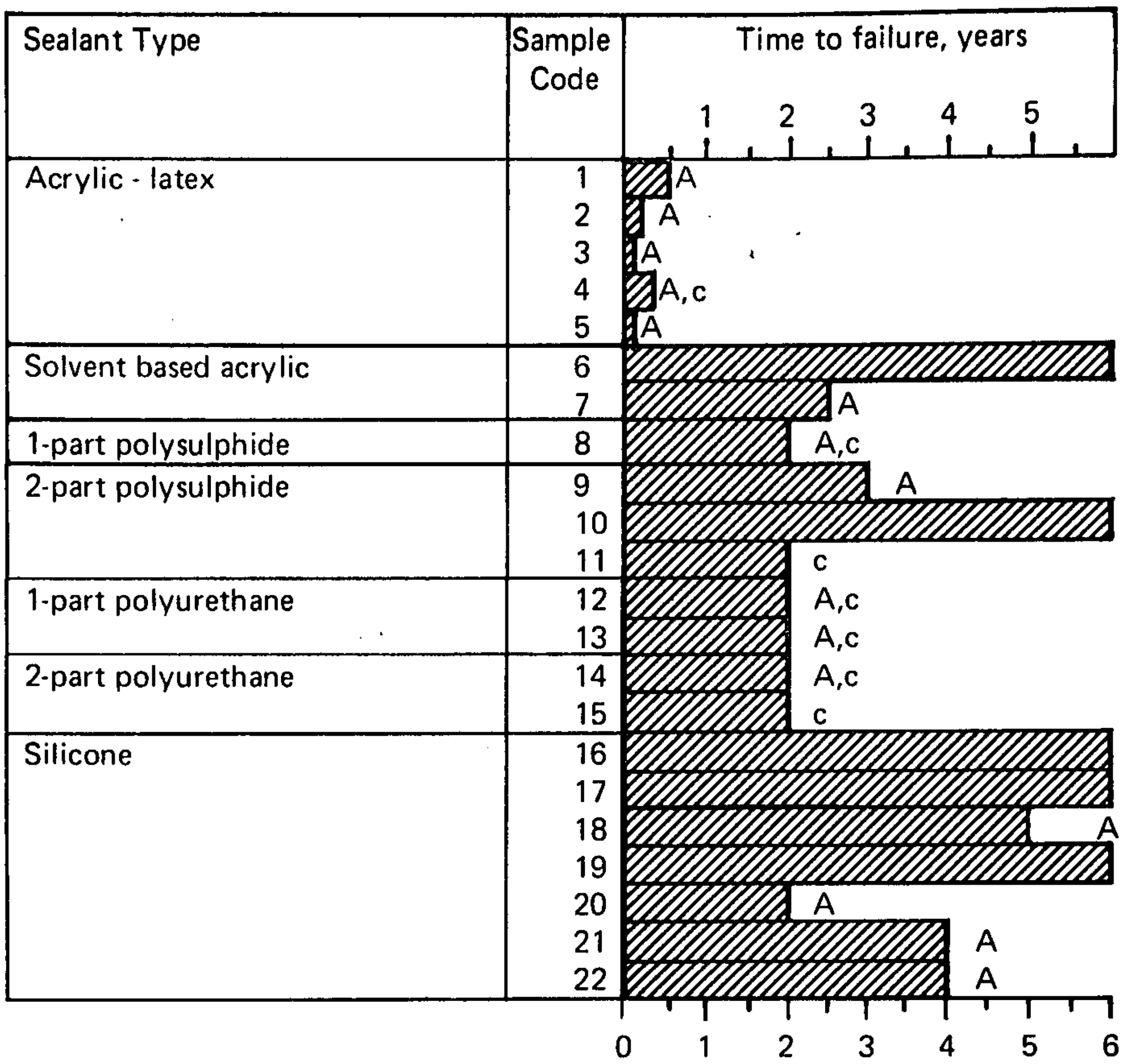

Fig 3 : Results for butt joints

Key: A = failure in adhesion to aluminium
c = cohesive failure

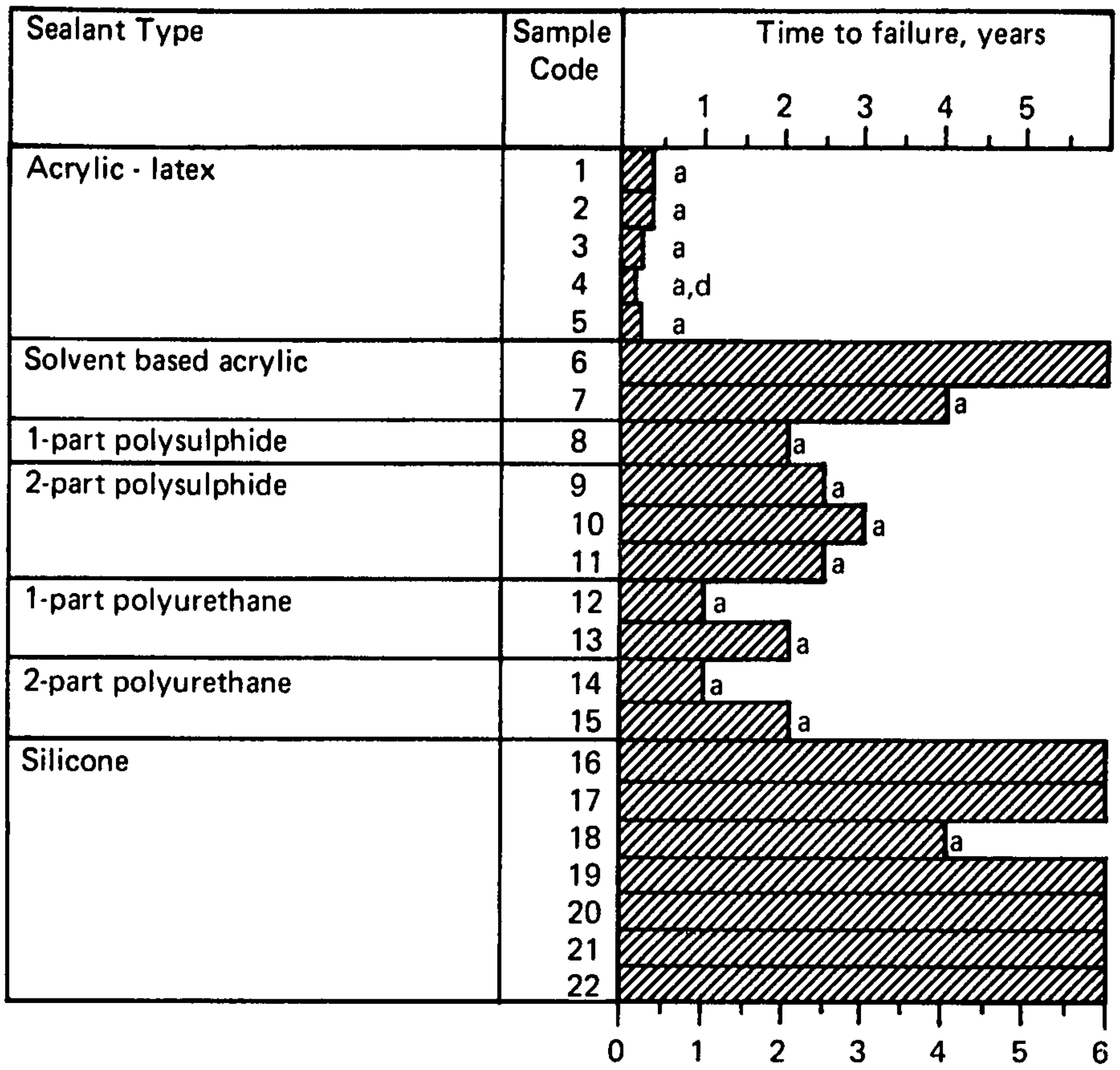

Fig 4 : Results for shear joints

Key : a = failure in adhesion to glass
d = disintegration

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