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THE EFFECT OF TIMBER MOISTURE CONTENT ON CONSTRUCTION ADHESIVES

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PREFACE

This report was prepared as part of BRANZ's research programme assessing the durability of building materials and systems.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of L. MacIsaac for testing of adhesive shear specimens.

This report is intended for manufacturers, designers and builders.

THE EFFECT OF TIMBER MOISTURE CONTENT ON CONSTRUCTION ADHESIVES

BRANZ Study Report 37 A.F. Bennett and P.J. Watkinson

REFERENCE

Watkinson, P.J. and Bennett, A.F. 1990. The effect of timber moisture content on construction adhesives. Building Research Association of New Zealand, BRANZ Study Report SR 37, Judgeford.

KEYWORDS

From Construction Industry Thesaurus - BRANZ edition: Bibliography; Adhesives; Cavities; Gypsum plasterboard; Linings; Moisture content; Shear strength; Timber

ABSTRACT

An experimental programme was carried out to determine whether high moisture contents in wall framing timber affected the performance of adhesives used to fix wall linings.

A range of construction adhesives (three water-based and two solvent-based) were used to prepare shear test specimens using timber at moisture contents of either 15% or 25% by weight. After curing for four weeks at either 65% RH or 95% RH, the specimens were tested in shear. To simulate drying of the timber after lining out, one set of specimens was prepared using timber at a moisture content of 25%, cured, then conditioned back to a moisture content approaching 15% by weight.

The differences in behaviour of the adhesives and the likely effect on performance of high moisture content timber are discussed.

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INTRODUCTION

An informal survey (Watkinson and Bennett 1987) of adhesive use in the New Zealand building industry in 1985 and 1986, identified that adhesive use in lining internal walls and ceilings was becoming more common. The adhesives used are commonly called construction or panel adhesives and are available in two main types; water-based (usually with acrylic resin) or solvent-based (usually SBR or neoprene rubber). Limited use is made of the adhesives as structural load-bearing components, but in two cases adhesives are claimed, when used with nailing, to be suitable for providing bracing resistance in a wall element.

Most of these adhesives are specified for use on dry timber. One product does allow use on green timber, but not when the timber is visibly wet. The term "dry" in timber construction is often taken as meaning that the timber has a moisture content of between 12 and 18 percent by weight. Lining out of timber frame dwellings is allowed when the framing timber has a moisture content of 24% or less (NZS 3602, 1975). Evidence of dampness in buildings suggests that lining of walls may occasionally take place at moisture contents in excess of 30 per cent. The behaviour of construction adhesives at higher moisture contents (i.e., 24% or more) is unknown. This report looks at the effect on the shear strength of construction adhesives when they are applied to timber with moisture contents of 24-26% by weight. The effect of drying to an equilibrium moisture content of 15% by weight after initially being prepared and conditioned at 24-26% moisture content was also investigated.

EXPERIMENTAL

Three water-based and two solvent-based construction adhesives were obtained from building supply merchants. The adhesives were conditioned at 20 ± °C for 24 hours prior to use. Boric treated (H1) Pinus radiata with nominal 47 x 96 mm dimensions was obtained in approximately two metre lengths. The timber was cut into two halves of approximately 22 mm x 96 mm with the two inner faces labelled for adhesive application. The timber was conditioned at either 65± % RH or 95± % RH until the weight change recorded was less than 0.1% (typically 6-8 weeks conditioning). This resulted in moisture contents of approximately 15% and 25% respectively. The nominal temperature of conditioning was 20 ± 2°C for both humidities; but in practice the 95% RH conditioning was carried out in cabinets using saturated potassium sulphate solution with electric fans for air circulation. This resulted in an approximately 2 °C rise in temperature compared to the 65% RH conditioning environment.

Specimens were prepared for shear testing in a similar fashion to that described in ASTM D 3931 (1980) The major difference was that the test specimens were prepared in batches of 4 to 6, being 96 mm wide and were cut to the correct dimensions (see Figure 1) immediately before testing. Glass microscope slides of thickness 1.3 ± 0.05 mm were used as spacers. Initial specimens were prepared by applying adhesive to one piece of timber, then clamping the second piece of timber onto the microscope slides, inserting nails then removing the clamps. This method proved to give a variable bondline thickness, so the nails were replaced by twinfast screws. The timber was planed on the surface to receive adhesive within 24 hours before adhesive application. Three sets of specimens were prepared for each adhesive. One set was prepared from the timber conditioned at 65% RH and two sets from the timber conditioned at 95% RH. After preparation the specimens were conditioned for a further four weeks at the same RH as prior to preparation. At the completion of this conditioning the samples were tested, except for the second set of specimens conditioned at 95% RH. This set was conditioned for six more weeks at 65% RH with the holding screws removed. Table 1 shows the conditioning used for the different specimens.

The specimens were cut into individual test specimens as described in ASTM D 3931 (1980) and tested using a shearing device (see Figure 2) similar to that described in ASTM D 905 (1949).

Nominally 25 samples were prepared for each test, but due to failure of the adhesive bond in some samples during cutting, the number tested varied between 18 and 25.

RESULTS

The results of the shear tests are given in Table 2. Table 3 shows the mode of failure of the adhesive during testing.

DISCUSSION

The two classes of construction adhesive used in this study have performed differently over the different conditioning regimes. The solvent-based adhesives showed less effect from different conditioning regimes than the water-based. For adhesive 4 there was no significant difference between the three regimes at the 95% level. Adhesive 5 showed differences significant at the 95% confidence level between the strengths developed under curing conditions going from 95% RH back to 65% RH, and the other two curing regimes.

The three water-based adhesives however, showed changes significant at the 99% confidence level. Two of the adhesives showed a steady increase in shear strength as the curing conditions went from 65% RH to 95% RH and also from 95% RH down to 65% RH. The remaining water-based adhesive showed an initial decrease in shear strength going from 65 % RH to 95% RH but regained the loss when conditioned from 95% back to 65% RH.

Several factors might be behind the apparent sensitivity of the water-borne adhesives in these tests. The increase in strength recorded by the water-based adhesives when cured at 95% RH then conditioned for a further four weeks is probably due in part to the lengthening of the cure period before testing.

Adhesive 2, which showed the largest increase in strength between a straight 65% RH cure and the 95% RH and back to 65% regime also showed a change in the failure mode during testing. At 65% RH the shear specimens failed mainly by adhesion loss. At 95% RH the failure mode was mainly cohesive failure of the adhesive and after samples had been conditioned back to 65% RH; the failure mode was almost entirely cohesive failure within the adhesive. This change in failure mode suggests that the adhesive-timber interface is affected by the different conditioning regimes used. The increased moisture content of the samples conditioned at

95% RH will have resulted in a slower loss of water from the adhesive into the timber. This may produce a more regular bond than when rapid water loss occurs. The surface of the timber at higher moisture content tended also to be less smooth than that at 65% RH even after machining. This may provide a better key for the water-based adhesives.

Adhesive 1 which showed a decrease in strength for specimens prepared and conditioned at high relative humidity, may be based on a more water sensitive resin. Steiner and Troughton (1980) reported that a polyvinyl acetate-based construction adhesive showed a decrease in strength when cured under moist conditions.

The solvent-based adhesives showed less variation with the different conditioning regimes. This is in line with results published by Beech (1973). Beech reported the results of testing on a range of solvent-based elastomeric building adhesives which included; reclaimed rubber, nitrile rubber, neoprene and styrene-butadiene rubber. These results suggested that for these adhesives there was not a large difference in shear strength between samples prepared and tested at normal humidities (25 °C and 65% RH) and high humidities (wet samples cured at 87% RH). Adhesive 5 showed a significant increase in strength when conditioned at 95% RH then back to 65% RH. This may be attributed to the additional cure time that this treatment involved. Beech also noted that the adhesives gained strength with time, but most of the strength increase occurred between three and twelve months.

Table 4 summarises the requirements in the Australian, ASTM and American Plywood Association Standards related to wall linings. The mean results reported in Table 2 for all the adhesives exceeded the requirements in ASTM C 557 of 0.276 MPa. In engineering design however, it is more common to include a safety factor, to account for statistical variation in the design of adhesive joints. One way that this is done is to ensure that the 5 percentile value of the materials strength equals or exceeds the required design value (CIRIA 1977). In other words in 95% of cases the actual value for any sample will exceed the design value.

In all cases except three, the 5 percentile value of the test data for each adhesive was above the requirement in ASTM C 557 (0.276 MPa). The exceptions were adhesive 1 after conditioning at 95% RH (5 percentile value = 0.26 MPa), adhesive 2 after conditioning at 65% RH (5 percentile value = 0.19 MPa) and adhesive 5 when conditioned from 95% RH to 65% RH (5 percentile value = 0.17 MPa). Adhesive 1 after conditioning to 65% RH from 95% RH (simulating a wall cavity drying out) comfortably exceeded the requirements of ASTM C 557 (0.39 MPa) at the 5 percentile level. Adhesive 2 when conditioned at 95% and, 95% followed by 65% RH, also exceeded the requirements of ASTM C 557 at the 5 percentile value. Adhesive 5 after conditioning from 95% RH to 65% RH had a high mean failure stress (1.9 MPa) but also had a large standard deviation (1.1 MPa). When the distribution of the data was analysed, it was observed to be bi-modal (see Figure 3). The two groups of data were subsequently analysed separately, each giving stress values that exceeded 0.276 MPa at the 5 percentile level (0.29 and 1.5 MPa). All the samples in the group with the lower stress level showed at least 20% adhesive failure while the higher group showed 5% or less adhesive failure. One possible cause for the difference in behaviour exhibited by the two groups in this case, is variations in the timber substrate used.

The shear tests carried out in this work used a bondline thickness of 1.3 mm. In practice, the gap between panel materials and timber framing will often be less than this. This will result in shear strength values higher than those reported here (Steiner and Troughton 1980, Beech 1973).

CONCLUSIONS

The durability of the five construction adhesives used in this study is unlikely to be adversely affected when used in walls containing framing timber with a high moisture content (24-26% by weight). Although one adhesive showed a decrease in shear strength when conditioned at 95% RH compared to 65% RH, the adhesive regained its shear strength when conditioned back to 65% RH.

Solvent-based adhesives showed relatively small differences between the three RH conditioning regimes used; whereas two of the water-based adhesives showed improved adhesion to the timber and greater shear strengths when prepared with timber conditioned at 95% RH.

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Table 1. Conditioning of Specimens Before Testing

Adhesive	Type	RH before assembly	RH after assembly
1	WB	65%	65%
1	WB	95%	95%
1	WB	95%	95% four weeks, 65% six weeks
2	WB	65%	65%
2	WB	95%	95%
2	WB	95%	95% four weeks, 65% six weeks
3	WB	65%	65%
3	WB	95%	95%
3	WB	95%	95% four weeks, 65% six weeks
4	SB	65%	65%
4	SB	95%	95%
4	SB	95%	95% four weeks, 65% six weeks
5	SB	65%	65%
5	SB	95%	95%
5	SB	95%	95% four weeks, 65% six weeks

WB - Water-based
SB - Solvent-based

Table 2. Results of Shear Testing on Construction Adhesives

Adhesive		Conditioning	Mean failure stress MPa	Std deviation	5% level	Extension (mm)	Std deviation
1	WB	65%	0.64	0.17	0.35	2.03	0.18
1	WB	95%	0.38	0.067	0.26	2.20	0.14
1	WB	95 then 65%	0.86	0.27	0.40	1.47	0.50
2	WB	65%	0.45	0.15	0.19	1.03	0.19
2	WB	95%	1.00	0.26	0.55	1.56	0.31
2	WB	95 then 65%	2.94	0.77	1.61	1.54	0.37
3	WB	65%	0.71	0.21	0.35	4.79	0.99
3	WB	95%	1.01	0.20	0.66	8.69	0.99
3	WB	95 then 65%	1.64	0.27	1.17	5.94	0.92
4	SB	65%	0.44	0.20	0.34	1.51	0.46
4	SB	95%	0.54	0.32	0.39	1.60	0.23
4	SB	95 then 65%	0.50	0.24	0.41	1.39	0.33
5	SB	65%	0.96	0.40	0.29	3.72	0.69
5	SB	95%	1.18	0.32	0.54	2.52	0.59
5	SB	95 then 65%	* 1.91	1.01	0.17	3.40	0.86

WB - Water-based
SB - Solvent-based
* mean and standard deviation calculated assuming normal distribution applies.

Table 3. Failure Mode of Adhesives During Testing

Adhesive	Conditioning used		
	65% RH	95% RH	95%-->65% RH
1	C	C	C*
2	Am	Cm	C
3	Cm	Cm	C
4	C	Am	C
5	Cm	Am	C*

C - Cohesive failure of adhesive
A - Adhesive failure of adhesive
Cm - Mainly cohesive failure of adhesive
Am - Mainly adhesive failure of adhesive
C* - A small amount of adhesive failure

Table 4. Requirements for Panel Adhesives

Standard	Test type	Failure stress	Conditioning
1 ASTM C 557	shear strength	0.276 MPa	14 days at 23±1°C, 50±2%RH
2 AS 2753	shear strength	0.300 MPa	14 days at 23±2°C, 50±5% RH
3 ASTM D 3498	shear strength	0.689 MPa *	28 days at 21±3°C, 50±3% RH
4 AFG 01	shear strength	0.689 MPa *	28 days at 21±3°C, 50±10% RH

* For gap filling option (i.e., 1.57 mm bondline)
Numbers 1 and 2 are for gypsum plaster, 3 and 4 for plywood, bonded to timber.

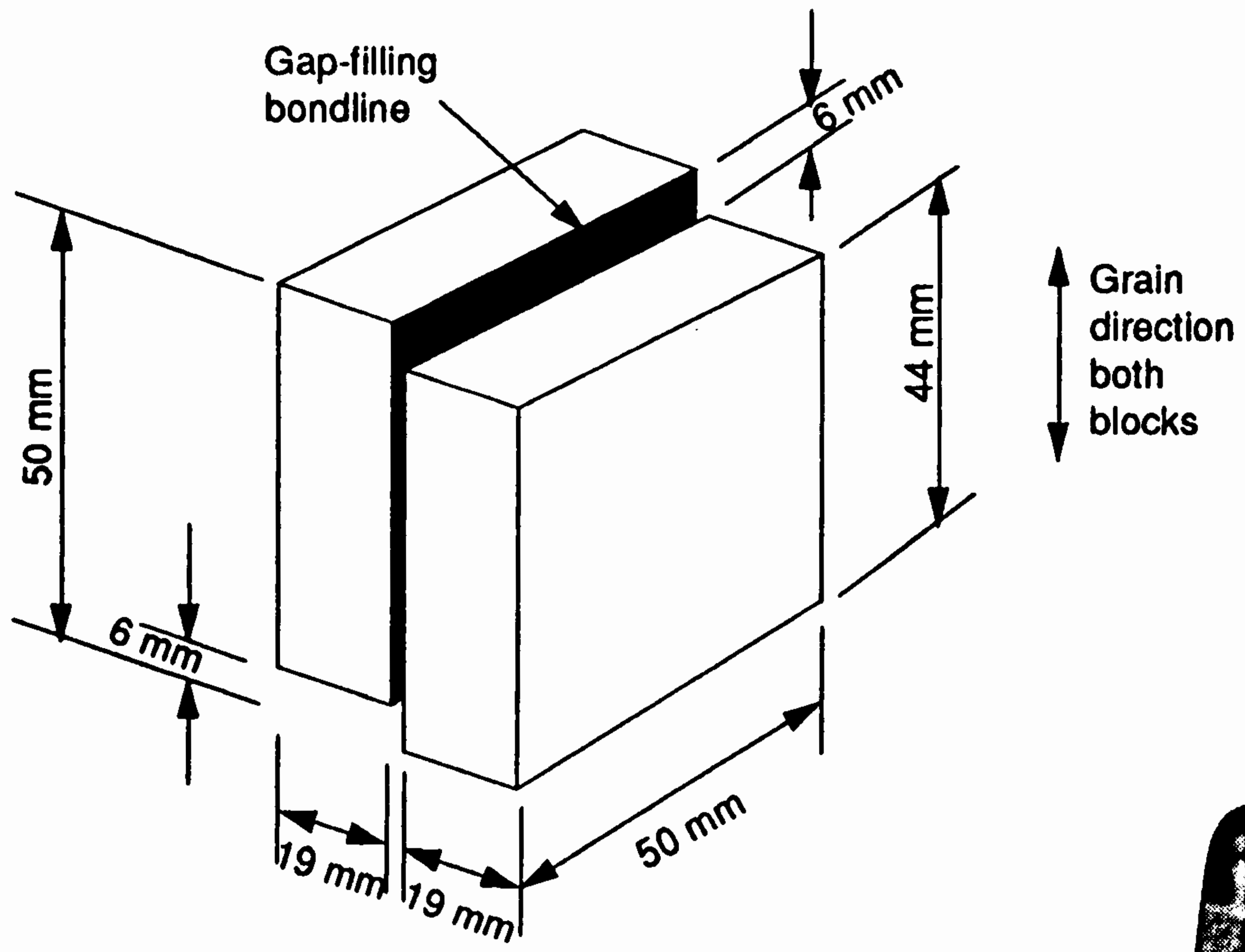

Figure 1:
Shear Test Specimen

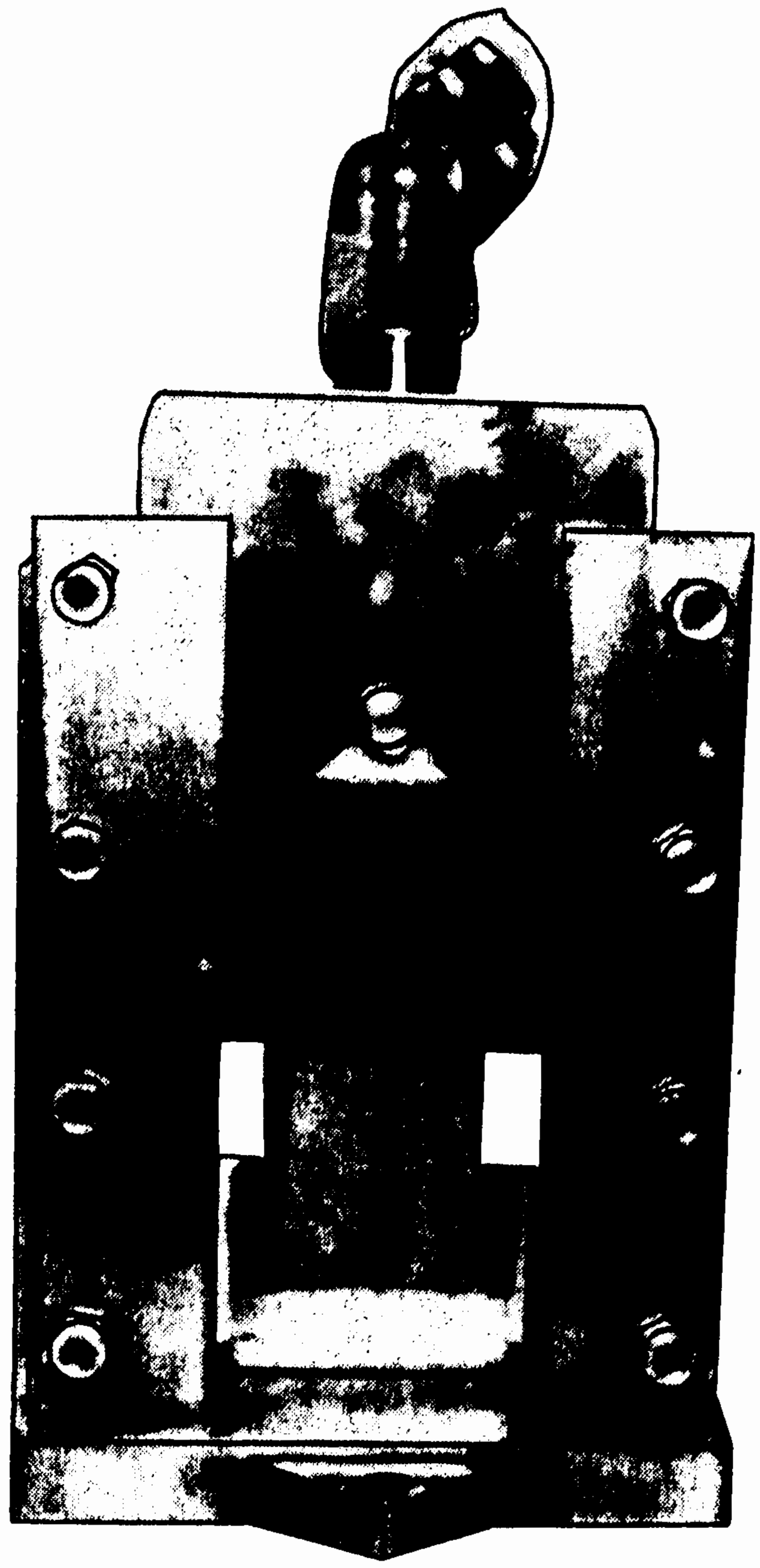

Figure 2:
Sheer Test Apparatus

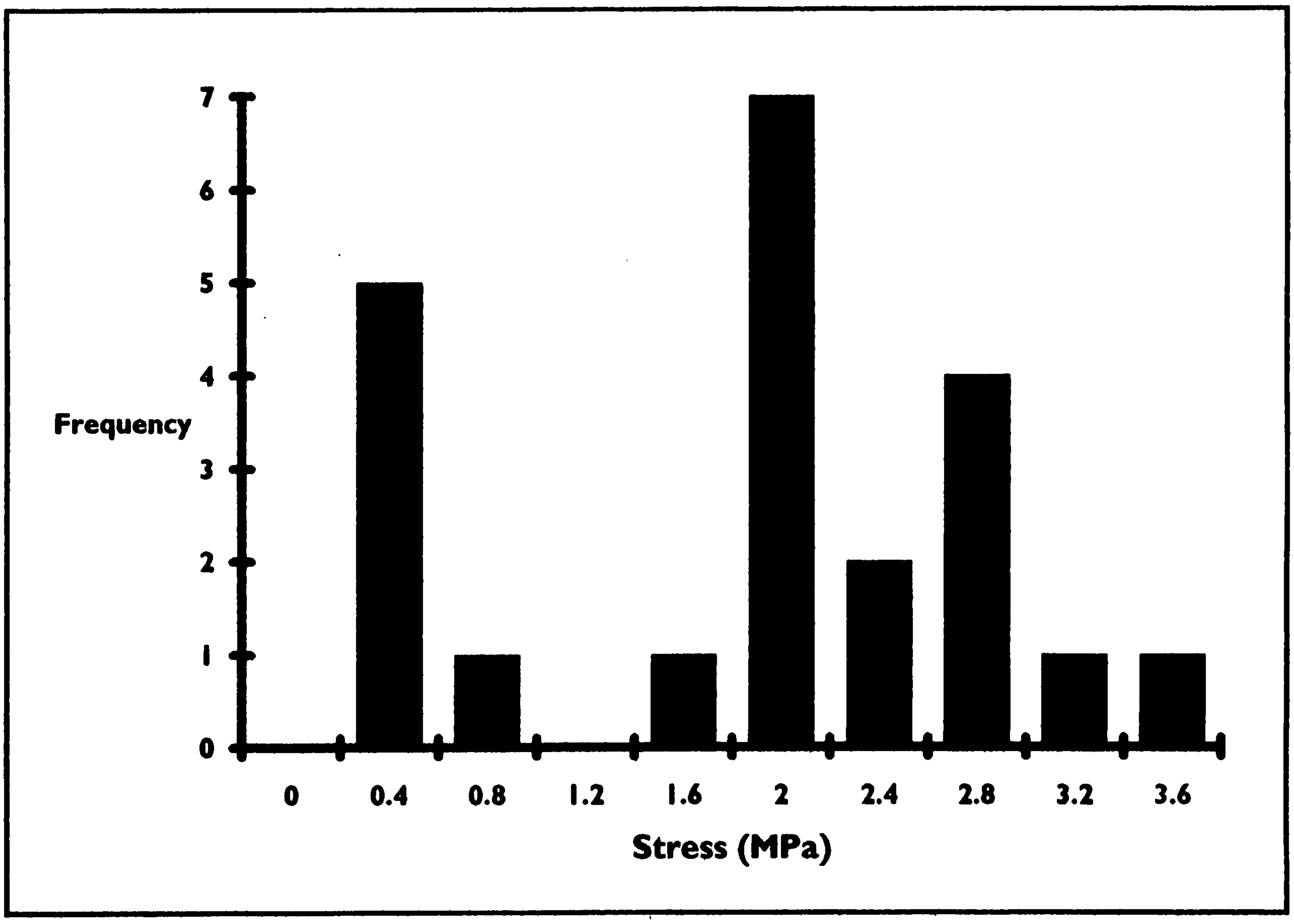

Figure 3. Bi-modal distribution of shear failure stresses for adhesive 5 conditioned from 95% to 65% RH

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