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THE BREAKING STRENGTH AND EXTENSION OF WEATHERED RUBBER-COATED --ETC(U)
MAR 77 J E SWALLOW, M WEBB

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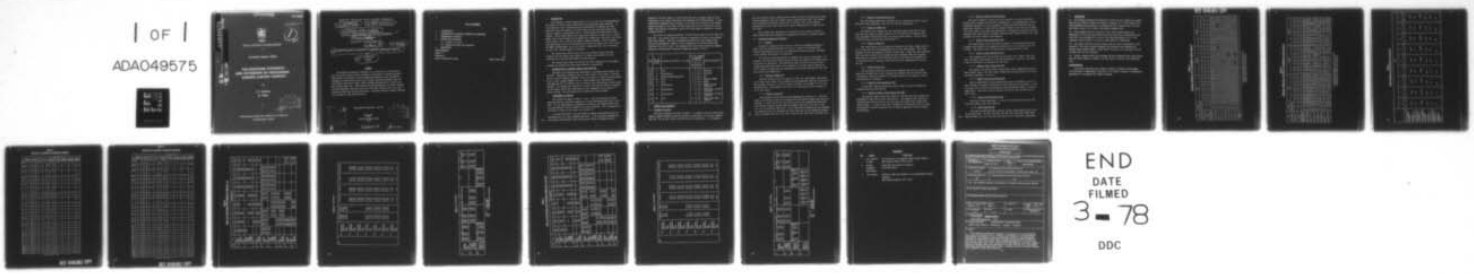

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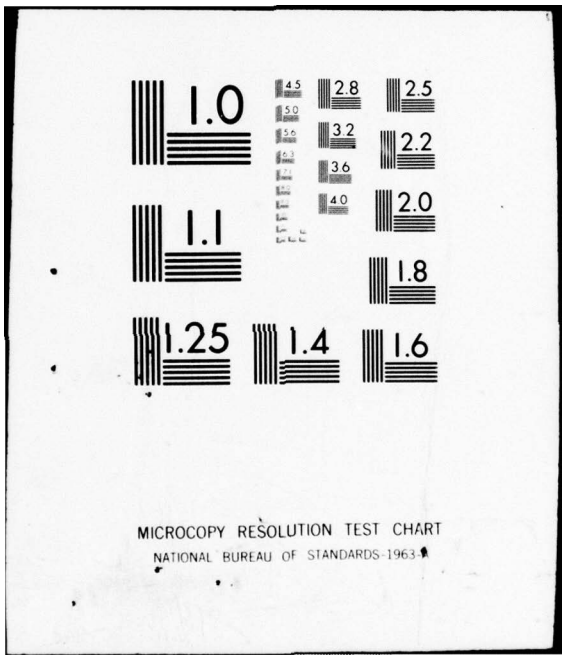
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Technical Report 77031

THE BREAKING STRENGTH AND EXTENSION OF WEATHERED RUBBER-COATED FABRICS

by

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SUMMARY

The breaking strength and extension of a nylon and of a cotton fabric, each coated with natural rubber, neoprene, polyurethane or chlorosulphonated polyethylene and exposed to various weathering conditions, were determined. Although the coated nylon fabrics were stronger and more extensible than the cotton ones, those with natural rubber coating deteriorated at a faster rate when exposed under load. Nylon coated with polyurethane was initially stronger and more extensible than when coated with the other rubbers, but in hot moist weathering conditions deteriorated faster. Extension was more severely affected than strength by load during exposure.

Departmental Reference: Mat 316

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1 INTRODUCTION

The exposure of rubber-coated fabrics for up to one year of weathering and the effects of this on their flexibilities have previously been reported[1]. In a collaborative trial involving several Establishments of MOD(PE) and JTRU, nylon and cotton base fabrics of similar mass per unit area were coated with natural, neoprene, polyurethane (PU) or chlorosulphonated polyethylene (CSPE) rubbers. These coated fabrics were exposed for periods of three, six or twelve months, and a second period of six months (6S) commencing at the end of the first, under loads of 1% or 10% of the nominal breaking strength. Pieces of fabric were positioned at 45° to the horizontal and facing the equator at a site in the UK (ERDE, Waltham Abbey) and at two sites in Queensland (hot, dry at Cloncurry and hot, wet, cleared jungle at Innisfail).

The coated nylon fabrics were found to be thicker, heavier and less flexible than the coated cotton fabrics; PU rubber, particularly on nylon, stiffened more than the other rubbers during exposure.

The present Report gives the results and their analyses for the breaking strength and extension of these coated fabrics on weathering.

2 DETERMINATION OF BREAKING STRENGTH AND EXTENSION

Strengths and extensions were determined in accordance with standard test methods[2]. Rectangular warpway strips of coated fabric, 30 cm long × 5 cm wide and cut from the exposed specimens[1], were positioned in a tensile testing machine so as to have a gauge length of 20 cm. These lengths were then broken in approximately 60 s at constant rate of traverse, the load-extension curves being recorded. The machine was situated in a room at 20°C and 65% relative humidity, and the fabric strips were conditioned in this atmosphere for at least 24 h before testing. Two test pieces were available from each specimen.

3 ARRANGEMENT OF RESULTS

The results are given in Tables 1 and 2. They were obtained by three operators and were inevitably separated in time of determination by well over a year. All the measurements of extension were made by one operator (JES) from the load-extension curves obtained by the three operators. For a discussion of the effect of these on the errors, see section 4.1.

As noted previously[1], the three month specimens from Australia were not differentiated as to their loading conditions. It was therefore assumed that
031 the columns containing the lower nylon/natural rubber strengths should be

ascribed to the 10% loading in accord with the lower strengths found for this combination at the longer times where the specimens were differentiated. If this unverifiable assumption were incorrect, or if some of the results in one column properly belonged to the other, the main effect would be an inflation of errors rather than reversed conclusions, and set (b) below might be expected to contain anomalous results.

Out of the 192 exposed specimens, 12 broke during exposure and of these five were lost. The results could not therefore be analysed in terms of the original five-factor design. They were consequently divided into nine complete four-factor sub-experiments, though 12 of the combinations for which results were available could not be used. The remaining 368 values were analysed by computer using sets containing the following columns from Tables 1 and 2:

Set	No. of columns in set	Columns from Tables 1 & 2 used	No. of columns determined by operator			Brief description[1]
			JES	MW	BM	
(a)	2	A,B	1	1	0	Controls
(b)	6	C,D,K,L,S,T	0	6	0	3 months
(c)	12	C,E,G,I,K,M,O,Q,S,U,W,Y	5	4	3	1%
(d)	24	C-Z	10	8	6	Natural rubber
(e)	8	C-J	4	4	0	ERDE
(f)	6	A,B,C,E,G,I	3	3	0	ERDE, 1%, with controls
(g)	6	A,B,K,M,O,Q	4	2	0	Cloncurry, 1%, with controls
(h)	6	A,B,S,U,W,Y	1	2	3	Innisfail, 1%, with controls
(i)	24	C-Z	10	8	6	Nylon with three rubbers

4 RESULTS AND DISCUSSION

4.1 Analysis of errors

The error variances are given in Table 3. In general, sets (i) and (h) had greater random variability than the others; in particular, (i) was more variable than (b), (e) and (g) at about the 99.9% level of probability. It is possible

that the external factors comprising the columns in these sets gave rise to more random variability than the internal factors comprising the rows. The columns also included more potential effects due to operator, and to time between performing the tests, since these effects were confounded with columns and not with rows.

The set means and coefficients of variation are also given in Table 3. These coefficients were comparable in magnitude with those for bending length[1].

4.2 Breaking strength and extension

4.2.1 General

Analysis of variance within each set is given for breaking strength in Table 4 and for breaking extension in Table 5. Certain interactions were directly determinate in each set, and comparisons between sets gave some additional indirect indication of interactions.

The effects are discussed below in roughly their order of importance. In general, only those which reached the 99.9% level of probability of being correct assertions are considered. The significant means are given in Tables 6 and 7, though where means were found to be significant in one set they are given for all the others in which they were determinate even though they may not have then been found to be significant.

4.2.2 Effect of fabric (F)

This had variance ratios of upwards of 1500; not surprisingly, the coated nylon fabrics were shown to be stronger and more extensible than the cotton ones. The strength ratio was 3.4 in the controls, falling to an average of 2.5 in the weathered sets. The extension ratio was 2.4 in the controls and an average of 2.6 in the others.

4.2.3 Effect of load (L)

The exposures at 10% load were more damaging than those at 1%. For this factor, the variance ratios for extension were consistently higher than those for strength. In sets (d) and (i) the variance ratios for strength were more than 100, and the strength retained under the higher load fell in set (d) to only 0.75 of that under the lower load. In all cases where determination was possible, the variance ratios for extension were more than 300, and the extension retained under the higher load fell in set (d) to only 0.63 of that under the lower load.

4.2.4 Fabric X load interaction (FL)

The 10% loading caused more strength loss on coated nylon fabrics than on the cotton ones, especially in set (d) (*cf* the FRL interaction).

4.2.5 Effect of rubber (R)

The fabrics were stronger and more extensible when coated with PU than with the other types of rubber, except in set (h) where the interaction with site (Innisfail) reduced the values for the PU coated fabrics. Such an effect at the hot moist site has been noted before[1,3].

4.2.6 Effect of time (T)

The coated fabrics lost strength and extension with time, though except in set (d) this did not become significant until after three months. The 6- and 6S-month results were generally similar to each other. There was some indication that the final controls were stronger and more extensible than the originals. This would be consistent with some other work on the effects of storage[3], but it could have been an operator effect since this was confounded with time in set (a).

4.2.7 Effect of site (S)

The Australian sites were usually more damaging than the one at ERDE. There was an indication of more strength and extension loss at Innisfail than at Cloncurry, which can probably be attributed mainly to the effect on the PU coated fabrics at Innisfail.

4.2.8 Rubber X load interaction (RL)

At 10% load, fabrics coated with natural rubber lost more strength and extension than the other fabrics.

4.2.9 Fabric X rubber X load interaction (FRL)

The natural rubber coated nylon fabric at 10% load lost more strength and extensibility than did the other combinations. This supports the observation concerning the FL interaction in set (d), where the fabrics were coated with natural rubber. It may be noted that although the FL interaction did not affect the extension, the FRL interaction was of similar magnitude for both strength and extension.

4.2.10 Fabric X rubber interaction (FR)

There was evidence in several sets that nylon/PU lost less, and nylon/neoprene more, strength than the other combinations. By comparing sets, the FR interaction appeared to be site dependent although the FRS interaction was not significant; however, it could only be directly tested in sets (b) and (c) where only short times or low loads were experienced. Although the variance ratios for extension were lower than for strength, there was some evidence from set (e) that nylon/PU lost less extension than expected.

4.2.11 Fabric X site interaction (FS)

The coated nylon fabrics lost more strength at the Australian sites than at ERDE, which supports the comparisons between sets (f), (g) and (h) for the F effect. The effect of the FS interaction on extension was not clear.

4.2.12 Fabric X time interaction (FT)

The strength ratio for the nylon to the cotton coated fabrics fell with time, the lowest found being 2.2 after twelve months at Cloncurry. The effect of the FT interaction on extension was not clear.

4.2.13 Rubber X time interaction (RT)

The results for natural rubber coated fabrics were comparatively worse at twelve months than at the other times, though this was only found to be of any noticeable importance in set (e).

4.2.14 Rubber X site interaction (RS)

The PU coated fabrics fared comparatively badly at Innisfail in set (c). This confirms the indirect indications of this interaction noted above. In the only other sets in which this interaction could be directly tested it was non-significant: these were (i) which did not include PU, and (b) which was for short times.

4.2.15 Load X site interaction (LS)

This was of minor importance. In set (i) the Cloncurry results at 10% load were perhaps lower than expected.

4.2.16 Other interactions

The other interactions which could be tested, though usually only in one or two sets, were: TS, FRT, FRS, FTL, FTS, RTL, RTS, TLS, FRTL, FRTS, FRLS, FTLS and RTLS, but in no case were they found to be of particular importance.

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5 CONCLUSIONS

(1) The breaking strength and extension of nylon and cotton fabrics of similar mass per unit area and coated with natural, neoprene, PU or CSPE rubbers have been determined after exposure to weathering in UK or Australia for up to one year under a load of 1% or 10% of the nominal breaking load.

(2) The strength ratio for the nylon to the cotton coated fabrics was originally 3.4, but the nylon fabrics were more affected by weathering and the ratio fell to an average of 2.5, and in the Australian desert to 2.2. The extension ratio was about 2.5, with no clear effects of weathering.

(3) The higher load had a greater effect than the lower, particularly on the extension. The lowest overall strengths and extensions were obtained for natural rubber coated fabrics: these ratios for high to low load were 0.75 for strength and 0.63 for extension.

(4) Fabrics coated with PU were stronger and more extensible than those coated with the other rubbers, by about 10 to 20%, except at the hot, wet Australian site.

Acknowledgments

The authors thank Miss B.M. McInroy (formerly of Materials Department) for assistance in experimental work and Mr J.H. Cadwell (formerly of Mathematics Department) for arranging the computer programs.

Table 1

BREAKING STRENGTH, kN, OF WEATHERED COATED FABRICS

Site		Controls		EDE								Cloncurry								Inniesfail							
Time, months		Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load, level %				1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Fabric	Rubber																										
Nylon	Natural	1.41 1.30	1.38 1.27	1.38 1.40	1.00 0.98	1.17 1.28	0.80 0.83	1.06 0.92	0.60 0.62	1.08 1.32	0.88 0.89	1.20 1.38	0.90 0.85	1.21 1.17	0.72 0.77	1.02 0.90	0.56 0.57	1.14 1.22	0.69 0.67	1.27 1.19	1.01 0.94	1.17 1.13	0.93 0.74	1.02 1.05	0.60 0.58	1.08 1.12	0,67 0.82
Nylon	Neoprene	1.24 1.17	1.27 1.17	1.19 1.30	1.30 1.23	1.17 1.26	1.25 1.17	1.08 1.09	1.31 1.27	1.32 1.21	1.30 1.24	1.27 1.11	1.24 1.18	1.24 1.21	1.07 1.22	0.77 0.89	0.97 0.79	1.26 1.25	1.09 0.82	1.24 1.19	1.26 1.16	0.95 1.05	1.03 1.14	0.76 0.95	0.85 1.16	0.99 1.06	1.16 1.12
Nylon	PU	1.37 1.37	1.47 1.37	1.43 1.41	1.45 1.41	1.36 1.34	1.43 1.43	1.34 1.45	1.26 1.37	1.46 1.40	1.44 1.38	1.42 1.35	1.37 1.35	1.32 1.32	(1.39) (1.33)	1.25 1.21	(1.21) (1.24)	1.35 1.37	- -	1.37 1.40	1.33 1.41	1.12 0.82	1.14 1.12	1.05 0.93	- -	1.03 1.05	(1.35) (1.32)
Nylon	CSPE	1.30 1.33	1.36 1.39	1.34 1.27	1.33 1.33	1.21 1.17	1.03 1.19	1.20 1.22	1.24 1.33	1.27 1.32	1.22 1.15	1.12 1.18	1.03 1.12	1.10 1.16	1.14 1.14	1.08 1.00	0.57 0.80	1.16 1.20	1.22 1.18	1.26 1.31	1.24 1.26	0.86 1.06	1.07 1.03	1.04 0.98	0.94 1.09	1.12 1.10	0.98 1.15
Cotton	Natural	0.44 0.36	0.48 0.50	0.43 0.47	0.48 0.43	0.39 0.40	0.34 0.35	0.18 0.17	0.16 0.13	0.37 0.43	0.43 0.50	0.47 0.47	0.47 0.47	0.52 0.48	0.51 0.49	0.40 0.39	0.43 0.48	0.48 0.47	0.52 0.49	0.43 0.46	0.49 0.43	0.47 0.43	0.47 0.27	0.45 0.44	0.44 0.35	0.42 0.42	0.34 0.36
Cotton	Neoprene	0.38 0.50	0.55 0.44	0.49 0.54	0.52 0.56	0.51 0.50	0.51 0.53	0.53 0.56	0.60 0.51	0.55 0.54	0.60 0.57	0.51 0.51	0.48 0.49	0.53 0.53	(0.47) (0.51)	0.52 0.52	- -	0.53 0.54	0.60 0.57	0.53 0.52	0.51 0.44	0.48 0.52	0.18 0.21	0.41 0.40	(0.44) (0.48)	0.47 0.46	0.38 0.50
Cotton	PU	0.52 0.53	0.59 0.58	0.49 0.47	0.55 0.59	0.52 0.48	0.49 0.51	0.52 0.54	0.50 0.57	0.53 0.53	0.59 0.60	0.51 0.51	0.45 0.53	0.57 0.52	0.59 0.56	0.48 0.52	(0.53) (0.52)	0.59 0.58	0.61 0.56	0.43 0.55	0.54 0.55	0.35 0.39	(0.43) (0.40)	0.16 0.19	0.29 0.33	0.51 0.20	0.50 0.51
Cotton	CSPE	0.44 0.43	0.54 0.54	0.50 0.50	0.51 0.40	0.49 0.50	0.50 0.43	0.47 0.46	0.48 0.46	0.50 0.53	0.52 0.49	0.47 0.44	0.48 0.50	0.51 0.48	- -	0.41 0.47	- -	0.36 0.48	0.50 0.52	0.50 0.39	0.43 0.47	0.47 0.46	0.38 0.34	0.37 0.47	0.40 0.43	0.38 0.50	0.43 0.42
Determinations made by		MW	JES	MW	MW	MW	MW	JES	JES	JES	JES	MW	MW	JES	JES	JES	JES	JES	JES	MW	MW	BM	BM	BM	BM	BM	BM

( ) specimen broke during exposure but pieces were recovered

\- specimen broke during exposure and pieces were lost

Duplicate results in each cell refer to replication

Table 2

BREAKING EXTENSION, PER CENT, OF WEATHERED COATED FABRICS

Site		Controls		ERDE								Cloncurry								Innisfail							
Time, months		Initial	Final	3		6		12		6S		3		6		12		6S		3		6		12		6S	
Load level, %				1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10	1	10
Column		A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Fabric	Rubber																										
Nylon	Natural	21.5 19	22.5 20	22.5 23.5	15.5 15.5	18 20	12.5 13	17.5 15.5	10.5 11	17.2 20.5	13.8 14	20 23	14 13.5	19.5 18.8	12.5 13	17.2 15.8	10.2 11	17.5 19.2	10.5 10.5	21.5 20	15.5 14.2	18.5 17	12.5 11	19 17.5	9.5 9.5	17.5 19.5	10.5 13
Nylon	Neoprene	18.8 18	21.8 20.2	20.5 22.5	20.2 18.8	20.5 21.5	20.5 19.5	18.2 18.5	20 18.5	23 21.2	19.8 19.5	20 18	18.5 17.5	20.2 19	16.5 17.5	14 15.5	15 12.5	19.5 19.5	15.5 12.8	22.5 21	20.5 22.5	19.5 18	18 17	13.5 17.5	14.5 17	17.5 20.5	17.5 16.2
Nylon	PU	22.2 22.2	25.8 23.8	24.5 23	21.8 21	22.5 23	22.5 21.5	22 22.5	18 20.5	24.5 24	22 21	22 21	22 22	24 24	- -	22 22	- -	21.8 21.5	- -	21.5 23	19.5 21	19 16	18 17	20 19.5	- -	20.5 18.5	- -
Nylon	CSPE	21.5 22.5	25.2 25	22 20	18.5 19	16 20	21 20.5	19.5 21	19.5 19.5	20.2 21.2	18.2 17.2	21 22	18 19.5	20.5 20.5	18.5 18.2	19.2 20	10.8 13.8	20.5 21	19 18.5	23 23	20 20	17 20	17 16.5	20.5 20	15 18	21 21.2	17.5 18.5
Cotton	Natural	8.5 7.5	9.2 9.5	6.5 7.2	4 4.5	7 7.2	2 2.5	3.5 3.5	2.8 2.8	6.5 7.2	4.2 5	8 8.5	5.5 5	8.5 7.5	5 4.8	6 6	3.5 4.5	7.2 7.2	4.8 4.2	7 7.5	4.5 3.2	7 6.5	4.5 1.5	6 5.5	3.5 2.2	6 5.8	2 3.5
Cotton	Neoprene	6.5 7.5	10.5 9	8 9.5	5 5.5	8 8.5	4.5 6	8.5 8.8	6 4.8	8.8 8.8	6.5 6	9 9.5	4 6	8 8.2	- -	7.5 7.5	- -	8 8.5	5.2 5.2	8.5 8	4 5	6.5 7.5	1 1	5.2 5.2	- -	6.5 6.5	3.5 4
Cotton	PU	9.8 10	12 11.8	9.5 9	6 7	9.5 9.5	6 6	9.8 10	6.2 7	9.8 9.8	7.5 7	10.2 10.8	5.5 6	10.2 9	6.8 6.5	9.5 10	- -	10 9.8	6 6	8 10.5	5.5 6.5	6 7	- -	2.5 3.5	2 2	8.5 3.5	4 4.2
Cotton	CSPE	8 8	10.8 10.5	8.5 9	6 5.5	9 10	6.5 7	8.8 8.8	7.8 7.5	9.2 9.8	9.8 9.2	10 9	7 7.5	9.2 9	- -	7.8 8	- -	6.2 8	6.5 6.5	8.5 8	5.2 7	8 7	4 3.5	6.5 7.8	4 4.2	7.5 7.5	4.5 4.5

( ) specimen broke during exposure but pieces were recovered

\- specimen broke during exposure and pieces were lost

Duplicate results in each cell refer to replication.

Table 3

ERROR VARIANCES AND COEFFICIENTS OF VARIATION

	Set								
	a	b	c	d	e	f	g	h	i
Error variance of breaking strength	2.64×10^{-3}	2.16×10^{-3}	3.58×10^{-3}	3.13×10^{-3}	2.18×10^{-3}	2.55×10^{-3}	2.38×10^{-3}	4.74×10^{-3}	5.88×10^{-3}
Set mean strength, kN	0.91	0.86	0.82	0.69	0.85	0.88	0.86	0.81	1.08
Coefficient of variation of strength, %	5.7	5.4	7.3	8.1	5.5	5.7	5.7	8.5	7.1
Error variance of breaking extension	0.789	0.758	1.023	0.806	0.659	0.888	0.609	1.339	1.520
Set mean extension, %	15.6	13.6	14.0	10.4	13.3	14.9	14.7	14.0	17.8
Coefficient of variation of extension, %	5.1	5.6	7.3	7.8	5.0	6.0	4.2	9.6	8.5
Degrees of freedom in error	16	48	96	48	64	48	48	48	72

Table 4

ANALYSIS OF VARIANCE OF BREAKING STRENGTH

Factor	No. of degrees of freedom	No. of levels	No. of results per level	Variance ratios for set								
				(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) EBDE	(f) EBDE, 1%, with controls	(g) Clonacurry, 1%, with controls	(h) Innisfail, 1%, with controls	(i) Nylon with 3 rubbers
Fabric F	1	2	16	2109								-
	1	2	48		6347		2362		6107	5492	2608	-
	1	2	64					8103				-
	1	2	96			6810						-
Rubber R	2	3	48				-					72.5
	3	4	8	9.5			-					
	3	4	24		49.4		-		35.3	31.9	1.8	
	3	4	32				-	205				
	3	4	48			15.5	-					
Time T	1	2	16	7.8	-							
	3	4	24		-		68.7					
	3	4	32		-			36.0				
	3	4	36		-							66.1
	3	4	48		-	53.4						
	5	6	16		-				13.8	27.4	37.0	
Load L	1	2	48	-	21.6	-	301.5		-	-	-	
	1	2	64	-		-		21.3	-	-	-	
	1	2	72	-		-			-	-	-	110.9
Site S	2	3	32	-	12.7		1.2	-	-	-	-	
	2	3	48	-				-	-	-	-	42.7
	2	3	64	-		59.6		-	-	-	-	
FR	3	8	4	3.1			-					-
	3	8	12		22.8		-		15.2	11.0	6.7	-
	3	8	16				-	30.8				-
	3	8	24			24.9	-					-
FT	1	4	8	2.2	-							-
	3	8	12		-		14.7					-
	3	8	16		-			5.5				-
	3	8	24		-	18.3						-
	5	12	8		-				3.4	19.3	12.3	-
FL	1	4	24	-	29.6	-	272.7		-	-	-	-
	1	4	32	-		-		34.0	-	-	-	-
FS	2	6	16	-	8.3		24.7	-	-	-	-	-
	2	6	32	-		21.9		-	-	-	-	-
RT	3	8	4	0.4	-		-					
	6	12	12		-		-					3.1
	9	16	8		-		-	16.7				
	9	16	12		-	2.8	-					
	15	24	4		-		-		5.6	2.6	2.7	
RL	2	6	24	-		-	-		-	-	-	98.6
	3	8	12	-	21.6	-	-		-	-	-	
	3	8	16	-		-	-	39.6	-	-	-	
RS	4	9	16	-			-	-	-	-	-	2.7
	6	12	8	-	1.2		-	-	-	-	-	
	6	12	16	-		14.5	-	-	-	-	-	
TL	3	8	12	-	-	-	0.6		-	-	-	
	3	8	16	-	-	-		0.9	-	-	-	
	3	8	18	-	-	-			-	-	-	0.6
TS	6	12	8	-	-		6.6	-	-	-	-	
	6	12	12	-	-			-	-	-	-	5.9
	6	12	16	-	-	5.7		-	-	-	-	
LS	2	6	16	-	1.0	-	0.2	-	-	-	-	
	2	6	24	-		-		-	-	-	-	8.1
FRT	3	16	2	0.4	-		-					-
	9	32	4		-		-	1.5				-
	9	32	6		-	2.6	-					-
	15	48	2		-		-		1.1	2.3	0.9	-
FRL	3	16	6	-	21.6	-	-		-	-	-	-
	3	16	8	-		-	-	32.2	-	-	-	-
FRS	6	24	4	-	2.4		-	-	-	-	-	-
	6	24	8	-		0.3	-	-	-	-	-	-
[illegible]	3	16	6	-	-	-	0.3		-	-	-	-
	3	16	8	-	-	-		1.8	-	-	-	-
FTS	6	24	4	-	-		1.5	-	-	-	-	-
	6	24	8	-	-	2.8		-	-	-	-	-
FLS	2	12	8	-	0.3	-	4.4	-	-	-	-	-
RTL	6	24	6	-	-	-	-		-	-	-	1.9
	9	32	4	-	-	-	-	2.1	-	-	-	
RTS	12	36	4	-	-		-	-	-	-	-	2.7
	18	48	4	-	-	3.7	-	-	-	-	-	
TLS	6	24	4	-	-	-	1.5	-	-	-	-	
	6	24	6	-	-	-		-	-	-	-	1.3
LSR	4	18	8	-		-	-	-	-	-	-	0.3
	6	24	4	-	1.0	-	-	-	-	-	-	
FRTL	9	64	2	-	-	-	-	1.4	-	-	-	-
FRTS	18	96	2	-	-	0.6	-	-	-	-	-	-
FRLS	6	48	2	-	1.2	-	-	-	-	-	-	-
FTLS	6	48	2	-	-	-	0.5	-	-	-	-	-
RTLS	12	72	2	-	-	-	-	-	-	-	-	2.1

- No determination possible in this set

Table 5

ANALYSIS OF VARIANCE OF BREAKING EXTENSION

Factor	No. of degrees of freedom	No. of levels	No. of results per level	Variance ratios for set								
				(a) Controls	(b) 3 months	(c) 1%	(d) Natural rubber	(e) ERDE	(f) ERDE, 1%, with controls	(g) Cloncurry, 1%, with controls	(h) Innisfail, 1%, with controls	(i) Nylon with 3 rubbers
Fabric	1	2	16	1598			3286					-
F	1	2	48		5457				4223	5534	2891	-
	1	2	64					7570				-
	1	2	96			7035						-
Rubber	2	3	48				-					114.6
R	3	4	8	21.9			-					
	3	4	24		43.2		-		52.2	77.1	12.7	
	3	4	32				-	186				
	3	4	48			49.1	-					
Time	1	2	16	51.6	-							
T	3	4	24		-		50.2					
	3	4	32		-			19.1				
	3	4	36		-							56.8
	3	4	48		-	45.2						
	5	6	16		-				21.3	40.0	39.6	
Load	1	2	48	-	308	-	674		-	-	-	
L	1	2	64	-		-		325	-	-	-	
	1	2	72	-		-			-	-	-	305
Site	2	3	32	-	0.4		4.1	-	-	-	-	
S	2	3	48	-				-	-	-	-	20.9
	2	3	64	-		37.0		-	-	-	-	
FR	3	8	4	3.8			-					-
	3	8	12		4.1		-		3.3	11.5	2.9	-
	3	8	16				-	20.8				-
	3	8	24			6.7	-					-
FT	1	4	8	0.1	-							-
	3	8	12		-		11.0					-
	3	8	16		-			9.6				-
	3	8	24		-	5.3						-
	5	12	8		-				3.3	4.3	2.2	-
FL	1	4	24	-	0.3	-	106.4		-	-	-	-
	1	4	32	-		-		0.1	-	-	-	-
FS	2	6	16	-	12.1		11.4	-	-	-	-	-
	2	6	32	-		6.9		-	-	-	-	-
RT	3	8	4	1.5	-		-					
	6	12	12		-		-					2.3
	9	16	8		-		-	7.6				
	9	16	12		-	3.6	-					
	15	24	5		-		-		4.5	3.1	2.4	
RL	2	6	24	-		-	-		-	-	-	57.9
	3	8	12	-	12.8	-	-		-	-	-	
	3	8	16	-		-	-	20.6	-	-	-	
RS	4	9	16	-			-	-	-	-	-	5.6
	6	12	8	-	2.9		-	-	-	-	-	
	6	12	16	-		12.6	-	-	-	-	-	
TL	3	8	12	-	-	-	0.9		-	-	-	
	3	8	16	-	-	-		2.7	-	-	-	
	3	8	18	-	-	-			-	-	-	2.3
TS	6	12	8	-	-		3.0	-	-	-	-	
	6	12	12	-	-			-	-	-	-	5.3
	6	12	16	-	-	4.7		-	-	-	-	
LS	2	6	16	-	0.2	-	1.3	-	-	-	-	
	2	6	24	-		-		-	-	-	-	5.5
FRT	3	16	2	0.1	-		-					-
	9	32	4		-		-	2.5				-
	9	32	6		-	3.8	-					-
	15	48	2		-		-		2.7	2.3	1.1	-
FRL	3	16	6	-	19.2	-	-		-	-	-	-
	3	16	8	-		-	-	17.8	-	-	-	-
FRS	6	24	4	-	2.9		-	-	-	-	-	-
	6	24	8	-		3.0	-	-	-	-	-	-
FTL	3	16	6	-	-	-	2.2		-	-	-	-
	3	16	8	-	-	-		7.4	-	-	-	-
FTS	6	24	4	-	-		0.6	-	-	-	-	-
	6	24	8	-	-	3.2		-	-	-	-	-
FLS	2	12	8	-	1.3	-	0.5	-	-	-	-	-
RTL	6	24	6	-	-	-	-		-	-	-	3.4
	9	32	4	-	-	-	-	2.2	-	-	-	
RTS	12	36	4	-	-		-	-	-	-	-	2.5
	18	36	4	-	-	2.2	-	-	-	-	-	
TLS	6	24	4	-	-	-	2.0	-	-	-	-	
	6	24	6	-	-	-		-	-	-	-	0.9
LSR	4	18	8	-		-	-	-	-	-	-	1.8
	6	24	4	-	0.3	-	-	-	-	-	-	
FRTL	9	64	2	-	-	-	-	2.6	-	-	-	-
FRTS	18	96	2	-	-	1.0	-	-	-	-	-	-
FRLS	6	48	2	-	1.9	-	-	-	-	-	-	-
FTLS	6	48	2	-	-	-	0.9	-	-	-	-	-
RTLS	12	72	2	-	-	-	-	-	-	-	-	1.7

- No determination possible in this set

Table 6

TABLE OF SIGNIFICANT MEAN BREAKING STRENGTHS, kN

Factor	Level	Set (see Table 4)								
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
F	Nylon	1.32	1.24	1.18	0.97	1.22	1.28	1.23	1.16	1.08
	Cotton	0.49	0.49	0.46	0.41	0.48	0.48	0.49	0.45	
R	Natural	0.88	0.79	0.79	0.69	0.68	0.82	0.84	0.82	0.97
	Neoprene	0.84	0.87	0.81		0.88	0.86	0.83	0.78	1.13
	PU	0.98	0.95	0.87		0.96	0.96	0.94	0.81	
	CSPE	0.92	0.85	0.81		0.86	0.89	0.83	0.82	1.14
T	Original	0.88					0.88	0.88	0.88	
	Final	0.93					0.93	0.93	0.93	
	3 months		0.86	0.89	0.79	0.90	0.91	0.87	0.88	1.19
	6 months			0.82	0.71	0.83	0.86	0.87	0.73	1.08
	12 months			0.74	0.56	0.79	0.80	0.74	0.67	0.94
	6S months			0.84	0.70	0.88	0.90	0.87	0.74	1.10
L	1%		0.89	0.82	0.79	0.87	0.88	0.86	0.81	1.14
	10%		0.84		0.59	0.83				1.01
S	ERDE		0.90	0.87	0.68	0.85	0.88			1.16
	Cloncurry		0.84	0.84	0.70			0.86		1.03
	Innisfail		0.86	0.76	0.69				0.81	1.04
FR		Nylon Cotton	Nylon Cotton	Nylon Cotton	Nylon Cotton	Nylon Cotton	Nylon Cotton	Nylon Cotton	Nylon Cotton	
	Natural	1.34 0.44	1.12 0.46	1.16 0.42		1.01 0.35	1.25 0.38	1.22 0.46	1.20 0.44	
	Neoprene	1.22 0.47	1.22 0.51	1.11 0.51		1.23 0.54	1.21 0.51	1.15 0.50	1.09 0.47	
	PU	1.40 0.56	1.39 0.51	1.27 0.46		1.40 0.53	1.40 0.52	1.35 0.54	1.20 0.42	
	CSPE	1.34 0.49	1.23 0.47	1.16 0.46		1.24 0.48	1.28 0.49	1.20 0.46	1.18 0.46	
FT	Original	1.31 0.45					1.31 0.45	1.31 0.45	1.31 0.45	
	Final	1.34 0.53					1.34 0.53	1.34 0.53	1.34 0.53	
	3 months			1.29 0.48	1.12 0.46	1.30 0.50	1.34 0.49	1.25 0.49	1.28 0.48	
	6 months			1.16 0.48	0.99 0.43	1.19 0.47	1.24 0.47	1.22 0.52	1.02 0.45	
	12 months			1.05 0.42	0.79 0.34	1.15 0.43	1.17 0.43	1.02 0.46	0.97 0.36	
	6S months			1.20 0.47	0.96 0.44	1.24 0.52	1.30 0.50	1.24 0.50	1.07 0.42	
FL	1%		1.29 0.48		1.16 0.42	1.26 0.47				
	10%		1.20 0.49		0.78 0.41	1.18 0.48				
FS	ERDE		1.30 0.50	1.26 0.47	1.01 0.35					
	Cloncurry		1.19 0.49	1.18 0.40	0.94 0.47					
	Innisfail		1.24 0.48	1.09 0.43	0.96 0.42					
RL			1% 10%		1% 10%	1% 10%				1% 10%
	Natural		0.88 0.70			0.78 0.59				1.16 0.78
	Neoprene		0.87 0.86			0.86 0.90				1.12 1.14
	PU		0.95 0.96			0.95 0.97				
	CSPE		0.90 0.89			0.87 0.85				1.16 1.12
LS	ERDE		0.91 0.88		0.78 0.59					1.22 1.10
	Cloncurry		0.87 0.81		0.81 0.60					1.13 0.93
	Innisfail		0.88 0.84		0.78 0.59					1.08 1.00

Table 6 (continued)

RT		Original	Final	3 months	6 months	12 months	6S months
	(a) Natural	0.88	0.91				
	Neoprene	0.82	0.86				
	PU	0.95	1.00				
	CSPE	0.88	0.96				
	(c) Natural			0.88	0.82	0.67	0.80
	Neoprene			0.87	0.83	0.71	0.84
	PU			0.95	0.84	0.80	0.88
	CSPE			0.86	0.79	0.76	0.83
	(e) Natural			0.82	0.70	0.48	0.74
	Neoprene			0.89	0.86	0.87	0.92
	PU			0.98	0.95	0.94	0.99
	CSPE			0.90	0.81	0.86	0.87
	(f) Natural	0.88	0.91	0.92	0.81	0.58	0.80
	Neoprene	0.82	0.86	0.88	0.86	0.82	0.90
	PU	0.95	1.00	0.95	0.93	0.96	0.98
	CSPE	0.88	0.96	0.90	0.84	0.84	0.90
	(g) Natural	0.88	0.91	0.88	0.84	0.68	0.83
	Neoprene	0.82	0.86	0.85	0.88	0.68	0.90
	PU	0.95	1.00	0.95	0.93	0.86	0.97
	CSPE	0.88	0.96	0.80	0.81	0.74	0.80
	(h) Natural	0.88	0.91	0.84	0.80	0.74	0.76
	Neoprene	0.82	0.86	0.87	0.75	0.63	0.74
	PU	0.95	1.00	0.94	0.67	0.58	0.70
	CSPE	0.88	0.96	0.86	0.71	0.72	0.78
	(i) Natural			1.13	0.90	0.79	0.97
	Neoprene			1.22	1.15	0.99	1.15
	PU						
	CSPE			1.23	1.10	1.04	1.17

Table 6 (concluded)

RS		(b)			(c)			(d)			(e)				(i)		
		ERDE	Cloncurry	Innisfail	ERDE	Cloncurry	Innisfail	ERDE	Cloncurry	Innisfail					ERDE	Cloncurry	Innisfail
	Natural	0.82	0.78	0.78	0.78	0.81	0.78								1.01	0.94	0.96
	Neoprene	0.89	0.85	0.86	0.86	0.82	0.75								1.23	1.09	1.07
	PU	0.98	0.94	0.95	0.95	0.93	0.72										
	CSPE	0.90	0.79	0.86	0.87	0.79	0.77								1.24	1.08	1.09
TS	3 months				0.91	0.87	0.88	0.82	0.78	0.78					1.25	1.13	1.19
	6 months				0.86	0.87	0.73	0.69	0.73	0.70					1.13	1.10	1.01
	12 months				0.80	0.74	0.67	0.48	0.59	0.62					1.08	0.83	0.92
	6S months				0.90	0.87	0.74	0.74	0.71	0.65					1.18	1.08	1.03
FRL		Natural	Neoprene	PU	CSPE						Natural	Neoprene	PU	CSPE			
	Nylon 1%	1.30	1.22	1.40	1.25						1.20	1.20	1.40	1.25			
	Nylon 10%	0.95	1.23	1.39	1.22						0.83	1.26	1.40	1.23			
	Cotton 1%	0.46	0.52	0.49	0.47						0.36	0.53	0.51	0.49			
	Cotton 10%	0.46	0.50	0.54	0.47						0.35	0.55	0.55	0.47			

Natural = natural rubber
PU = polyurethane
CSPE = chlorosulphonated polyethylene

Table 7

TABLE OF SIGNIFICANT MEAN BREAKING EXTENSIONS, PER CENT

Factor	Level	Set (see Table 4)								
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
F	Nylon	21.9	20.2	20.1	15.7	19.5	21.2	20.6	20.3	17.8
	Cotton	9.3	7.1	7.9	5.2	7.1	8.7	8.8	7.6	
R	Natural	14.7	12.1	12.8		10.5	13.4	13.6	13.3	15.7
	Neoprene	14.0	13.5	13.6		13.6	14.5	13.5	13.2	18.5
	PU	17.2	14.9	15.2		15.1	16.7	16.5	14.4	
	CSPE	16.4	14.1	14.4		13.9	15.2	15.1	14.9	19.3
T	Original	14.5					14.5	14.5	14.5	
	Final	16.7					16.7	16.7	16.7	
	3 months		13.6	15.2	12.1	13.7	15.4	15.1	15.1	19.8
	6 months			13.9	10.4	13.2	14.4	14.8	12.5	17.8
	12 months			12.8	8.9	12.5	13.5	13.0	11.9	16.0
	6S months			14.1	10.3	13.8	15.1	14.1	13.0	17.8
L	1%		15.2	14.0	12.8	14.6	14.9	14.7	14.0	19.6
	10%		12.1		8.1	12.0				16.0
S	ERDE		13.7	14.6	10.5	13.3	14.9			18.7
	Cloncurry		13.5	14.2	10.7			14.7		17.1
	Innisfail		13.6	13.1	10.1				14.0	17.8

FR		Nylon	Cotton	Nylon	Cotton	Nylon	Cotton	Nylon	Cotton	Nylon	Cotton	Nylon	Cotton	Nylon	Cotton	
	Natural	20.8	8.7	18.2	6.0	19.0	6.6			16.3	4.8	19.8	6.9	19.5	7.8	19.5	7.2	
	Neoprene	19.7	8.4	20.2	6.8	19.2	7.9			20.2	7.1	20.4	8.5	18.7	8.3	19.1	7.3	
	PU	23.5	10.9	21.9	7.9	21.8	8.6			22.1	8.1	23.3	10.0	22.7	10.3	21.0	7.8	
	CSPE	23.6	9.3	20.5	7.6	20.4	8.4			19.6	8.3	21.2	9.2	21.6	8.7	21.7	8.2	
FT	Original	20.7	8.2									20.7	8.2	20.7	8.2	20.7	8.2	
	Final	23.0	10.4									23.0	10.4	23.0	10.4	23.0	10.4	
	3 months					21.7	8.7	18.2	6.0	20.6	6.9	22.3	8.4	20.9	9.4	21.9	8.2	
	6 months					19.7	8.1	15.5	5.3	19.5	6.8	20.2	8.6	20.8	8.7	18.1	6.9	
	12 months					18.7	6.9	13.7	4.2	18.3	6.7	19.3	7.7	18.2	7.8	18.4	5.3	
	6S months					20.4	7.8	15.3	6.7	19.8	7.8	21.5	8.7	20.1	8.1	19.5	6.5	

FS																	
	ERDE			20.6	6.9	20.8	8.4	16.3	4.8								
	Cloncurry			19.5	7.6	20.0	8.5	15.4	6.0								
	Innisfail			20.5	6.7	19.5	6.7	15.4	4.8								

RL				1%	10%			1%	10%	1%	10%					1%	10%
	Natural			14.6	9.6					12.7	8.4					19.0	12.4
	Neoprene			14.8	12.3					14.7	12.6					19.2	17.7
	PU			16.1	13.7					16.4	13.8						
	CSPE			15.3	12.8					14.6	13.3					20.6	18.0
LS	ERDE			15.4	12.1			12.7	8.4							20.0	17.3
	Cloncurry			15.1	12.0			13.1	8.3							19.2	14.9
	Innisfail			15.1	12.1			12.6	7.5							19.6	15.9

FL																	
	Nylon			21.7	18.7			19.0	12.4	20.8	18.3						
	Cotton			8.7	5.5			6.6	3.8	8.4	5.8						

Table 7 (continued)

RT			Original	Final	3 months	6 months	12 months	6S months
	(a)	Natural	14.1	15.3				
		Neoprene	12.7	15.4				
		PU	16.0	18.4				
		CSPE	15.0	17.9				
	(c)	Natural			14.6	13.0	11.1	12.6
		Neoprene			14.8	13.8	11.7	14.0
		PU			16.1	15.0	14.4	15.2
		CSPE			15.3	13.9	14.0	14.4
	(e)	Natural			12.4	10.3	8.4	11.0
		Neoprene			13.8	13.6	12.9	14.2
		PU			15.2	15.1	14.5	15.7
		CSPE			13.6	13.8	14.1	14.4
	(f)	Natural	14.1	15.3	14.9	13.0	10.0	12.8
		Neoprene	12.7	15.4	15.1	14.6	13.5	15.4
		PU	16.0	18.4	16.5	16.1	16.1	17.0
		CSPE	15.0	17.9	14.9	13.8	14.5	15.1
	(g)	Natural	14.1	15.3	14.9	13.6	11.2	12.8
		Neoprene	12.7	15.4	14.1	13.8	11.1	13.9
		PU	16.0	18.4	16.0	16.8	15.9	15.8
		CSPE	15.0	17.9	15.5	14.8	13.8	13.9
	(h)	Natural	14.1	15.3	14.0	12.2	12.0	12.2
		Neoprene	12.7	15.4	15.0	12.9	10.4	12.8
		PU	16.0	18.4	15.8	12.0	11.4	12.8
		CSPE	15.0	17.9	15.6	13.0	13.7	14.3
	(i)	Natural			18.2	15.5	13.7	15.3
		Neoprene			20.2	19.0	16.2	18.5
		PU						
		CSPE			20.9	18.8	18.1	19.5

Table 7 (concluded)

RS		(b) ERDE	(b) Cloncurry	(b) Innisfail	(c) ERDE	(c) Cloncurry	(c) Innisfail	(d) ERDE	(d) Cloncurry	(d) Innisfail	(e)	(i) ERDE	(i) Cloncurry	(i) Innisfail
	Natural	12.4	12.2	11.7	12.7	13.1	12.6					16.3	15.4	15.4
	Neoprene	13.8	12.8	14.0	14.7	13.2	12.7					20.2	17.0	18.3
	PU	15.2	14.9	14.4	16.4	16.1	13.0							
	CSPE	13.6	14.3	14.3	14.6	14.5	14.2					19.6	18.8	19.6
TS	3 months				15.4	15.1	15.1	12.4	12.2	11.7		19.9	18.8	20.7
	6 months				14.4	14.8	12.5	10.3	11.2	9.8		18.6	17.9	16.8
	12 months				13.5	13.0	11.9	8.4	9.3	9.1		17.4	14.6	16.0
	6S months				15.1	14.1	13.0	11.0	10.1	9.7		18.8	17.0	17.5

FRL		Natural	Neoprene	PU	CSPE	Natural	Neoprene	PU	CSPE
	Nylon 1%	21.8	20.8	22.5	21.8	19.3	20.7	23.3	20.0
	Nylon 10%	14.7	19.7	21.2	19.2	13.2	19.6	21.0	19.2
	Cotton 1%	7.4	8.7	9.7	8.8	6.1	8.6	9.6	9.1
	Cotton 10%	4.5	4.9	6.1	6.4	3.5	5.5	6.6	7.4

FTL		(d) 3 mths	(d) 6 mths	(d) 12 mths	(d) 6S mths	(e) 3 mths	(e) 6 mths	(e) 12 mths	(e) 6S mths
	Nylon 1%	21.8	18.6	17.1	18.6	22.3	20.2	19.3	21.5
	Nylon 10%	14.7	12.4	10.3	12.1	18.8	18.9	17.2	18.2
	Cotton 1%	7.4	7.3	5.1	6.7	8.4	8.6	7.7	8.7
	Cotton 10%	4.5	3.4	3.2	4.0	5.4	5.1	5.6	6.9

Natural = natural rubber
PU = polyurethane
CSPE = chlorosulphonated polyethylene

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2	British Standards Institution	Inspection and testing of textiles. BS 3F 100 (1975)
3	J.E. Swallow	Effects of dyes and finishes on the weathering of nylon textiles. RAE Technical Report 74179 (1975)

REPORT DOCUMENTATION PAGE

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17. Abstract

The breaking strength and extension of a nylon and of a cotton fabric, each coated with natural rubber, neoprene, polyurethane or chlorosulphonated polyethylene and exposed to various weathering conditions, were determined. Although the coated nylon fabrics were stronger and more extensible than the cotton ones, those with natural rubber coating deteriorated at a faster rate when exposed under load. Nylon coated with polyurethane was initially stronger and more extensible than when coated with the other rubbers, but in hot moist weathering conditions deteriorated faster. Extension was more severely affected than strength by load during exposure.

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