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# 6—THE INFLUENCE OF THE POLYMER ON THE PROPERTIES OF FOAM BACKING FOR CARPETS*

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The three commonest polymers used for foam-rubber carpet-backing are polyisoprene (natural rubber (NR)), styrene–butadiene rubber (SBR), and carboxylated styrene–butadiene rubber (C-SBR). Each polymer has different properties and contributes to the characteristics of the carpet-backing foam. A study is reported in this paper of the properties of carpet-backing foams prepared from the polymers under comparable conditions. The compression modulus of the foam for NR is equivalent to that for SBR but lower than that for C-SBR. However, flex loss and the effect of water-soaking are greater for SBR and C-SBR. The same trend is seen for the delamination-resistance, hysteresis loss, resilience, and tearing strength. The ageing of the systems is discussed. The present position with regard to specifications for carpets is briefly outlined and the effect these have on the polymer choice examined.

## 1. INTRODUCTION

Tufted carpets, mostly with foam backings, continue to show a healthy growth. The figures in Table 1 show the U.K. sales in recent years.

Table I

| Year | Tufted-carpet Sales | Woven-carpet Sales |
|---|---|---|
| 1967 | 52·7 | 35·7 |
| 1968 | 59·5 | 39·9 |
| 1969 | 63·3 | 39·2 |
| 1970 | 72·6 | 38·0 |
| 1971 | 84·5 | 37·5 |
| 1972 | 104·9 | 40·0 |

Figures are in units of million square yards (data from the Department of Trade).

Foam-backed tufted carpets are economic to buy, are simple to install, and provide a feel of luxury. They are popular in the medium-to-low price bracket and have gained the confidence of the public for durability. One of the developments taking place in the British carpet industry is the present and future emergence of specifications for tufted carpets. The U.S.A. has a specification published by the American Carpet and Rug Institute[1].

On September 30th, 1973, the U.K. Department of the Environment published Specification 252 for 'heavy-contract-quality tufted carpets'[2]. This specification is very comprehensive and includes minimum values for properties of the pile, tuft-bonding, foam backing, compressive durability, etc. Of special concern to latex technologists are specifications on anchor-coating, interfacial adhesion, compression after static and dynamic loading, dimensional stability, flammability, and static electricity.

The existence of specifications and the desire to meet them require a knowledge of the physical properties of all parts of the carpet. The Latex Technology Group of the Malaysian Rubber Producers' Research Association has been studying for some time the properties of the anchor-coating and foam backing that are relevant to the usage of the carpet. There are three major polymers used in carpet-backing: natural rubber (NR or polyisoprene); styrene–butadiene rubber (SBR); and carboxylated styrene–butadiene rubber (C-SBR). Other polymers used are polyvinyl chloride and polyurethane. Each polymer has different properties and so affects the physical properties of the foam backing. The polymers can be blended, if desired, in all proportions.

The processing of the polymers also affects their properties, and the effect of gelling and non-gelling systems has been studied for NR and SBR; C-SBR is always processed

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as a non-gelling system. These different systems are summarized as follows:

*gel foam:* foam latex $\xrightarrow[\text{gelling agent}]{\text{heat}}$ gelation $\xrightarrow[\text{dry, vulcanize}]{\text{oven}}$ product;

*no-gel foam:* foam latex $\xrightarrow[\text{dry, vulcanize}]{\text{oven}}$ product.

The formulations and properties of these two processes are different and give different results. The purpose of this paper is to report findings concerning the influence of the polymer on the properties of the foam-rubber backings. The results refer to laboratory and pilot-plant studies but are related to plant performance.

General information on the foam backing of carpets is available[3-13]. Some of the data presented here have appeared in more detail elsewhere[14].

## 2. PREPARATION OF SAMPLES

Normal commercial supplies of latices and rubber-compounding ingredients were used. Batches of latex compound were foamed at maximum speed in the bowl of a Kenwood 'Chef' domestic mixer to the required volume increase. Foam times ranged from 10 to 120 sec and were followed by refining for 180 sec at a slow speed. The gelling agent (ammonium acetate solution) was added at this stage for gelled foams. The foam was spread onto PTFE–glass-fibre plates to give a wet foam thickness of 4·5 mm and vulcanized for 30 min at 150°C. This cure time was selected to give the minimum time for drying and vulcanizing and was fixed for all samples. For backed-carpet studies, the foam was spread onto the back of tufted-carpet samples already anchor-coated and was then cured as above. The carpet was of a cut-pile type and made from viscose rayon. Formulations are given in Table II. These formulations are to be regarded, not as the best recommended ones, but as ones that are representative of the different systems.

Table II

| Additive | A(Gel) | B(No-gel) |
|---|---|---|
| 60% Centrifuged concentrate—high ammonia | 167·0 | |
| 60% Centrifuged concentrate—low ammonia (Santobrite) | - | 167·0 |
| 50% Sulphur | 4·0 | 4·0 |
| 50% Zinc oxide | 8·0 | 8·0 |
| 50% Zinc mercaptobenzthiazole | 3·0 | 3·0 |
| 50% Zinc diethyldithiocarbamate | 3·0 | 3·0 |
| 50% Flectol H | 2·0 | 2·0 |
| 20% Potassium oleate (Prifac FO15 (Price Ltd)) | 20·0 | — |
| Alcopol FA (30% active (Allied Colloids Ltd)) | — | 18·0 |
| 28% Sodium dodecylsulphate (Empicol LX28 (Marchon Ltd)) | — | 3·6 |
| Whiting (Snowcal 2 ML) | 0–200 | 0–200 |
| 20% Ammonium acetate | 12·5 | — |
| Tetron (Tetrasodium polyphosphate) | — | 1·0 |
| 10% Rohagit S-MV (Rohm & Haas Co. Inc.) | 5·0 | 5·0 |

For comparison with different polymers, SBR-Intex 128 (15% styrene) was introduced to replace NR with the same formulation, except that gelling was facilitated for 100% SBR when 1% ammonia was added. Samples of carboxylated SBR foam were prepared as above from a commercially available sulphur-vulcanizing system based on Revinex 34D40.

## 3. TESTING OF SAMPLES

All samples were matured for 24 hr before being tested at 20°C and 60% r.h. Samples were then tested for compression modulus, density, tensile properties, compression set, resilience, delamination strength, tearing strength, carpet thickness, compression, and recovery, static loading, skin-scuff resistance, resistivity, dimensional stability, flammability, compression, crack-resistance, and dynamic loading*.

## 4. RESULTS AND DISCUSSION

### 4.1 Compression Modulus

The compression modulus ($C$) at any given deformation is primarily controlled by the density ($D$) of the foam. Studies over a wide range of densities, filler levels, and polymeric systems indicate that Shipley's relation[15] holds true:

$$C = KD^n, \qquad \ldots\ldots (1)$$

where $C$ = compression modulus at a given deformation, $D$ = density, and $K$ and $n$ are constants, i.e.:

$$\log C = \log K + n \log D. \qquad \ldots\ldots (2)$$

This suggests a linear relation between $\log C$ and $\log D$, which was confirmed by least-squares computation and is illustrated in Fig. 1. NR and SBR show equivalent compression moduli with density, but C-SBR shows slightly higher values. This is because C-SBR has a higher styrene content and is inherently a stiffer polymer.

The filler has a softening effect on the modulus, and this is demonstrated for NR in Fig. 2. The other polymers behave similarly. A comparison of gel and no-gel systems showed little difference in the modulus characteristics.

Specification 252 expresses the hardness of the foam backing in terms of the percentage deformation at a fixed load of 0·35 kgf/cm² and requires a range of 25–40%. By using the compounds described previously, this was achieved in a density range of 0·24–0·29 g/cm³ (15–18 lb/ft³), which is given by a wet density of 0·45–0·50 g/cm³.

The effect of soaking in water was examined, and the results are shown in Fig. 3. The first aspect to note is that all no-gel systems are water-sensitive and lose their modulus values on soaking, whereas gel systems are relatively insensitive to water. Replacement of NR by SR increases water sensitivity for gel systems, but less effect is seen for no-gel foams.

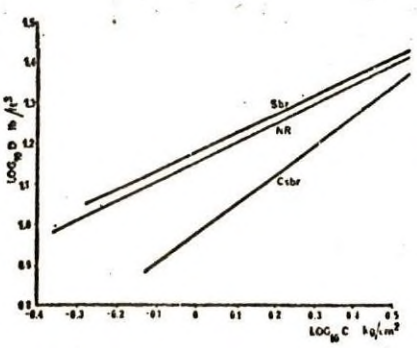


**Fig. 1**
The effect of density ($D$) g/cm³ on the 50% compression modulus ($C$) kgf/cm² for no-gel + 100 p.h.r.† filler foams

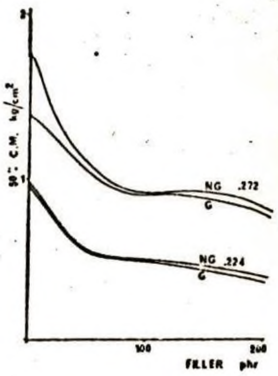


**Fig. 2**
The effect of filler (Whiting 2ML) on the 50% compression modulus (C.M.) at two densities (0·272 and 0·224 g/cm³) for gel (G) and no-gel (NG) NR foams

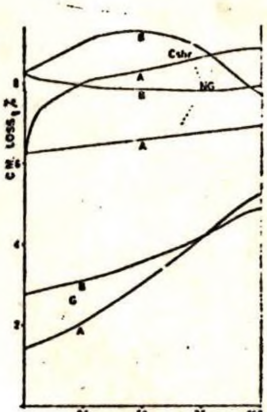


**Fig. 3**
The loss of compression modulus (C.M.) on soaking in water for different polymer systems (expressed as % SBR) at two filler levels (A = 100 p.h.r., B = 200 p.h.r.) for gel (G) and no-gel (NG) systems

*Details of the test methods used, together with Tables III–VII, are deposited at the British Library, Lending Division, as SUP 12035 (7 pages) under the Supplementary Publications Scheme.

† p.h.r. = parts per hundred of rubber; this abbreviation is also used in the captions of several of the figures that follow.

All carpets in use are subjected to compression cycles, and the effect of prolonged cycling or flexing is to reduce the foam hardness, as is shown in Fig. 4. The general trend is that NR foam backings retain their modulus on prolonged flexing better than those of SBR.

Studies on the dynamic compression set after flexing for 250,000 times at 4 flexes/sec indicate that, for gel systems, SR is inferior to NR, but, for no-gel foams, the effect of the polymer is less pronounced, and two samples of SR gave slightly improved sets.

**4.2 Tensile Properties**

The tensile and tearing strengths of the foam backing of a carpet are measures of its durability in transportation, handling, and laying. A strong foam that resists being torn is a good selling factor for the carpet. The tensile strengths of foam systems are shown in Fig. 5. NR foams were superior to SR foams, with C-SBR in an intermediate position. As the filler level increases, the tensile strength decreases. The effect of the polymer on the elongation at break is illustrated in Fig. 6. The incorporation of SBR or C-SBR markedly

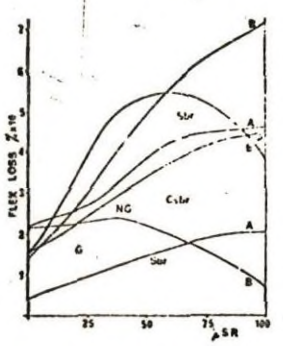

Fig. 4
The flex loss of modulus with polymer (% S.R.) for gel (G) and no-gel (NG) systems at two filler levels (A = 100 p.h.r., B = 200 p.h.r.)

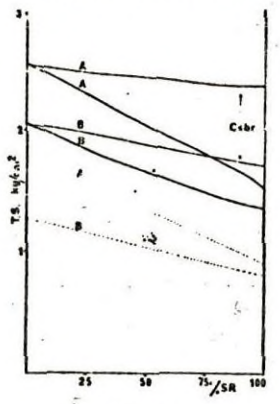

Fig. 5
The effect of the polymer (% S.R.) on the tensile strength (T.S.) of foams for gel (broken lines) and no-gel (solid lines) at two filler levels (A = 100 p.h.r., B = 200 p.h.r.)

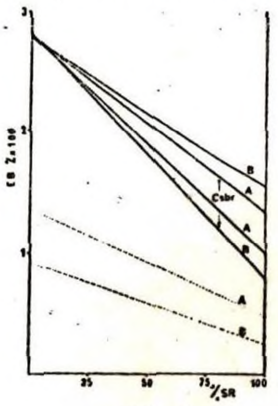

Fig. 6
The effect of the polymer (% S.R.) on the elongation at break (E.B.) of foams for gel (broken lines) and no-gel (solid lines) at two filler levels (A = 100 p.h.r., B = 200 p.h.r.)

reduces the elongation at break. Previous data[14] have shown clearly the superiority of no-gel foams over gel foams for tensile strength, tearing strength, and elongation at break.

The effect of the polymer on the tearing strength is shown in Table III*. NR gives a better tearing strength than SBR and C-SBR, C-SBR being superior to SBR. The tearing strength falls off with the filler content.

**4.3 Resilience**

The resilience of a foam backing is a measure of the springiness of the carpet of which it forms part. It is also believed that a highly resilient foam is most suitable for carpeted areas in hospitals where trolleys are used, since it will minimize the effort required in pushing them. The results of falling-ball resilience studies on backings are shown in Fig. 7. NR gel systems provide the highest resilience of the foams studied. Replacement of NR by SBR gives a lower resilience. The very low values for 100% C-SBR should be noted; this polymer gives a very 'loggy' foam, with a slow recovery after deformation.

A similar picture emerges when the 0–50–0% compression hysteresis loss is examined (Fig. 8). More energy is absorbed for SBR and C-SBR than for NR.

**4.4 Delamination Strength**

The delamination strength or interfacial adhesion is the force necessary to tear the foam rubber from the back of the carpet. It affects the laying and relaying properties of the carpet. Specification 252 requires a minimum value of 2·2 kgf per 50-mm width.

* SUP 12035.

The delamination strength for NR systems is displayed in Fig. 9. A filler reduces the streagth at any given density, as is shown in Fig. 10. No-gel systems are superior to gel

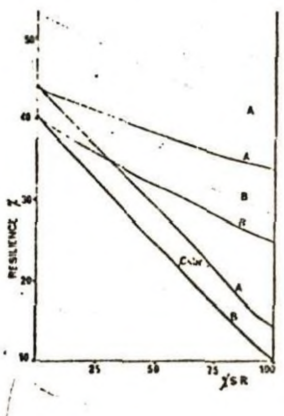


Fig. 7
The effect of the polymer (% S.R.) on the resilience for gel (broken lines) and no-gel (solid lines) at two filler levels (A=100 p.h.r., B=200 p.h.r.)

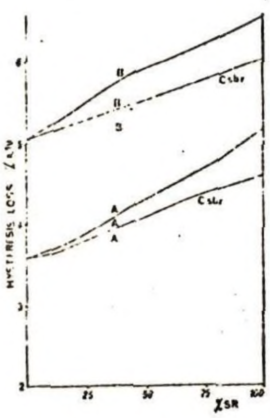


Fig. 8
The effect of the polymer (% S.R.) on the hysteresis loss (0–50–0% compression) for gel (broken lines) and no-gel (solid lines) at two filler levels (A=100 p.h.r., B=200 p.h.r.)

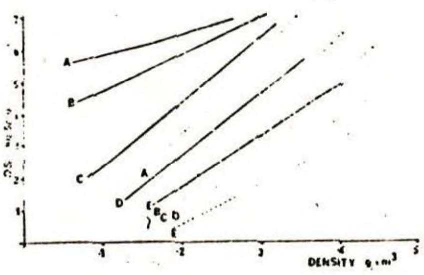


Fig. 9
The relation between delamination strength (D.S.) and foam density for no-gel (solid lines) and gel (broken lines) for different filler contents: A=0, B=50, C=100, D=150, E=200 p.h.r.

systems, although strength is lost when the backing becomes wet. The effect of the polymer is demonstrated in Fig. 11. Replacement of NR by SBR gives a marked reduction in the delamination strength, but replacement of NR by C-SBR gives less reduction in the strength.

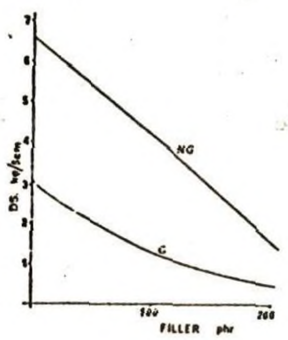


Fig. 10
The effect of filler on the delamination strength (D.S.) for gel (G) and no-gel (NG) foams at the same density (0·200 g/cm³)

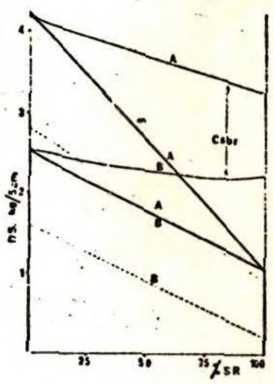


Fig. 11
The effect of the polymer (% S.R.) on the dry delamination strength (D.S.) for gel (broken lines) and no-gel (solid lines) at two filler levels (A=100 p.h.r., B=200 p.h.r.)

These results are to be expected, since the delamination strength is a measure of the tensile- and tearing-strength properties of the foam carpet-backing.

## 4.5 Compression Set

The set of foam backings is summarized in Table IV*. The American Carpet and Rug Institute imposes a maximum set of 15% after 22 hr at 70°C.

* SUP 12035.

The different polymers do not show great variation in their compression-set characteristics. A filler appears to reduce the set slightly, perhaps owing to a reduction in the cell-wall tack. Gel systems appear slightly better than no-gel foams. Almost all foams are satisfactory for the 15% limit after 22 hr at 70°C.

### 4.6 Ageing

Foam backings are subjected to accelerated-ageing tests to predict service performance, and oven-ageing is used at temperatures from 70°C upwards. The prediction of ambient behaviour from ageing results is known to be hazardous. Ageing for seven days at 70°C is stipulated in Specification 252, whereas the American specification refers to 24 hr at 135°C. The effect of accelerated ageing on some properties of foams is given in Table V*.

The effect of ageing differs according to the conditions employed. At the times used in this study, temperatures of 70 and 100°C increase the foam modulus and generally decrease the tensile strength and elongation at break. All polymeric systems behave similarly, though NR is affected more at elevated temperatures of ageing. Crack-resistance is satisfactory except for the NR–G–100 sample.

The American 135°C ageing test was met without difficulty, but the Specification 252 requirement of not more than 10% change in strain after seven days at 70°C was not satisfied.

There is no evidence to lead to the belief that the natural polymer would not perform satisfactorily at ambient temperature as a result of oxidative ageing. The causes for this failure are being examined, and further studies are in progress.

### 4.7 Carpet-loading Studies

The effects of loading according to B.S. 4098: 1967 (on dry and wet samples) and by deadweight loading (45 kgf/26 mm²) were examined, and the results are shown in Table VI*. The results for the dry B.S. 4098: 1967 test are within the Specification 252 limit of 90% minimum except for C-SBR + 200 filler. The bracketed results indicate that the foam rubber itself recovers better on the whole than the carpet. The actual presence of the foam on the carpet improves the recovery.

The recovery of wet samples tested to B.S. 4098: 1967 is lower for all systems than that in the corresponding dry tests. The Specification 252 limit of not more than 10% change in recovery was not satisfied, but the unsupported foam could generally meet this limit. For the deadweight tests, no sample of carpet gave the required 90% recovery. NR–no-gel–200 gave the best results. The unsupported foams gave 97–100% recovery for all samples. It is believed that these loading tests are primarily a test of the pile of the carpet and that backing plays only a secondary part in determining recovery.

The dynamic loading according to B.S. 4052: 1966 was studied on wet and dry samples, and the results are given in Table VII*. The presence of foam rubber improves the dynamic-loading thickness loss. In the dry state, NR and SBR foams are slightly better than C-SBR, with blends showing up well. Water-soaking appears to have little effect on the loss of thickness. The Specification 252 maximum level of 10% loss was not satisfied. The pile of the carpet seems to be the controlling factor for this test.

### 4.8 Other Properties

The flammability requirement of Specification 252 was satisfied without special compounding. Values for vertical resistivity were comparable with the specification's requirements. Dimensional-stability studies indicated that this property is mainly affected by the primary fabric and anchor-coating rather than the foam backing. Jute fabric was preferable to polypropylene in the preliminary results. Skin-scuff resistance on the crockmeter showed most foams satisfactory, but NR–gel–200 and SBR–no-gel–100 failed. NR–no-gel was superior to the others.

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* SUP 12035.

## 5. CONCLUSIONS

It is now possible to summarize the influence of the polymers investigated on the various properties of foam backings of carpets, and this is done in Table VIII.

Table VIII

| Property | Effect of Replacing SBR or C-SBR by NR |
|---|---|
| Compression modulus—dry | =(SBR) —(C-SBR) |
| Compression modulus—soaked | ++ |
| Flexing behaviour | ++ |
| Tensile strength | +++ |
| Elongation at break | +++ |
| Tearing strength | +++ |
| Tensile product | ++++ |
| Resilience | +++ |
| Hysteresis loss | +++ |
| Delamination strength | +++ |
| Compression set | = |
| Ageing (high-temperature) | — |
| Carpet loading | = |

*Note:* +Small increase; ++medium increase; +++large increase; ++++very large increase; =no change; —decrease.

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