INVESTIGATION IN THE USE OF COWPEA CHAFF AS AN ADDITIVE FOR NATURAL RUBBER.

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Abstract

Natural rubber is a gummy liquid obtained from the sap fluid of the tree Hevea brasiliensis. It is a natural hydrocarbon polymer of 2-methyl-1,3-butadiene (isoprene), which contains one double bond per repeating unit, whose structural arrangement typifies that of a cis-isomer (cis-polyyisoprene). Natural rubber in its raw gum state is tacky, fairly elastic but suffers some limitations such as poor resistance to weathering condition, low tensile strength and hence additives are always added to improve on the limitations of the natural Rubber. Most additives are imported hence constituting additional cost. Cowpea chaff was used in this study as one of the additives. The cowpea chaff was chosen for this research due to its availability and cost since it is a waste material and expected to reduce cost of production. The cowpea chaff was grinded and sieved to fine particles (powder) using 100µm. The cowpea chaff powder was divided into portions and part were modified via nitration. The modified and unmodified cowpea chaff powders were characterized to determine the Ash content, Moisture content, Volatile content, pH, Loss on ignition, X-ray florescence (XRF) analysis was carried out to ascertain the elemental composition and Infra-red spectroscopy (FT-IR) to determine the functional groups and extent of the reaction of the samples. Each of the portions were compounded with Natural Rubber (NR) using calcium carbonate as control. The physico-mechanical properties of the vulcanizates obtained were determined. The study showed that chemically modified and unmodified cowpea chaff powders were good additives (softeners). Based on the parameters tested, it can be concluded that cowpea chaff can be substituted with CaCO₃ filler in NR vulcanizates.

INTRODUCTION

The economic importance of Natural Rubber Latex (NRL) cannot be overemphasized due to its wider application in technological uses [1]. Natural rubber is a renewable agricultural resource that is commercially used as an outstanding polymeric material and it has economic values with unique performance in elasticity, flexibility, high resilience, great tensile strength and efficient heat dispersion [2-4]. Despite the wide range of properties of NR, it does have some deficiencies which affect its efficiency, NR is susceptible to being broken down as a result of oxidative and thermal degradation of its unsaturated backbone, especially when it is used without any form of modification. NR also has some undesirable properties such as low heat and abrasion resistance, poor ageing properties and low oil and flame resistance. [5] had linked these drawbacks to the high unsaturation of the molecular chain and the non-polar character of Natural rubber. In the virgin form, NR does not meet the required industrial benchmarks in terms of quality for industrial applications and as such it is imperative that some modifications be carried out on the NRL in a bid to improve its mechanical properties, thermal stability, electrical conductivity and many other properties. [6] in response to a poser about why Natural Rubber needs to be compounded, stated that “Natural Rubber ultimately requires compounding due to its tremendous Molecular weight which restrict the incorporation of additives into it. Once Natural rubber is masticated, its molecular weight is reduced and
the various compounding ingredients are added to it which enhances the life and durability of rubber.”

According to [7], Additives are materials which when incorporated into a polymer base, helps to ensure easy processing, reduce cost of products and service properties. Additives which can be incorporated into Natural rubber are of different types with each of them serving different functions but with the sole aim of improving the properties of rubber. The different types of additives used in the processing of Natural rubber into products include Vulcanizing agent, accelerators, activators, anti-degradants, fillers, softeners, thickeners, gel sensitizers, colourants, etc. In our society, agricultural products with a number of potentials are yet to be explored and exploited. In time past, researches have been carried out on agricultural products such as cherry seed shells, coconut husks and shells etc. The use of rubber seed shell cocoa pod husk and groundnut husk as additives in rubber compounding have been previously documented [2-4]. However, the use of Cowpea chaff as an additive in rubber compounding is still novel and hence serve as basis for this research work.

**EXPERIMENTAL**

**MATERIALS**

Natural Rubber latex from NIG 902 clone, having the characteristics as shown in Table I, was obtained from the estates of the Rubber Research Institute of Nigeria (Benin City, Nigeria).

| Table 1; Showing the characteristics of the natural rubber latex used. |
|--------------------|-----------------|
| PARAMETERS          | COMPOSITION (%) |
| Dry Rubber Content (DRC) | 36.26 |
| Total Solid Content (TSC) | 38.30 |
| Moisture Content     | 56.67 |
| Ash Content          | 2.13 |
| Mechanical Stability | 550  |

Cowpea chaff for this research work was obtained from local retailers of cowpea chaff around Camp area of Abeokuta. This chaff was dried at ambient temperature after which it was ground into fine powder. The powdered form of the cowpea chaff was passed through a 100 µm particle-size mesh.

**METHODS**

**Preparation of crumb rubber**

The NRL was transferred into a clean bowl and 5 % acetic acid was added with continuous stirring until the rubber coagulates. It was then washed with distilled water and was cut into small pieces and was washed again with distilled water; It was spread on a foil paper and was then placed in a drying cabinet at 80 ⁰C for up to 6 hours.

**Nitration of cowpea chaff**

This was carried out by preparing 2 M Trioxonitrate (V) acid solution. This solution was added to the ground sample of Cowpea chaff and allowed to mix for up to one hour. The resulting solution was then washed with distilled water and decanted. The residue from the decantation was then placed in the oven to dry after which it was transferred to the desiccator. The dried residue was then crushed into powdered form.

**FOURIER TRANSFORM INFRARED (FT-IR) SPECTROSCOPY ANALYSIS**

This was done on the modified (nitrated) and unmodified cowpea chaff to determine the presence of N-H group difference in both samples.

**MICROPIXE ANALYSIS**

This analysis was carried out to determine the elemental composition of the unmodified and modified (nitrated) Cowpea chaff which is to be used as an additive in the compounding of Natural Rubber. The results were compared to discover their effect on Natural Rubber
COMPOUNDING FORMULATION FOR RUBBER AND COWPEA CHAFF [8]

Table 2: Showing compounding formulation for rubber, cowpea chaff and other additives

| RECIPE/MIX | CONTROL | MIX 1A | MIX 1B | MIX 2A | MIX 2B |
|------------|---------|--------|--------|--------|--------|
| Crumb rubber (g) | 100 | 100 | 100 | 100 | 100 |
| Carbon black (g) | 40 | 20 | 0 | 20 | 0 |
| Modified Cowpea chaff (g) | 0 | 20 | 40 | 20 | 40 |
| Unmodified Cowpea chaff (g) | 0 | 20 | 40 | 20 | 40 |
| ZnO (g) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Stearic acid (g) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| MBTS (g) | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| TMQ (g) | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Sulphur (g) | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Flectol H (g) | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |

RESULTS AND DISCUSSION

Table 3: SHOWING THE PHYSICO-CHEMICAL PROPERTIES OF COMPOUNDED RUBBER

| S/N | Parameters | 1A | 1B | 2A | 2B | CONTROL | Unit |
|-----|------------|----|----|----|----|---------|------|
| 1   | Yield Load | 4.90 | 4.30 | 4.60 | 4.40 | 5.10 | Kgf  |
| 2   | Yield Elongation | 32.80 | 36.00 | 35.20 | 37.70 | 30.50 | Mm   |
| 3   | Tensile Strength at yield load | 7.63 | 7.43 | 7.35 | 7.44 | 7.92 | MPa  |
| 4   | Breaking load | 4.50 | 4.80 | 4.60 | 5.30 | 4.40 | Kgf  |
| 5   | Elongation at break load | 327.05 | 321.85 | 340.32 | 352.60 | 325.30 | Mm   |
| 6   | Tensile strength at breaking load | 9.56 | 9.10 | 8.35 | 7.88 | 10.70 | MPa  |
| 7   | Tenacity at breaking load | 38000 | 33000 | 16000 | 13000 | 16000 | gms/Denier |
| 8   | Elongation % at break | 697.34 | 748.95 | 724.65 | 782.67 | 683.00 | %    |
| 9   | Maximum load | 19.10 | 19.40 | 18.00 | 19.30 | 21.60 | Kgf  |
| 10  | Elongation at maximum load | 352.30 | 364.10 | 344.75 | 396.25 | 346.20 | Mm   |
| 11  | Tensile strength at maximum load | 10.89 | 10.74 | 10.44 | 10.25 | 11.35 | MPa  |
| 12  | Tenacity at Maximum load | 41000 | 34100 | 20200 | 25400 | 36000 | gms/Denier |
| 13  | Elongation % at Maximum load | 340.38 | 355.13 | 364.75 | 395.25 | 282.75 | %    |
| 14  | Modulus Elasticity | 5.44 | 5.25 | 5.39 | 5.10 | 5.6 | MPa  |
| 15  | 0.1 % Offset yield Strength | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | MPa  |

1A: Unmodified Cowpea chaff + Rubber + Carbon Black (20:100:20), 1B: Unmodified Cowpea chaff + Rubber (40:100), 2A: Modified (Nitrated) Cowpea chaff + Rubber + Carbon Black (20:100:20), 2B: Modified (Nitrated) Cowpea chaff + Rubber (40:100), CONTROL SAMPLE: Carbon black + Rubber (40:100)
TENSILE STRENGTH AT BREAKING LOAD
It reflects the average strength of the vulcanizate when it is put to use. The tensile value at breaking load in Table 3 varied from 10.70 MPa for the control sample, 9.56 MPa for sample 1A, 9.10 MPa for sample 1B, 8.35 MPa for sample 2A and 7.88 MPa for sample 2B. The control sample [Natural rubber and carbon black (Ratio 100:40)] has the highest tensile value in this trend when compared with other mixes. Comparing the other mixes with the control sample which has high level of carbon black (40 g) and highest tensile value in the trend, indicating that the control sample act less as a softener in comparison with the other mixes. The reduction in the tensile strength of the other mixes points to the fact that the Cowpea chaff has not enhanced strength reinforcement. Hence, the trend of the tensile shows that the Cowpea chaff acted as a softener and not a reinforcing material. Therefore, the tensile strength at breaking load as shown in Table 3 suggests that the vulcanizate can find uses in some applications where high strength is not required.

ELONGATION % AT BREAK
It shows the extent of flexibility of the material at a specific applied force. It is also known as fracture strain, is the ratio between changed length and initial length after breakage of the test specimen [9]. The control sample which has the highest level of carbon black was found to have lower value of elongation % at break (683.00 %). The high value of the elongation % at break of sample 2B [Natural rubber + modified Cowpea chaff (100:40)] is attributed to the presence of more fiber as well as the presence of nitro group in the mix which enhance its flexibility hence, the material has the ability to be stretched farther in comparison with other mixes. The result of elongation % at break also supports the assertion that the Cowpea chaff serves more as a softener which will make the material more easily stretched.

MODULUS OF ELASTICITY
An elastic modulus (also known as modulus of elasticity) is a quantity that measures an object or substances’ resistance to being deformed elastically (i.e., non-permanently) when a stress is applied to it. The elastic modulus of an object is defined as the slope of its stress-strain curve in the elastic deformation region [10]. A stiffer material will have a higher elastic modulus. An elastic modulus has the form:

\[ \lambda = \frac{\text{stress}}{\text{strain}} \]

Where; Stress is the force causing the deformation divided by the area to which force is applied and Strain is the ratio of the change in some parameter caused by the deformation to the original value of the parameter [11]. The result for Modulus of elasticity follows the trend of elongation % at break and supports the ongoing softening properties of Cowpea chaff. Sample 2B [Natural rubber and modified Cowpea chaff (100:40)] has the lowest value of modulus of elasticity when compared with other mixes and the control sample has the highest value for modulus of elasticity which suggest that it is more stiff and cannot be stretched to the same extent the vulcanizate from other mixes can be stretched.

This trend indicates that modified (nitrated) and unmodified Cowpea chaff has little effect on the physical parameter of the vulcanizate in essence, it does not influence the physical properties of the Natural rubber as a filler to a large extent but act more as a softener.

Summarily, the vulcanizate 1A, 1B, 2A and 2B which were compounded with unmodified and modified Cowpea chaff shows lower value in the following parameters when compared with the control vulcanizate; Yield load, tensile strength at yield load, tensile strength at breaking load, maximum load, tensile strength at maximum load, modulus elasticity. However, the result shows that they have high values in the following parameters; Yield elongation, breaking load, elongation at break load, elongation % at break. Meanwhile, the values for Tenacity at breaking load varies.
Hardness tests

TABLE 4; Showing result of hardness tests

| SAMPLE | TEST 1  | TEST 2  | TEST 3  | AVERAGE (IRHD) |
|--------|---------|---------|---------|----------------|
| 1A     | 41.70   | 43.10   | 43.00   | 43.20          |
| 2A     | 42.60   | 44.00   | 43.00   | 42.60          |
| 1B     | 38.20   | 35.80   | 36.40   | 36.80          |
| 2B     | 35.20   | 34.40   | 35.40   | 35             |
| CONTROL| 43.8    | 45.3    | 42.9    | 44             |

It shows the resistance of the vulcanize to indentation. A high hardness value signifies a well cross linked material [12]. The control sample [Natural rubber + carbon black (100:40)] has the highest value when compared with other mixes, which implies that the Cowpea chaff, though can serve as good softener but it does not really improve the hardness of Natural rubber when compared with carbon black.

Swelling and solubility tests

The resistance of the vulcanize to Ethyl-acetate, chloroform, kerosene and distilled water were determined with the methods described in ASTM D 361021 with a slight modification. [13-15]

The vulcanizates were cut into small bits and submerged into the different solvents. The weight of the vulcanizate was taken at an interval of 2 hours. Thereafter, the sample was further dried to a constant weight. The percentage increase in weight of the sample was calculated as the swelling, whereas the percentage loss in weight after it dried to a constant weight was calculated as the solubility:

Swelling % = \(\frac{W_2 - W_1}{W_1}\) \times 100

Solubility % = \(\frac{W_1 - W_3}{W_1}\) \times 100

where \(W_1\) is the initial weight of the sample, \(W_2\) is the weight after swelling, and \(W_3\) is the weight after drying to a constant weight.

Table 5: Showing Swelling and Solubility of Sample 1A

| Solvent        | Initial weight (g) | Weight @ 2hrs | Weight @ 4hrs | Weight @ 6hrs | Weight @ 8hrs | Weight @ 24hrs |
|----------------|--------------------|---------------|---------------|---------------|---------------|----------------|
| Ethyl-acetate  | 0.9                | 1.2           | 1.4           | 1.4           | 1.5           | 1.8            |
| Chloroform     | 0.8                | 2.3           | 2.5           | 1.9           | 1.6           | Slurry         |
| Kerosene       | 0.8                | 1.7           | 1.8           | 2.0           | 2.1           | 2.5            |
| Distilled water| 0.8                | 0.8           | 0.8           | 0.8           | 0.8           | 0.8            |

Table 6: Showing Swelling and Solubility of Sample 1B

| Solvent        | Initial weight (g) | Weight @ 2hrs | Weight @ 4hrs | Weight @ 6hrs | Weight @ 8hrs | Weight @ 24hrs |
|----------------|--------------------|---------------|---------------|---------------|---------------|----------------|
| Ethyl-acetate  | 1.0                | 1.3           | 1.3           | 1.5           | 1.7           | 2.4            |
| Chloroform     | 0.8                | 1.7           | 2.0           | 2.0           | 1.8           | 1.4            |
| Kerosene       | 0.7                | 1.1           | 1.2           | 1.4           | 1.5           | 1.9            |
| Distilled water| 0.8                | 0.9           | 0.9           | 0.9           | 0.9           | 0.9            |
The vulcanizate were tested for their swelling and solubility test at different intervals with constant weighing. From the result, each vulcanizate had a marked increase in swelling value in Ethyl-acetate, Chloroform and Kerosene. Meanwhile, in distilled water, all the vulcanizate shows no solubility nor swelling ratio and this could be attributed to the cross-linking of the vulcanizate.
Fig 1: Graph Showing Swelling Power of Vulcanizate in Different Solvents

Table 10: Showing FT-IR Spectra Interpretation for Modified Cowpea Chaff

| S/N | Wavenumber cm\(^{-1}\) | Transmittance% | Band Position cm\(^{-1}\) | Interpretation                                      |
|-----|-------------------------|-----------------|---------------------------|-----------------------------------------------------|
| 1   | 3273.76                 | 89              | 3400-3200                 | Strong (broad) O-H stretching (Alcohol)              |
| 2   | 2920.32                 | 91              | 3000-2840                 | Strong N-H stretch (Amine salt) OR Medium C-H stretch (Alkane) |
| 3   | 2854.89                 | 92              | 3000-2840                 | Strong N-H stretch (Amine salt) OR Medium C-H stretch (Alkane) |
| 4   | 1730.20                 | 89              | 1750-1735                 | Strong C-O stretching (Aldehyde)                     |
| 5   | 1629.73                 | 87              | 1662-1626                 | Medium C=C stretch (di-substituted cis)              |
| 6   | 1533.10                 | 92              | 1550-1500                 | Strong N-O stretch (Nitro compound)                  |
| 7   | 1317.81                 | 85              | 1390-1310/1350-1300       | Medium O-H bend (Phenol) OR Strong S=O stretch (Sulphone) |
| 8   | 1144.62                 | 85              | 1200-1100                 | Flouroalkanes (Trifluoromethyl)                      |
| 9   | 1010.76                 | 70              | 1100-1000                 | Ordinary Flouroalkanes                              |
| S/N | Wavenumber cm\(^{-1}\) | Transmittance(%) | Band Position cm\(^{-1}\) | Interpretation |
|-----|---------------------|-----------------|-----------------|-----------------|
| 1   | 3311.12             | 70              | 3350-3310        | Medium N-H stretching (Secondary amine) |
| 2   | 2921.34             | 80              | 3000-2840        | Medium C-H stretch (Alkane) |
| 3   | 2853.19             | 85              | 3000-2840        | Medium C-H stretch (Alkane) |
| 4   | 1731.86             | 85              | 1750-1735        | Strong C-O stretching (Aldehyde) |
| 5   | 1605.14             | 70              | 1640-1560/ 1610-1550 | Strong N-H stretch (Primary amine) OR C=O stretch of carboxylate salt. |
| 6   | 1411.46             | 75              | 1440-1395        | Medium O-H bend (Carboxylic acid) |
| 7   | 1370.32             | 75              | 1390-1310        | Medium O-H bend (Phenol) |
| 8   | 1316.35             | 76              | 1350-1300        | Strong S=O stretch (Sulphone) |
| 9   | 1235.91             | 74              | 1275-1200        | Strong C-O stretch (alkyl, aryl or ether) |
| 10  | 1144.45             | 70              | 1150-1085        | Strong C-O stretch (Aliphatic ether) |
| 11  | 1013.85             | 45              | 1400-1000        | Strong C-F stretch (Flouro compound) |
| 12  | 831.90              | 70              | 840-790          | Medium C=C bend (Vinylidene) |
| 13  | 520.23              | 45              | 690-515          | Strong C-Br stretch (Halo compound) |

The result from the FT-IR analysis was presented in Tables 10 and 11. From the spectra interpretation, it was observed that the unmodified Cowpea chaff contains secondary and primary amine, aldehyde, carboxylic acid, phenol, sulphone, carbonyl of alkyl, aryl and ether, alkanes, alkenes, alkynes, halo compounds while the modified Cowpea chaff contains alcohol, amine salt, alkane, aldehyde, alkene, nitro compound (N-O), phenol, sulphone, flouro alkanes. Functional groups such as Carboxylic acid, primary amine, alkyne, carbonyl of alkyl, aryl and ether and other halo compounds besides flouro-compounds present in the unmodified Cowpea chaff were found to be absent in the modified Cowpea chaff.
The result obtained from Micropixe analysis as provided in Table 12 provides information on the elemental composition of all the elements present in the unmodified and modified (nitrated) Cowpea chaff. From the table, Hydrogen (H) increased from 16.110 % for the unmodified Cowpea chaff to 17.154 % in the modified Cowpea chaff, Lithium (Li) increased from 0.244 % to 0.287 %, Boron (B) reduced from 0.055 % to 0.024 %, Carbon (C) reduced from 54.345 % to 50.128 %, Nitrogen (N) increased from 8.184 % to 9.648 %, Oxygen (O) increased from 8.163 % to 8.962 %, Sodium (Na) increased from 0.001 % to 0.005 %, Magnesium (Mg) increased from 0.346 % to 0.390 %, Aluminum (Al) increased from 2.077 % to 2.779 %, Silicon (Si) increased from 0.289 % to 0.469 %, Phosphorus (P) reduced from 0.122 % to 0.097 %, Sulphur (S) reduced from 0.101 % to 0.088 %, Chlorine (Cl) reduced from 0.192 % to 0.067 %, Potassium (K) increased from 1.869 % to 5.722 %, Calcium (Ca) reduced from 6.460 % to 4.639 %, Titanium (Ti) reduced from 0.036 % to 0.009 %, Manganese (Mn) which has a composition of 0.007 % was found to be negligible in the modified (nitrated) Cowpea chaff, Chromium (Cr) which was negligible in the unmodified was found to have a 0.009 % composition in the modified (nitrated) Cowpea chaff, Iron (Fe) increased from 0.029 % to 0.348 %, Copper (Cu) increased from 0.001 % to 0.002 % and Zinc (Zn) which has a composition of 0.002 % was found to be of negligible value in the modified (nitrated) Cowpea chaff. From the observed changes in the values of the elements, it can be deduced that the values for Hydrogen, Nitrogen and Oxygen indeed increased which confirms that Nitration of the Cowpea chaff indeed took place.

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% Increase of Hydrogen = \( \frac{\text{Value of H in Nitrated CC} - \text{Value of H in Unmodified CC}}{\text{Value of H in Modified Cowpea Chaff}} \times 100 \)

\[
= \frac{(0.154 - 0.110) \times 100}{0.154}
\]
% Increase of Hydrogen = 28.57 % increase.
% Increase of Nitrogen = 88.83 % increase
% Increase of Oxygen = 86.72%

The percentage increase in Hydrogen, Nitrogen and Chlorine is an indication that effective modification of the Cowpea chaff has been carried out.

CONCLUSION

This study has exposed us to the influence of modified (nitrated) and unmodified Cowpea chaff as additives in NR compounding. It was established that Cowpea chaff serves more as a softener in the vulcanizate hence, it cannot be used as a replacement for carbon black in applications where high tensile strength and hardness are required. Be that as it may, the modified (nitrated) and unmodified Cowpea chaff will serve as good additives in applications requiring a vulcanizate with less hardness and high elasticity as the result obtain has shown.

REFERENCES

1. Akinlabi A.K., Okeimen F.E., Okwu U.N., Oladoja N.A. (2007). Journal of Applied Polymer Science, Wiley Interscience. 104 (5) 2830
2. Akinlabi A.K., Okeimen F.E., Okwu U.N., Oladoja N.A. (2007). Chemical Engineering Communications, 194 (1) 1.
3. Akinlabi A.K. (2007) Progress in Rubber, Plastics and Recycling Technology. 23(1), 57.
4. Imanah J. E. and Okeimen F. E. (2003). ‘The Characterization of agricultural waste product as filler in NR formulations.’ Nigerian Journal of Polymer Science and Technology. 3 (1), 178-240
5. Mark J.E., Erman B. and Eirich F.R., 2005. Science and Technology of Rubber, Academic press.
6. Kaveri Lynn Ya., 2017 Former Research Intern at Universite INRS
7. Wong, N. P. and Loo, C. T. (1985). Proceedings of International Rubber Technology Conference, Kaula Lumpur, 1985. Volume II, p 487.
8. NIIR Board of Consultants and Engineers, 2006. Complete Book on Rubber Processing and Compounding Technology. ISBN: 8178330059
9. S.R. Djafari, Advanced High Strength Natural Fibre Composites in Construction, 2017.
10. Askeland, Doald R.; Phule, Pradeep P. (2006). The Science and engineering of Materials 5th Edition. Cengage Learning Pg. 198
11. Beer, Ferdinand P.; Johnston, E. Russell; Dewolf, John; Mazurek, David (2009).
12. Method for Determination of Hardness; HW Wallace & Co., Ltd., Croydon: UK. BS 903 Part A26; 1995.
13. Determination of Mechanical Properties of Rubber Compounds; ASTM D 412-87; American Society for Testing and Materials: West Conshohocken, PA, 1992.
14. Method for Determination of Compression Set at Ambient, Elevated or Low Temperatures; HW
15. Wallace & Co., Ltd., Croydon: UK. BS 903 Part A6; 1992.