# MECHANICAL PROPERTIES OF *EUCALYPTUS TRERETICORNIS*

*by*

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1. **Introduction.** *The history of the introduction of the genus Eucalyptus in the Indo-Pakistan subcontinent dates back to* 1867. *Since then a large number of species have been tried in nurseries as well as in plantations. The number of species which have been planted in different areas is somewhat limited the most common being Eucalyptus tereticornis and Eucalyptus camaldulensis. According to Parker* (7), *Eucalyptus tereticornis is the most common species found in the Punjab and with the possible exception of Eucalyptus rudis it has the fastest rate of growth. It has been tried in Andaldal Plantation of Shikarpur Forest Division and in Daphar Plantation of the Gujrat Forest Division. Pure stands of Eucalyptus tereticornis are found in several places in Abbottabad and Changa Manga. On account of its adaptability to a wide range of climatic conditions and its past performance in Africa and India, it has been recommended by Pryor* (8) *that this species should be preferred keeping in view the overall needs of timber for various end-uses.*

*Like other phenomenon in the universe, trees also require a systematic study. The growth of the trees is influenced by a number of factors involving a study of physiology, ecology and the silvicultural practices. But the foremost consideration which determines their commercial exploitation for various purposes is the basic information about their technological properties. The lack of such information about the home grown species has always been a serious set back in their proper utilization. An investigation on the technical properties of Eucalyptus tereticornis was therefore undertaken in order to provide reliable data often required for determining its utility. The present study is just a beginning of the work on the mechanical properties of some of the relatively uncommon timbers grown in Pakistan. Although this study is based on the material from only one locality, it is planned to extend this work to material growing in other areas as well.*

## 2. DESCRIPTION OF THE WOOD

**Eucalyptus tereticornis** is a hard and heavy wood, averaging about 44 lbs. per cft. in air-dry weight. It is medium textured with somewhat interlocked grain with colour of heartwood ranging from red to reddish brown. It is a diffuse porous wood with indistinct growth rings. The pores are small, mostly solitary, often filled with tyloses. Rays are fine, numerous and indistinct.

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The average fibre length in this species has been found to be 1.045 mm. with individual values ranging from 0.725 mm to 1.346 mm. The average fibre diameter has a value of 10.8 microns with lumen diameter of 5.6 microns. The Runkel ratio for this species works out to 0.92.

## 3. *MATERIAL AND METHODS*

3.1. **General.** The material consisted of a log of *Eucalyptus tereticornis* which was obtained from a 12-year old tree in the Andaldal Plantation of the Shikarpur Forest Division in Sind. The log was 5 ft. 9 inch in length having average diameter of 15 inches. There were no signs of any fungal or insect attack in the log, which had well pronounced eccentric growth. Deep cracks were present on both the cross-cut ends as depicted in Plate 2.

3.2 **Selection and Preparation of Test Specimens and their testing:**

The log was converted into 2½" x 2½" scantlings, which were marked as $N_1$, $N_2$, $N_3$, ............ and as $S_1$ and $S_2$ to fix their position in the log as shown in Fig. 1.

In order to reduce the moisture content from the initial value of about 93%, these scantlings were stored in constant humidity chambers running at a temperature of 35°C and different relative humidities. These were progressively shifted from 92% R.H. to 52% R.H. chambers. During drying, the scantlings had developed collapse which was removed by reconditioning them in a seasoning kiln at a temperature of 50°C and 85% relative humidity for about 5 hours. The material was finally kiln dried to 12 % moisture content.

The scantlings were then converted into small clear specimens for various strength properties. Because of the limited quantity of the material, efforts were made to get the maximum number of specimens for each test as detailed in Table I. In some samples oblique grain was present, but the extent of slope of grain was within the permissible limits. The samples were prepared and tested in accordance with the British Standard No. 373; 1957 except in the case of compression and shear, specimens were made in sizes other than those prescribed in the said Standard. Before testing, the samples prepared to finished sizes were again conditioned at a temperature of 35°C and 52% relative humidity for about 4 weeks. With the exception of the shear test all tests were conducted on Amslar Universal Testing Machine of 4,000 Kg. capacity. The shear test was done on Losenhausen Universal Testing Machine using special attachment for this purpose. The rate of loading on Amslar machine was controlled by timing the movement of the loading ram. The moisture content and density were determined for each test specimen.

## 4. *RESULTS AND DISCUSSION.*

4.1. **Mechanical Properties.** The results of the mechanical tests carried out on *E. tereticornis* are given in Table 2.

## Table 2. STRENGTH PROPERTIES

| PROPERTY | $N_1$ | $N_2$ | $N_3$ | $N_4$ | $N_5$ | $N_6$ | $N_7$ | $N_8$ | $N_9$ | $N_{10}$ | $N_{11}$ | $N_{12}$ | $S_1$ | $S_2$ | Total Average | Standard Deviation | Maximum Value | Minimum Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| Density lbs./c.ft. .. | 43.60 | 41.09 | 44.22 | 44.40 | 42.06 | 46.83 | 48.20 | 43.59 | 47.00 | 39.99 | 43.03 | 42.73 | 45.39 | 49.34 | 44.39 | ±3.59 | 52.94 | 36.71 |
| *Moisture Content%* . | 10.78 | 11.13 | 11.61 | 11.66 | 10.73 | 10.95 | 10.86 | 11.14 | 11.05 | 10.31 | 11.38 | 11.56 | 10.52 | 11.27 | 11.07 | .. | 11.61 | 10.31 |
| *Static Bending.* | | | | | | | | | | | | | | | | | | |
| Modulus of rupture : lbs/sq. in. | 15,145 | 12,412 | 13,785 | 12,782 | 11,240 | 15,754 | 16,973 | 12,051 | 17,204 | 12,181 | 12,530 | 12,085 | 12,580 | 16,199 | 13,921 | ±2,419 | 18,463 | 9,122 |
| Modulus of Elasticity ; 1,000 lbs/sq. in. | 1,137 | 1,035 | 1,125 | 1.066 | 1,155 | 1,389 | 1,375 | 1,012 | 1,397 | 1,148 | 1,024 | 940 | 1,434 | 1,330 | 1,185 | ± 185 | 1,589 | 922 |
| Work to proportional limit: lb.in/in³ | 4.72 | 4.58 | 4.36 | 3.86 | 4.13 | 4.77 | 4.83 | 4.06 | 4.34 | 3.33 | 4.65 | 4.20 | 3.46 | 3.70 | 4.20 | ± 0.81 | 5.86 | 2.56 |
| Work to Maximum load lb. in/in³ | 14.98 | 14.16 | 15.66 | 13.93 | 7.51 | 16.20 | 18.51 | 13.00 | 16.85 | 8.98 | 11.73 | 14.64 | 14.86 | 14.63 | 14.39 | ± 3.40 | 19.98 | 7.88 |
| Total work : lb in/in³ | 35.34 | 31.61 | 33.04 | 28.60 | 18.70 | 19.23 | 41.83 | 28.36 | 38.13 | 23.70 | 26.18 | 25.80 | 41.86 | 31.69 | 30.40 | ± 6.71 | 41.86 | 19.23 |
| *Compression.* | | | | | | | | | | | | | | | | | | |
| Compressive strength parallel to grain at Elastic limit; lbs. /in² | 5,410 | 4,822 | 5,003 | 5,316 | 5,378 | 5,870 | 6,059 | 5,210 | 5,840 | 4,983 | 4,629 | 4,476 | 7,640* | 5,963 | 5,363 | ± 596 | 6,718 | 4,150 |
| Max. Compressive strength parallel to grain: lbs./in² | 7,644 | 6,563 | 6,981 | 7,349 | 6,659 | 7,775 | 8,614 | 7,153 | 8,331 | 6,701 | 6,701 | 6,613 | 10,337 | 8,427 | 7,443 | ± 854 | 9,082 | 5 518 |

Table 1—SHOWING THE NUMBER OF SPECIMENS FOR VARIOUS TESTS

| Serial No. | PROPERTY | Number of Specimens from Different Scantlings | | | | | | | | | | | | | | TOTAL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | $N_1$ | $N_2$ | $N_3$ | $N_4$ | $N_5$ | $N_6$ | $N_7$ | $N_8$ | $N_9$ | $N_{10}$ | $N_{11}$ | $N_{12}$ | $S_1$ | $S_2$ | |
| 1. | Static Bending .. | 4 | 3 | 4 | 5 | 2 | 3 | 5 | 6 | 5 | 4 | 3 | 4 | 3 | 4 | 55 |
| 2. | Impact Bending .. | 4 | 3 | 3 | 5 | 2 | 3 | 5 | 6 | 5 | 4 | 2 | 4 | 3 | 3 | 52 |
| 3. | Compression parallel to grain .. | 4 | 4 | 4 | 6 | 3 | 3 | 5 | 6 | 5 | 4 | 2 | 5 | 2 | 4 | 57 |
| 4. | Compression perpendicular to grain .. | 4 | 4 | 4 | 5 | 3 | 3 | 5 | 6 | 5 | 4 | 3 | 5 | 2 | 5 | 58 |
| 5. | Tensile strength perpendicular to grain | 4 | 4 | 4 | 3 | 3 | 3 | 5 | 6 | 5 | 4 | 3 | 5 | 3 | 7 | 59 |
| 6 | Shear .. | 4 | 4 | 4 | 3 | 3 | 3 | 5 | 6 | 5 | 4 | 3 | 5 | 2 | 4 | 55 |
| 7. | Hardness .. | 4 | 3 | 4 | 5 | 2 | 3 | 5 | 6 | 5 | 4 | 3 | 4 | 3 | 4 | 55 |
| 8. | Cleavage .. | 4 | 4 | 4 | 4 | 3 | 3 | 5 | 6 | 5 | 4 | 2 | 5 | 2 | 4 | 55 |
| | | | | | | | | | | | | | | Total :— | | 446 |

| | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Compressive strength Perpendicular to grain at elastic limit : lbs./in² | 1,789 | 1.368 | 1,722 | 1,840 | 1,370 | 1,625 | 1,757 | 1,754 | 1,691 | 1,237 | 1,532 | 1,848 | 1,289 | 1,683 | 1,642 | ± 258 | 2,065 | 1,031 |
| *Tension.* | | | | | | | | | | | | | | | | | | |
| Max. tensile strength Perpendicular to grain : lbs/in² | 507 | 532 | 515 | 508 | 478 | 544 | 575 | 418 | 451 | 474 | 605 | 464 | 615 | 431 | 501 | ± 75 | 633 | 285 |
| *Toughness* | | | | | | | | | | | | | | | | | | |
| Max. energy required to cause failure: lbs in. | 128 | 105 | 151 | 113 | 79 | 107 | 190 | 123 | 145 | 70 | 146 | 117 | 199* | 257 * | 125 | ± 36 | 197 | 63 |
| *Shear* | | | | | | | | | | | | | | | | | | |
| Max. shearing strength Parallel to grain: lbs./in | 2,279 | 1,837 | 1,671 | 1,704 | 1,289 | 1,773 | 1,673 | 1;911 | 1,535 | 1,506 | 1,760 | 1,487 | 2,597 | 1,977 | 1,770 | ± 481 | 2,649 | 1,114 |
| CLeavage : lbs/in | 209 | 201 | 191 | 194 | 179 | 198 | 215 | 182 | 201 | 173 | 182 | 188 | 169 | 176 | 189 | ± 34 | 233 | 152 |
| *Hardness.—* | | | | | | | | | | | | | | | | | | |
| Side : lbs. | 851 | 709 | 811 | 883 | 632 | 868 | 976 | 881 | 879 | 610 | 799 | 821 | 617 | 978 | 808 | ± 202 | 1,035 | 511 |
| End : lbs. | 1,123 | 1,020 | 1,141 | 1,227 | 980 | 1,134 | 1,352 | 1,213 | 1,251 | 848 | 1,130 | 1,200 | 958 | 1,312 | 1,135 | ± 274 | 1,420 | 793 |

Abnormal values rejected in calculating Standard Deviation.

Columns 2-15 give the average strength values for each scantling, whereas the column 16 stands for the average value based on the total number of specimens tested for each property. The standard deviation, maximum value and minimum value are given in columns, 17, 18 and 19 respectively. The maximum and minimum values have been assigned to each property after rejecting the abnormal results falling outside the range of Average $\pm 2.33$ times the Standard Deviation. These values were located from the pooled data for all scantlings in respect of each property.

4.2 **Variability of the Material**—Like all other species of wood, *Eucalyptus tereticornis* shows considerable variation in the density and consequently in the strength properties within a single stem. The range of variation in most cases is more than 100%, when taken as the difference between the maximum and the minimum value using the latter as the base. It is also worth mentioning here that in spite of the large range of variation beween the two extreme limits as given in Table II, certain values did fall outside this range. These values were, of course, rejected treating them as abnormal. The maximum variation was observed in the case of Impact Bending where this property varied from 419 in. lb. to 22 in. lb. This extreme difference cannot be considered normal on account of other causes. The Impact Bending strenghth is, in fact, very much affected by several other factors such as slight variations in moisture content, orientation of growth rings (Keith, C.T. 1964), slope of grain and local weakness in timber. The failure in most of the specimens with extremely low values was of brash type. Another striking feature observed in the case of impact bending was that the brash failure took place mostly in samples taken from near the pith.This abnormal behaviour could possibly be explained by the presence of juvenile wood or could be attributed to brittle heart as reported by Dadswell and Langlands 1938).

The least variation in strength was observed in the case of compression parallel to the grain. This is in line with the findings of other workers like Harris and Orman (1958). The end hardness was found to be about 40% higher than the average hardness for the tangential and the radial faces.

During the compilation of the strength data it was observed that only a few specimens were responsible for extreme variations in strength values. This conclusion is supported by the histograms for density and Impact Bending in Figures 3 and 4. In the case of density 84% of the values fall within a small range of 40 to 49 lbs/c.ft . Similarly, in the case of Impact Bending about 70% of the results range from 50 to 150 lb. in.

4.3 **Variation of Strength Properties with distance from the pith** :—Because of the accentric growth in the experimental log, it was not possible to measure the distances from pith strictly along the radii. For the same reason, no uniform behaviour could be expected in specimens obtained from areas having wide and narrow rings. However, to get some idea of variation in strength properties of specimens in relation to the distance from the pith, the location of the geometrical centre of the scantling was regarded as fairly representative for this purpose. The average strength value for each scantling was plotted against the respective distance. Fig. (5) shows graphically the variation in strength with distance from pith for different properties. From these graphs it will be seen that neither the density nor the strength properties follow any regular trend over the whole cross-section of the log. It is, however, interesting to find that with the exception of Cleavage and Shearing strength, the variations in all other mechanical properties follow more or less the same pattern as is exhibited by density of wood with respect to distance from the pith. This obviously establishes the closer relationship between these strength properties and density as compared to cleavage and shearing strength. The latter properties seem to be affected by other factors like the arrangement of the fibres and the adhesive bond between them. It is also of interest to note that the curves for end and side hardness run almost parallel to each other.

**Conclusions :—**From the strength data for *Eucalyptus tereticornis* it can be concluded that this wood is quite hard and elastic, having strength properties comparable with those of other timbers of the same density. The comparison of the strength properties of home and Australian grown *Eucalyptus tereticornis,* however, shows that the home grown material is inferior to that grown in Australia in almost all respects. The average air-dry density of the Australian timber is about 63 lbs./c.ft. as against 44.4 lbs./c.ft. for the home grown material. On the whole, *Eucalyptus tereticornis* can be classed as moderately hard and heavy timber with strength properties somewhat inferior to *Dalbergia sissoo,* and should do fairly well for constructional works and rural use. On account of the satisfactory value of Runkel's ratio, *Eucalyptus tereticornis* also appears to be fairly good raw material for the production of pulp and paper.

*ACKNOWLEDGEMENTS*

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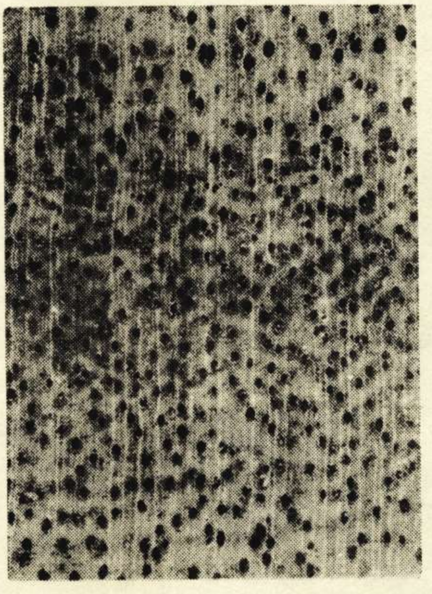

Fig. 1: *Eucalyptus tereticornis* (10X)

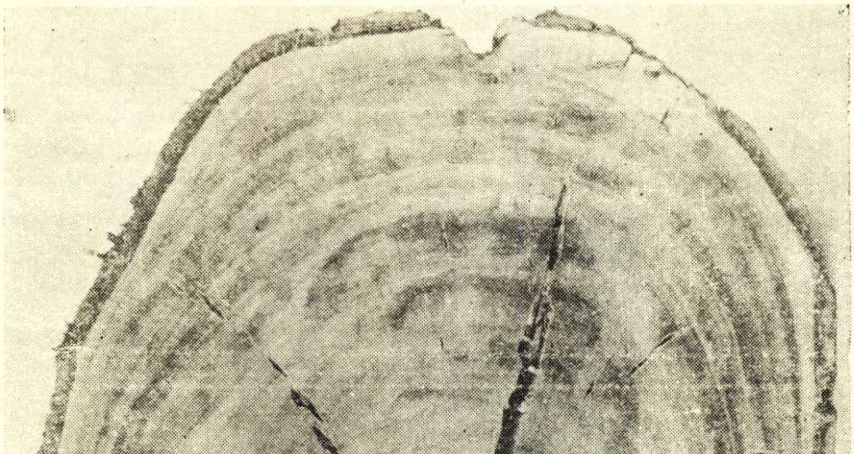

Fig. 2 : Showing the chocks in the experimental on *Eucalyptus tereticornts.*

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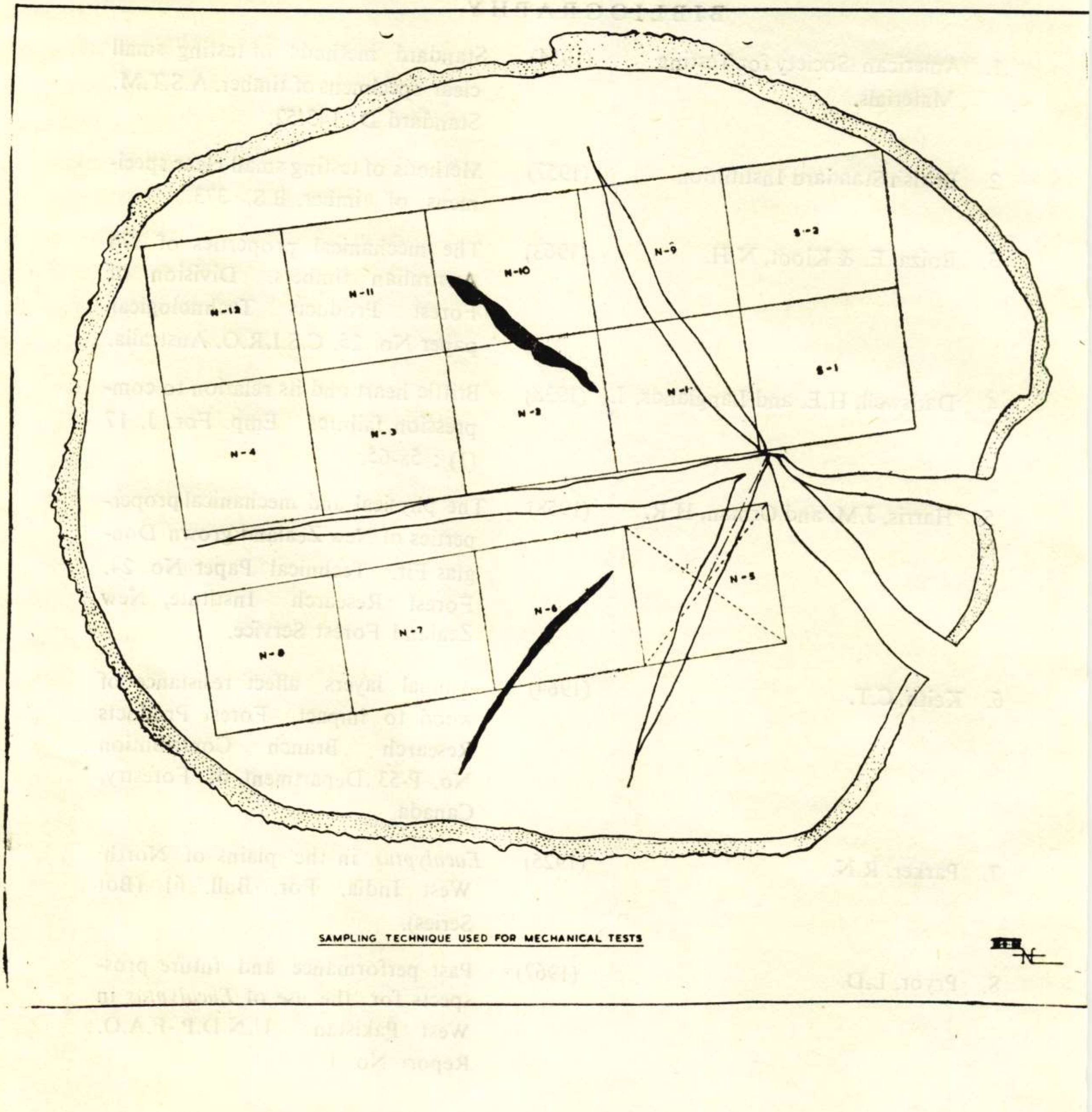



SAMPLING TECHNIQUE USED FOR MECHANICAL TESTS

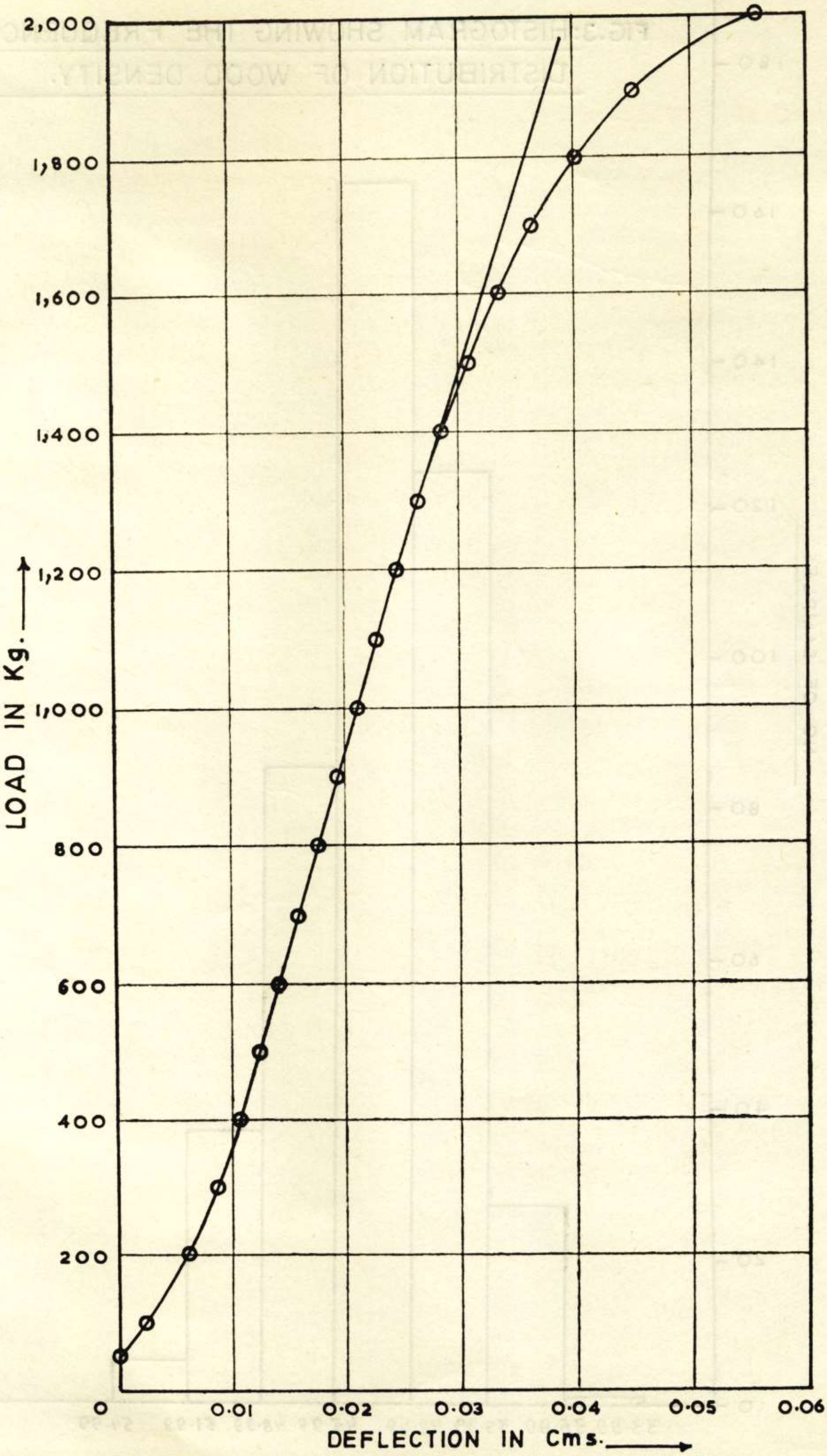



FIG. 2: A TYPICAL LOAD-DEFLECTION CURVE FOR COMPRESSION PARALLEL TO THE GRAIN.

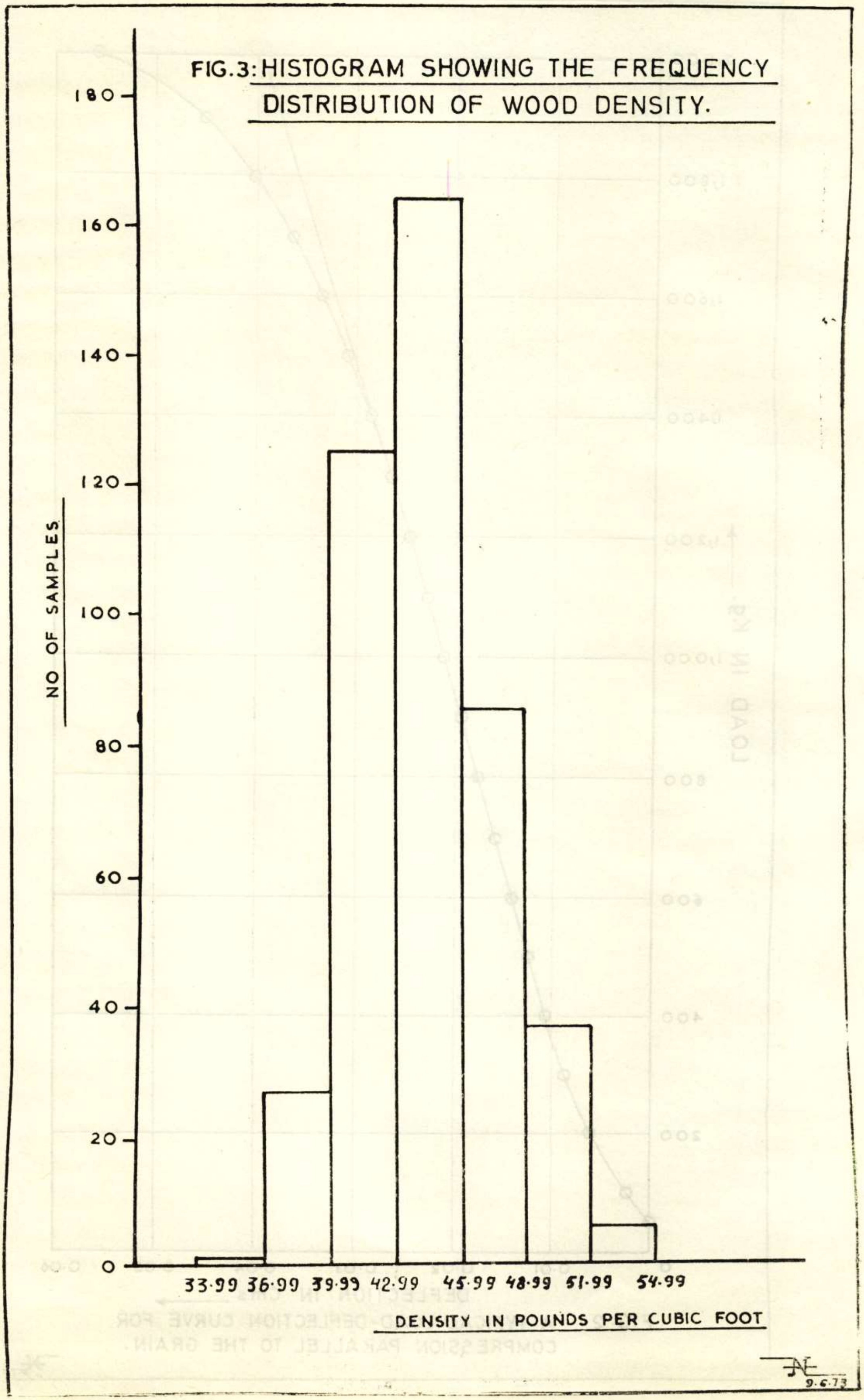
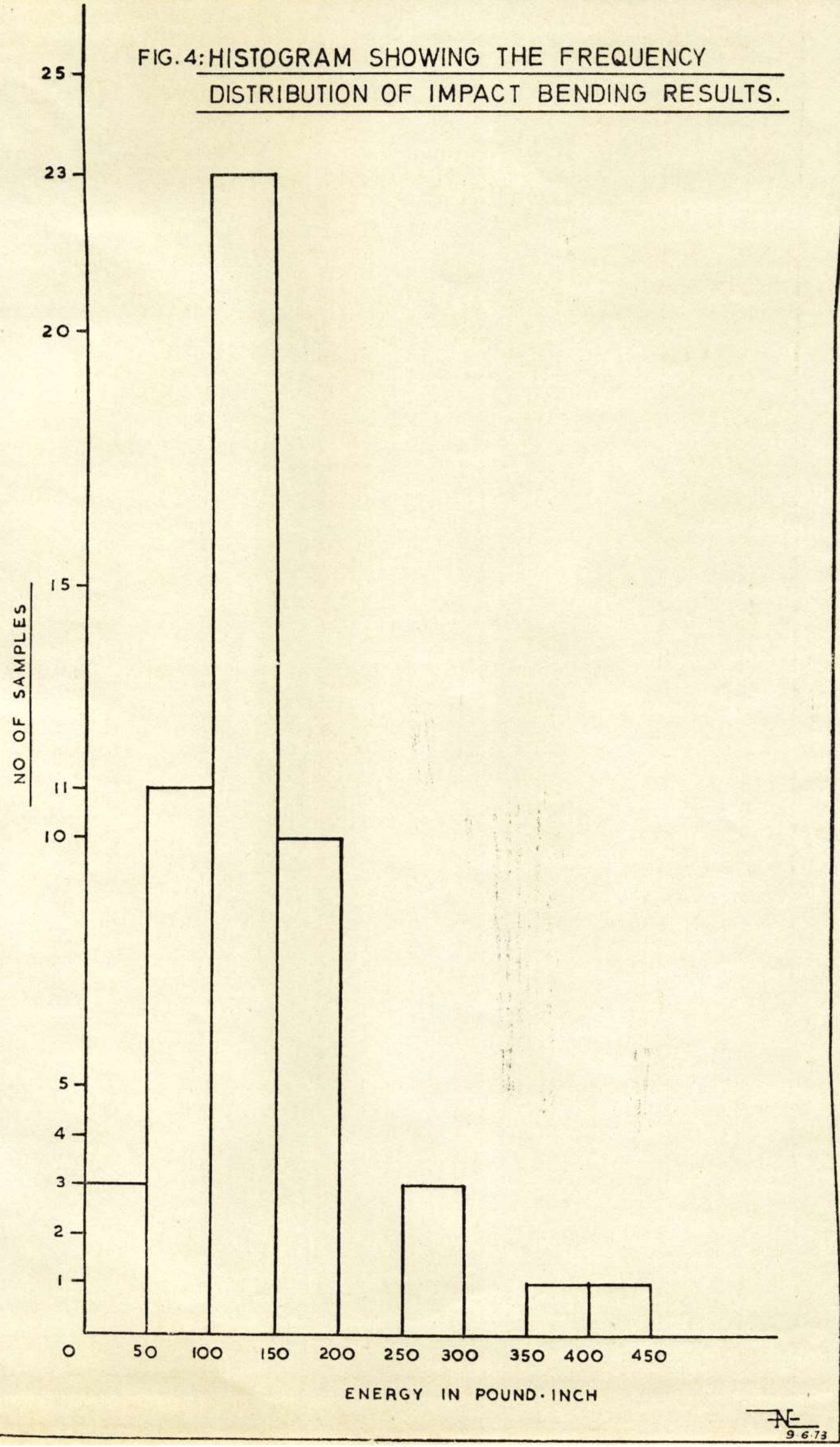
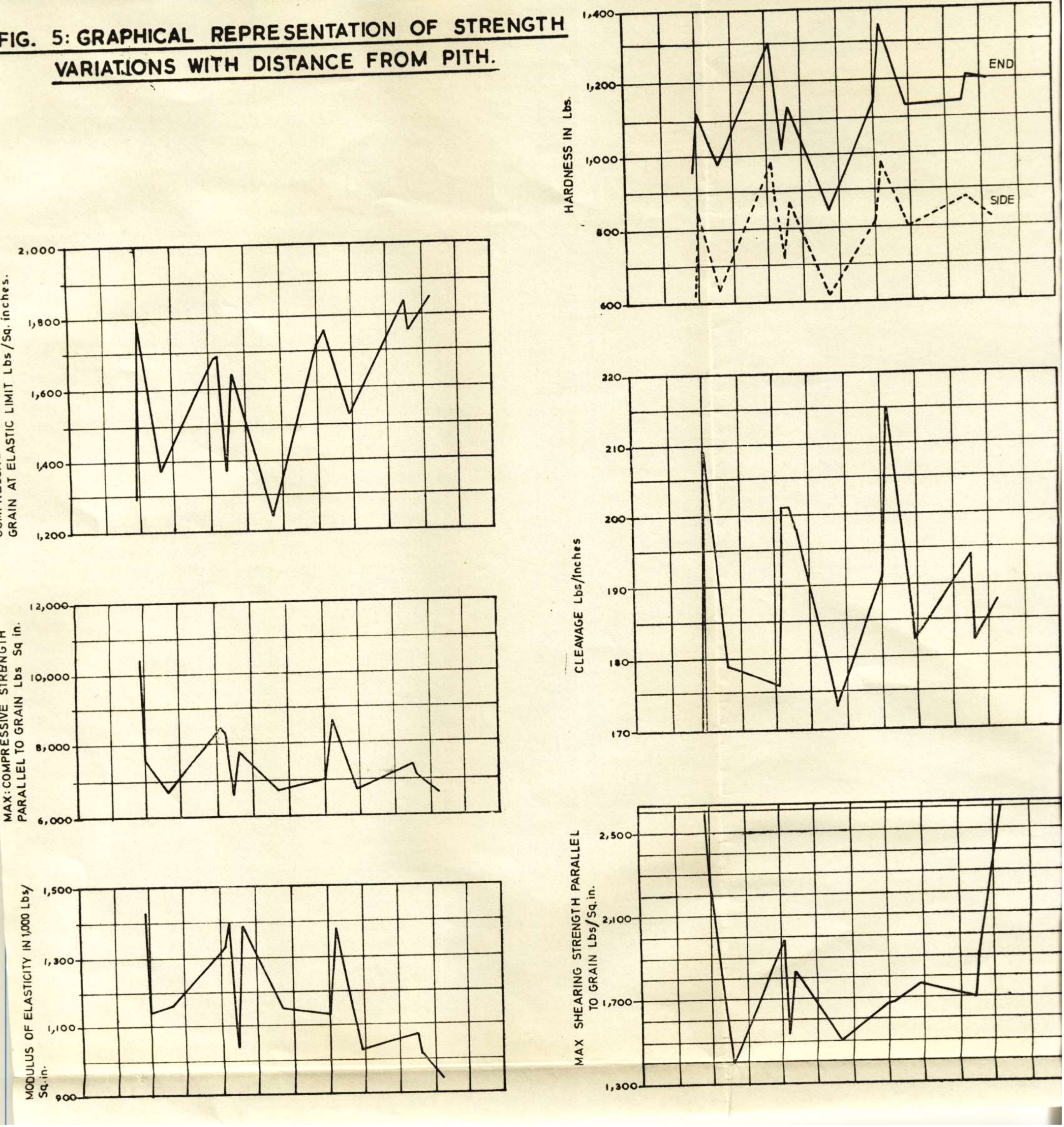


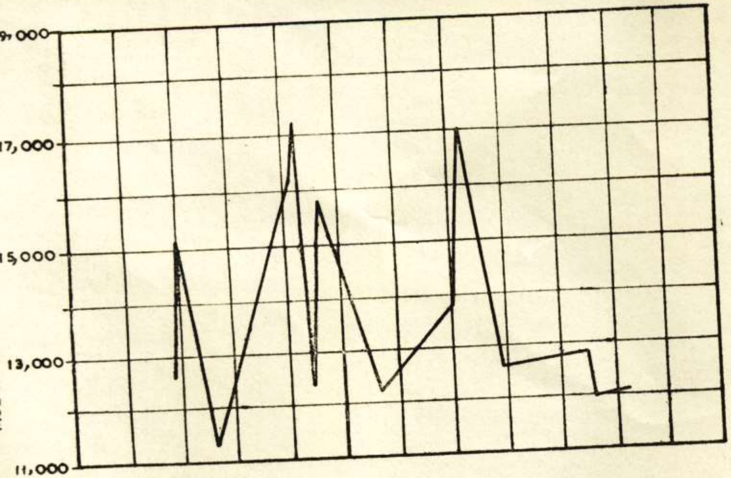
FIG. 3: HISTOGRAM SHOWING THE FREQUENCY DISTRIBUTION OF WOOD DENSITY.
NO OF SAMPLES
180
160
140
120
100
80
60
40
20
0
33·99
36·99
39·99
42·99
45·99
48·99
51·99
54·99
DENSITY IN POUNDS PER CUBIC FOOT

FIG. 4: HISTOGRAM SHOWING THE FREQUENCY DISTRIBUTION OF IMPACT BENDING RESULTS.

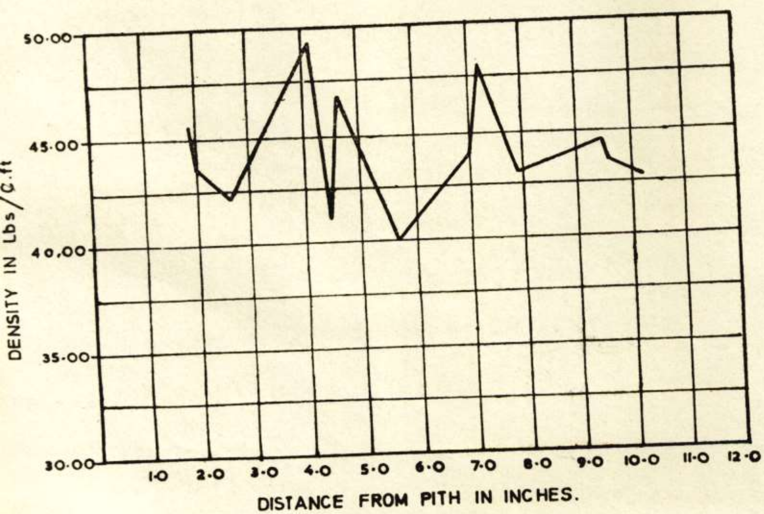


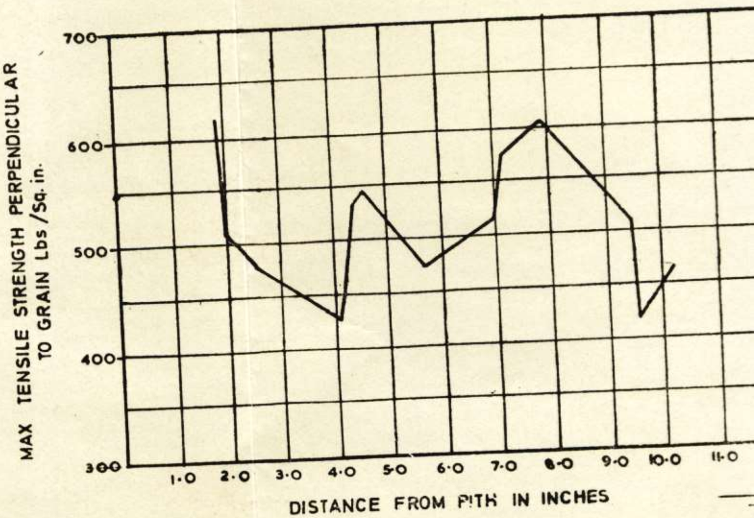
# FIG. 5: GRAPHICAL REPRESENTATION OF STRENGTH VARIATIONS WITH DISTANCE FROM PITH.




19,000
17,000
15,000
13,000
11,000


MAX ENERGY REQUIRED TO CAUSE FAILURE Lbs INCHES
270
220
170
120
70


DENSITY IN Lbs/C.ft
50.00
45.00
40.00
35.00
30.00
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
12.0
DISTANCE FROM PITH IN INCHES.


MAX TENSILE STRENGTH PERPENDICULAR TO GRAIN Lbs /Sq. in.
700
600
500
400
300
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
9.0
10.0
11.0
DISTANCE FROM PITH IN INCHES