CHAPTER TWO

The Structure and Properties of Jute

WHEN jute is extracted from the bast of its parent plant it is in the form of a long mesh of interconnecting fibres, in some places compacted into a flat ribbon and in others opening out into a network. This is the smallest unit of the commercial raw jute trade and is known as the reed, i.e. the aggregation of fibres coming from the stem of one plant. The reeds may be 3 to 14 ft long, depending on the grade, and they show quite clearly the taper of the stem from root to crop. Generally, long reeds have thicker root ends than short ones. Reeds which are thick all along their length tend to give coarse fibres and thin reeds tend to give fine fibres.

During manufacture the reeds are opened out and split into their component fibres; these are the fibre entities as far as the manufacturer is concerned. The weight per unit length of individual fibres varies from 0·7 to 5·5 tex but the average is between 1·9 and 2·2 tex. There is no clearly defined average fibre length and any sample of jute fibres contains large numbers of short fibres and a few long ones. Figure 2.1 shows the type of fibre length diagram obtained from jute; this pattern, combined with the relatively large diameter of the fibres, confines the use of jute to the heavier counts of yarn in comparison with wool, cotton, or flax, for if fine yarns are to be spun then fine fibres are a necessity.

The spinner's fibre is, in turn, composed of a number of smaller cells—the ultimates. There are usually between 6 and 20 ultimates in each cross-section of a fibre and in diameter they range from 6 to 20 microns and in length from 0·7 to 6·0 mm with an average of 2·5 mm. The cell walls are thick and in the centre of the cell is a hollow lumen which, in life, is filled with protoplasm. The lumen is irregular in cross-section sometimes becoming broad, making the cell walls thin at that point. Plate I shows a transverse section and a longitudinal view of a jute fibre. The characteristic shape of the ultimates can be seen.

Jute, like most of the other textile fibres, is hygroscopic, i.e. it takes in or gives out moisture to its surrounding atmosphere. This it does

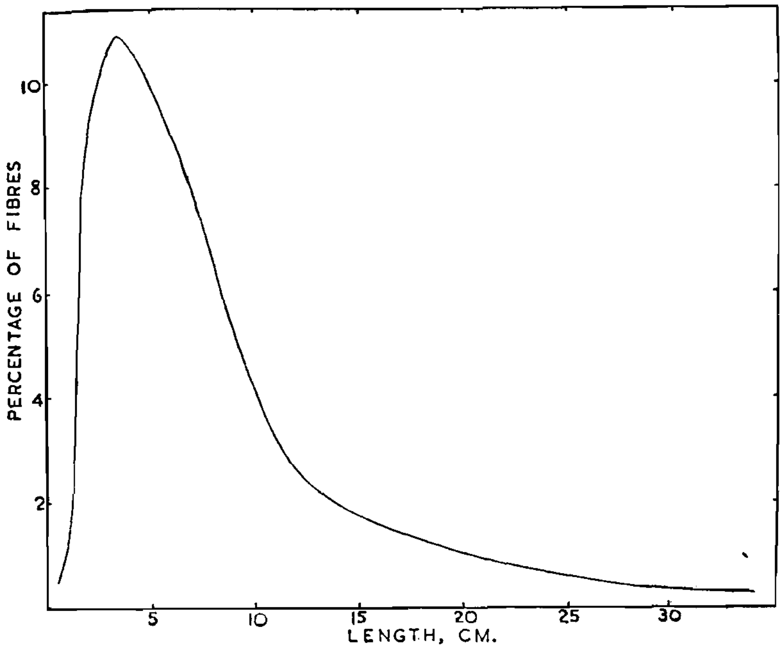

Figure 2.1. Typical fibre length distribution of finisher card sliver

at a rate depending upon the relative humidity of the air around it and fibres exposed to a certain relative humidity will adjust the amount of moisture they hold to suit the ambient conditions. When they neither absorb nor give up moisture to the air around them they are said to be in equilibrium with that particular atmosphere. Thus jute freely conditioned in certain ambient conditions contains a specific quantity of moisture. The amount of moisture held by jute can be expressed in two ways, by moisture content or moisture regain:

$$\text{Moisture content (\%)} = \frac{\text{Weight of moisture present} \times 100}{\text{Total weight of sample}}$$

$$\text{Moisture regain (\%)} = \frac{\text{Weight of moisture present} \times 100}{\text{Weight of bone-dry fibre}}$$

For reasons which will appear later, moisture regain is to be preferred.

If a sample of jute is split into two halves, one of which is dried in an oven and the other soaked in water, and the two allowed to condition

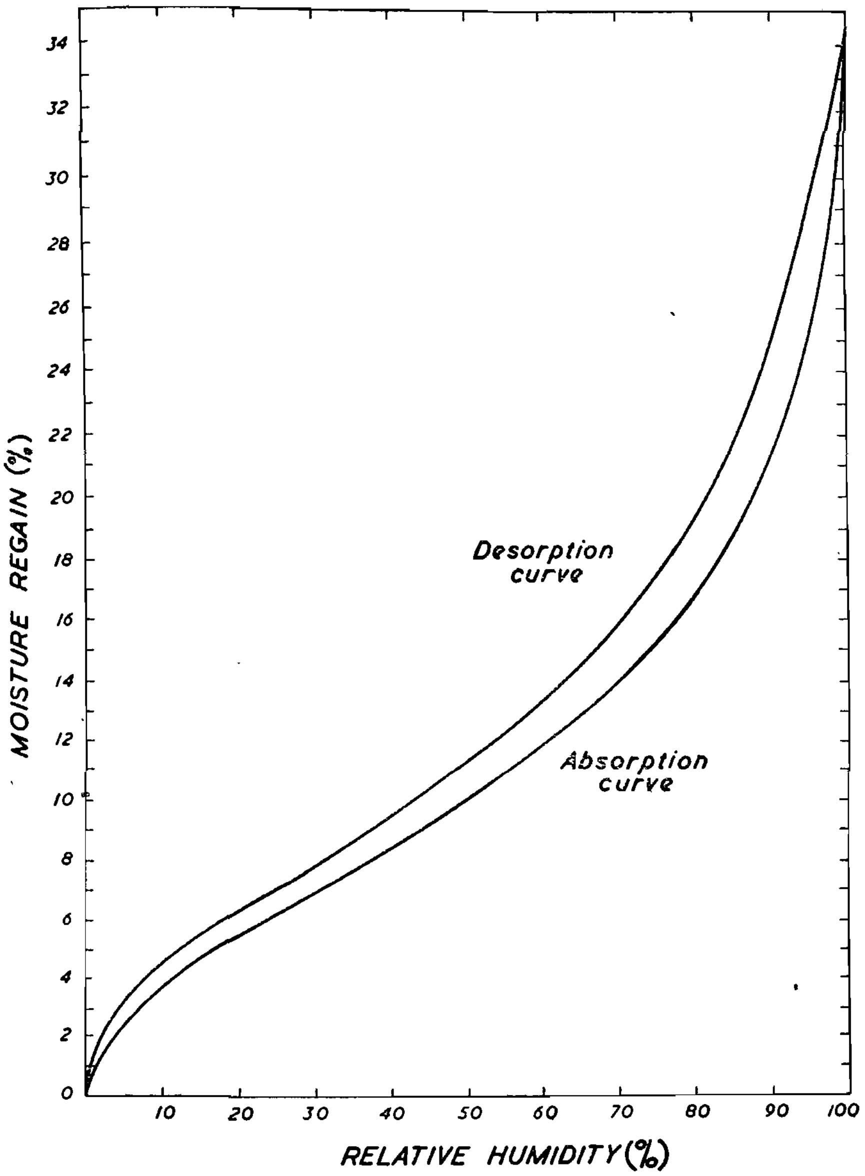

Figure 2.2. Moisture regain of jute at various humidities

in a certain atmosphere, they will not ultimately contain exactly the same amount of moisture. This is a result of a hysteresis effect. Figure 2.2 shows the moisture regains of jute conditioned at various humidities, with the hysteresis loop clearly shown. If jute approaches its equilibrium regain from the 'wet' side it is said to be on the desorption part of the curve and if it approaches it from the 'dry' side it is on the absorption part of the curve. At the standard relative humidity of 65 per cent at 20° C the two regains are about 2 per cent apart. In normal conditions of jute spinning the fibre always approaches equilibrium from the 'wet' side.

It may be mentioned in passing that moisture has another effect on the fibre which is used as a basis for measuring the moisture regain of the material. As the moisture regain increases, the electrical resistance of the fibres becomes less and their dielectric constant increases. These phenomena are utilized in two types of electronic moisture meters which measure the resistance or the dielectric constant of the fibres. These measurements can then be converted into moisture regain figures by consulting a calibration chart.

The tensile strength of a textile material is not an absolute figure but depends upon the well known influence of test length, method of loading adopted, machine capacity, etc., which the reader will find discussed in text books on testing. The effect of test length on the tenacity of jute is illustrated by the following figures taken from data by Mukherjee, Sen, and Wood (*J. text. Inst.* **39**, P243 (1948)).

Test length (*in.*)	*Tenacity* (*g/tex*)
0·5	60
1·0	49
1·5	46
2·0	43
2·5	40

Table 2.1 shows comparative tenacities for a selection of bast and leaf fibres (6 mm test length, constant-rate-of-loading machine, time-to-break 10 sec).

Chemically, jute has three main constituents: (1) Cellulose; (2) Hemicellulose; (3) Lignin. Small amounts of nitrogenous and inorganic material are present as well as variable amounts of water. So that differences in the percentage composition may not result simply from different levels of moisture in the fibre it is customary to express the

TABLE 2.1. FIBRE TENACITIES AND EXTENSIONS AT BREAK

Fibre	*Tenacity (g/tex)*	*Extension at break (per cent)*
Jute	70	2·0
Hemp	84	4·2
Ramie	80	3·9
Sisal	52	5·0
Manila	65	7·8

analysis on an oven-dry basis. This has been done in Table 2.2. where the chemical compositions of jute and some other fibres are compared.

TABLE 2.2. CHEMICAL COMPOSITION (PER CENT) OF JUTE AND OTHER FIBRES

Fibre	*Cellulose*	*Hemi-cellulose*	*Lignin*	*Pectin*	*Water-solubles*	*Fats and waxes*
Jute	65·2	22·2	10·8	—	1·5	0·3
Hemp	77·5	10·1	6·8	2·9	1·8	0·9
Ramie	76·6	8·0	5·6	3·8	5·6	0·4
Sisal	71·5	18·1	5·9	2·3	1·7	0·5
Flax	71·3	18·5	2·2	2·0	4·3	1·7
Cotton	91·5	5·8 (with pectins)	—	—	1·1	0·7

The cellulose, hemicellulose, and lignin all exist in the form of long-chain molecules, as indeed do all the principal chemical compounds in textile fibres. Just as the individual fibres in a yarn are long and thin and hold together by a mixture of entanglement and inter-fibre friction so the long-chain molecules in the fibre are long and thin and hold together by a mixture of entanglement and chemical forces. The long-chain molecules can be likened to a string of beads, each bead being the characteristic building unit of the molecule.

Cellulose is the only 'pure' substance to be found in jute and the cellulose extracted from the jute fibre is identical with that found in all other cellulosic fibres. The building unit of the long-chain cellulose molecule is the simple sugar, glucose, which has been made by the plant from the elements carbon, hydrogen, and oxygen.

The hemicellulose molecule is made up of smaller units, just as pure cellulose, but in this case the 'beads' are different types of sugars and the chains are very much shorter. Another difference between the two types of cellulose lies in the shape of the long-chain molecules; the cellulose chain has many identical glucose units strung head-to-tail but the hemicellulose molecule has short side-chains sticking out at intervals along its length. These side-chains are acidic in nature and it is they which give jute its slightly acid reaction and its affinity for basic dyestuffs.

Lignin differs from the other two main components of jute in not being made up from sugar units. Lignin is an important constituent of wood and though its chemical structure has been under examination for more than 100 years its exact nature has not yet been established. Jute is the most highly lignified fibre of commercial importance, a feature which determines many of its characteristic properties. For instance, the strength of the fibre is higher than would be expected from an examination of the molecular structure of the fibre, and it is thought that this is due to the lignin molecules forming linkages which help to give the fibre additional strength. These same linkages, however, reduce the flexibility and extension of the fibre. Lignin, too, is thought to be responsible for the wide colour range of the fibre—far wider than that of any other textile fibre. The yellowing of jute on exposure to sunlight is due to the lignin, while the fibre's good resistance to bacterial degradation is another example of this compound's important role in determining some of the properties of jute.

Jute, in common with many of the other textile fibres, may be degraded by sunlight, heat, mildew, acids, and alkalis, but by the choice of suitable reagents the fibre's resistance to these damaging influences may be improved and the life of the product prolonged considerably. Treatment with copper salts gives jute a good resistance to microbiological attack although this treatment is not recommended for material which will ultimately be used for packing foodstuffs. When jute is exposed to acid fumes, as it may be when used to pack some types of fertilizers, a pre-treatment with sodium benzoate will provide adequate protection to the fibre or a paper or polythene liner may be used in the sack to keep the acid fumes away from the jute. Jute will ignite and burn but its flammability may be reduced by treating it with a borax and boric acid mixture, antimony salts, or other media, and finishes are available which inhibit flaming and smouldering and will withstand immersion in sea-water for 6 months. To reduce the damage done to jute by sunlight, copper salts and certain dyestuffs, e.g. Chlorazol Brown M.S., may be used. There is, however, another phenomenon connected with sunlight—yellowing. When jute is exposed to the light it gradually assumes a yellowish tinge. This, as has already been indicated, is due to colour changes within the fibre connected with the lignin molecules. It may be made more obvious by an additional factor, viz., discoloration of the mineral oil applied to lubricate the fibre during manufacture. If jute has been used as a base cloth for polyvinyl chloride coatings, the oil will gradually migrate into the plastic and turn yellow on exposure to light. This defect is normally associated with light pastel shades of coating. The remedy is to reduce the quantity of oil which is added at spinning to 1 per cent or less, or to use a more highly refined oil which will not yellow, e.g. technical white oil.

The main properties of jute can be summarized as

Ultimates	
length	2·5 mm
diameter	18 microns
Single fibres	
length	0·2–30 in.
tex	1·9–2·2
tenacity	40–70 g/tex
extension at break	2·0 per cent
Moisture regain at 65 per cent R.H.	
absorption	12·8 per cent
desorption	14·6 per cent
Specific gravity	1·48