# STRENGTH PROPERTIES OF TEN SOUTH INDIAN CANES

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*Received June 1991*

**BHAT, K.M., THULASIDAS, P.K. & MOHAMED, C.P. 1992. Strength properties of ten South Indian canes**. Selected mechanical properties such as static bending, tensile and compression strengths (parallel to grain) of ten South Indian rattan species representing large, medium and small diameter categories were determined. Based on the mean strength values, these species may be classified into strong to very strong (Class I - MOR and UTS > 70 $Nmm^{-2}$, moderately strong (Class II - MOR and UTS 45-70 $Nmm^{-2}$) and weak (Class III - MOR and UTS < 45 $Nmm^{-2}$) rattans. The two strongest rattans, *viz Calamus nagbettai* and *C. gamblei* come under the Class I while the weakest rattans, *C. lacciferus* and *C. metzianus*, which are commercially less important species, fall under the Class III. Majority of the species come under Class II. Generally, the strength values of Indian rattans are comparable to those of Southeast Asian rattans. Within the stem, strength decreases from the periphery to the centre and from the base to the top correlating with fibre proportion and specific gravity. The most important factors that influence strength properties are species, age, stem position, fibre (sclerenchyma) proportion, specific gravity and moisture content.

Key words: Rattans (*Calamus* spp.) - mechanical properties - classification - age effect - within-stem variation - specific gravity

**BHAT, K.M., THULASIDAS, P.K. & MOHAMED, C.P. 1992. Sifat-sifat kekuatan bagi sepuluh spesies rotan di India Selatan.** Beberapa sifat mekanikal seperti lenturan statik, kekuatan tegangan dan kemampatan 10 spesies rotan India selatan, yang mencangkupi, kategori diameter besar, sedang dan kecil telah ditetapkan. Berdasarkan nilai kekuatan purata, spesies-spesies ini dapat dikelaskan kepada Kelas I hingga Kelas III: kekuatan yang tinggi (Kelas I - MOR dan UTS > 70 N $mm^{-2}$), kekuatan yang sedang (Kelas II - MOR dan UTS 45 -70 N $mm^{-2}$) dan lemah (Kelas III - MOR dan UTS <45 N $mm^{-2}$). Dua dari rotan yang terkuat, *Calamus nagbettai* dan *C. gamblei* termasuk dalam Kelas I sementara rotan yang terlemah, *C. lacciferus* dan *C. metzianus*, merupakan species rotan yang kurang penting dari segi komersial, jatuh dalam Kelas III. Kebanyakan dari spesies terletak dalam Kelas II. Secara amnya nilai kekuatan rotan India adalah setanding dengan rotan dari Asia Tenggara. Di dalam batang, kekuatan berkurangan dari sisi hingga ke pusat dan dari pangkal ke pucuk berkadar terus dengan perkadaran serat dan graviti tentu. Satu faktor terpenting yang mempengaruhi sifat-sifat kekuatan adalah spesies, umur, kedudukan batang, jumlah serat (sclerenchyma), graviti tentu dan kandungan air.

KFRI Scientific Paper No. 235

## Introduction

Although four genera, *viz Calamus, Daemonorops, Korthalsia* and *Plectocomia* are known to occur in India, only the genus *Calamus* represents the canes (rattans) from the southern region in the Western Ghats (Basu 1985). Recent taxonomic collections in the Kerala Forest Research Institute, however, added at least six new species to the list of South Indian species (Renuka *et al.* 1987, Renuka personal communications). Depending on the stem diameter, these climbing palms are generally classified into large diameter (> 18 *mm*), medium diameter (10 - 18 *mm*) and small diameter (< 10 *mm*) rattans (Bhat & Renuka 1986). With the exception of a couple of species, these rattans have commercial value particularly for furniture trade. By and large, medium and large diameter canes are used for furniture frames, walking sticks, sports goods and rural bridges. Small diameter ones find application, either in round or split form, in basket making, chair seats, lampshades and a variety of handicraft items (Bhat *et al.* 1989).

One major complaint in the rattan trade is that the quality of Indian canes is inferior to that of the Southeast Asian canes (Badhwar *et al* .1957). The major quality attributes include not only the colour and appearance of rattan skin but also the inherent stem strength. No data are, however, available for strength properties of Indian canes, except the preliminary test results in *C. tenuis* (Sekhar & Rawat 1965), to compare the mechanical behaviour with that of imported canes. Recent studies showed that density and shrinkage behaviour of rattans depend on stem anatomy, particularly fibre proportion, fibre wall thickness and metaxylem vessel diameter (Bhat *et al*. 1990, Bhat & Varghese 1991). One important determining factor, however, is stem age as the fibre wall thickness increases with age resulting in greater stiffness and possibly strength (Bhat *et al*. 1990).

The purpose of this study was to determine the strength properties and the factors influencing them in ten selected rattan species commonly growing in the Western Ghats (South India).

## Material and methods

Ten species from the Western Ghats representing large, medium, and small diameter rattans were selected. Five stems were obtained for each species with the exception of two (*Calamus nagbettai* and *C. karnatakensis*), for which only two to three stems could be tested because of immaturity of growing stock of rattans. As there is no readily available method to determine the age of these climbing palms, stems of harvestable size for the species were chosen by noting the relative maturity (Table 1). The sample origin (location) of each species with mean stem length and diameter is given in Table 1.

Samples of 25 *cm* length were cut from the base, middle and top positions in each stem to test the strength properties. For compression tests, however, samples of 6 *cm* length were used. As the preliminary tests showed that no significant differences exist between the samples with node and those without node, nodal factor was not taken into consideration. This is mainly because there is no interruption in the alignment of cells in nodal region although specific gravity difference was often noted by Casin (1975) in some Philippines rattans. The following tests were conducted on a Universal Testing Machine depending on the stem thickness:

a) Large-diameter stems: Static bending (modulus of rupture-MOR, modulus of elsticity - MOE), tension (ultimate tensile stress-UTS) and compression (maxi mum compressive stress) parallel to grain;
b) Medium-diameter stems: Static bending (MOR and MOE) and tension (UTS) parallel to grain;
c) Small - diameter stems: Static bending (MOR and MOE) and tension (UTS) parallel to grain.

**Table 1.** Locations of sample origin with mean values of stem size (length and diameter) in selected ten species of *Calamus* growing in Western Ghats

| Species | Location | Mean stem length (*m*) | Mean stem diameter (*mm*) | Relative maturity of stem compared to plant habit |
|---|---|---|---|---|
| **Large diameter** | | | | |
| *C. nagbettai* | Subrahmanya (Karnataka) | 4.7 | 26.6 | Young |
| *C. thwaitesii* | Achenkovil (Kerala) | 9 | 29.2 | Young |
| **Medium diameter** | | | | |
| *C. gamblei* | Nelliampathy (Kerala) | 18 | 18.1 | Moderately mature |
| *C. hookerianus* | Nelliampathy (Kerala) | 5.9 | 16.3 | Young |
| *C. karnatakensis* | Agumbe (Karnataka) | 4.8 | 16.1 | Young |
| *C. lacciferus* | Agumbe (Karnataka) | 11.9 | 12.3 | Moderately mature |
| *C. pseudotenuis* | Peermedu (Kerala) | 6.4 | 13 | Young |
| **Small diameter** | | | | |
| *C. metzianus* | Nilambur (Kerala) | 10.5 | 6.3 | Moderately mature |
| *C. rotang* | Harippad (Kerala) | 6.6 | 7.2 | Young |
| *C. travancoricus* | Ariankavu (Kerala) | 3.4 | 3.5 | Young |

*C. gamblei* and *C. travancoricus* were exceptions; the former was tested for compression strength due to its relatively large stem diameter while the latter could not be tested for bending strength due to the high pliable nature of its extremely thin stems (Table 1).

In order to determine the radial pattern of variation in strength, tension (UTS) parallel to grain was tested in three radial positions of a given internode, *viz* periphery, intermediate and centre in six species. Fibre percentage of tested samples was estimated from 15-20 $\mu m$ thick cross sections under microscope using point count technique with the help of eye-piece graticule (Curtis 1960). To show the influence of age on strength behaviour, test results of mature and young stems, as determined by the total stem length, were compared in two species. Further, samples were also tested from green and relatively air dried material of two species *C. thwaitesii* and *C. hookerianus,* to estimate the strength differences between the green and dry rattans.

## Results and discussion

### *Factors influencing strength properties*

#### Species

Mean values of different strength properties for various species are presented in Table 2. Among the ten species studied, *C. nagbettai* appears to be the strongest cane as it displayed highest mean values of MOR and MOE in static bending as well as relatively high compressive stress although *C. gamblei* had the highest UTS value probably because of greater maturity of the stem. In contrast, *C. metzianus* had the lowest strength with exceptionally low values of MOR, MOE and UTS. While *C. lacciferus* comes closer to this species with relatively low values, the rest of the species may be considered as moderately strong canes. With low strength values, canes of *C. metzianus* and *C. lacciferus* break easily and have lesser commercial value than those of other species (Bhat & Thulasidas 1989).

Based on the mean values, South Indian rattans may be grouped into the following three strength classes: Class I - strong to very strong rattans (mean MOR and UTS values > 70 $N\,mm^{-2}$), Class II - moderately strong (MOR and UTS 45 - 70 $N\,mm^{-2}$) and Class III - weak rattan (MOR and UTS < 45 $N\,mm^{-2}$).

With the exception of *C. metzianus* and *C. lacciferus,* the bending strength values of these species are comparable to those of *C. tenuis* tested from Uttar Pradesh and Assam (Sekhar & Rawat 1965). Similarly, the strength appears to be in no way inferior to that noted in several Indonesian rattans including *C. manan* (Hadikusumo 1988), although higher tensile strength is reported for the latter from Malaysia (Ismail *et al.* 1989). The maximum compressive stress value recorded in *C. nagbettai, C. thwaitesii* and *C. gamblei* is comparable to that in *C. manan,* one of the superior quality rattans of Malaysia and Indonesia (Ismail *et al.* 1989).

It should be noted that comparison of strength properties among the different rattan species may not be precise unless the stems of the same age groups are sampled particularly because stem structure and resultant properties change significantly with age (Bhat *et al.* 1990, Bhat & Varghese 1991). As noted in Table 1, owing to the availability of relatively young stems for sampling, the present values need to be treated with caution at least for some species. For example, in *C. thwaitesii,* the mean values of MOR and UTS in the oldest stem sampled are 75.2 $N\,mm^{-2}$ and 67.8 $N\,mm^{-2}$ respectively as against the corresponding values of 43.2 $N\,mm^{-2}$ and 37.5 $N\,mm^{2}$ in the youngest stem studied. Age effect on strength properties is also shown for other species elsewhere in this treatise. However, it appears that generally the strength values of rattans are lower than those of other forest products, *viz* bamboos like *Dendrocalamus strictus* and timbers like *Tectona grandis* (Limaye 1952), although strength figures in mature or over mature stems of some rattan species are not necessarily lower.

**Table 2**. Mean values of different strength properties of air dried rattans (minimun and maximum values in parentheses)

| Species | Specific gravity | Static bending ($N\ mm^2$) | | Max. tensile stress ($N\ mm^2$) | Max. compressive stress ($N\ mm^2$) | Fibre content (%) | Remarks |
|---|---|---|---|---|---|---|---|
| | | MOR | MOE | | | | |
| **Large-diameter** | | | | | | | |
| *C. nagbettai* | 0.666 | 91.0 | 4057 | 86.5 | 33.6 | 37 | Relatively |
| | (.580-.778) | - | - | (81.9-95.7) | | | young stem |
| *C. thwaitesii* | 0.480 | 51.3 | 2156 | 45.9 | 29.2 | 30 | Relatively |
| | (.414-.626) | (35.9-78.3) | (1196-3470) | (29.7-76.4) | (28.2-30.0) | | young stem |
| **Medium-diameter** | | | | | | | |
| *C. gamblei* | 0.659 | 71.5 | 3098 | 96.6 | 29.9 | 39 | Relatively |
| | (.570-.808) | | | (46.9-159.2) | | | young stem |
| *C. hookerianus* | 0.514 | 52.7 | 1754 | 57.2 | - | 32 | Relatively |
| | (.380-.635) | (37.2-78.2) | (1167-2157) | (27.7-98.3) | - | | young stem |
| *C. karnatakensis* | 0.536 | - | - | 46.6 | - | 26 | Relatively |
| | (.418-.675) | | | (39.0-60.0) | - | | young stem |
| *C. lacciferus* | 0.459 | - | - | 44.8 | - | 23 | Moderately |
| | (.438-.495) | | | (32.5-59.8) | - | | mature stem |
| *C. pseudotenuis* | 0.524 | 69.8 | 2088 | 51.4 | - | 36 | Moderately |
| | (.394-.731) | (42.3-85.7) | (1558-2931) | (35.0-81.4) | - | | mature stem |
| **Small-diameter** | | | | | | | |
| *C. metzianus* | 0.368 | 37.0 | 1666 | 22.5 | - | 14 | Moderately |
| | (.300-.423) | (21.9-43.9) | ( 853-2549) | (15-27.3) | - | | mature stem |
| *C. rotang* | 0.495 | 59.3 | 1666 | 22.5 | - | 27 | Relatively |
| | (.409-.609) | (43.1-88.7) | (1068-1862) | (22.9-57.6) | - | | young stem |
| *C. travancoricus* | 0.526 | - | - | 50.6 | - | 27 | Relatively |
| | (.430-.600) | | | (31.2-69.9) | - | | young stem |
| *Dendrocalamus strictus* (bamboo) | 0.757 | 128.4 | 17682 | - | 61.7 | | Limaye (1952) |
| *Tectona grandis* (teak) | 0.611 | 103.6 | 12985 | - | 60.7 | | " |

## Stem position

Mechanical properties like MOR and UTS decrease not only from the periphery to the centre in a given internode but also from the base to the top within a stem. The extent of variation is higher in radial than in longitudinal direction within the stem as the UTS value is often two to three times greater in the periphery than in the stem centre (Figure 1). The pattern of longitudinal variation is opposite to that of bamboos as the strength properties like maximum crushing strength tend to increase from the bottom to the top with the increase in cell wall thickness in bamboo culms (Liese 1985, 1987).

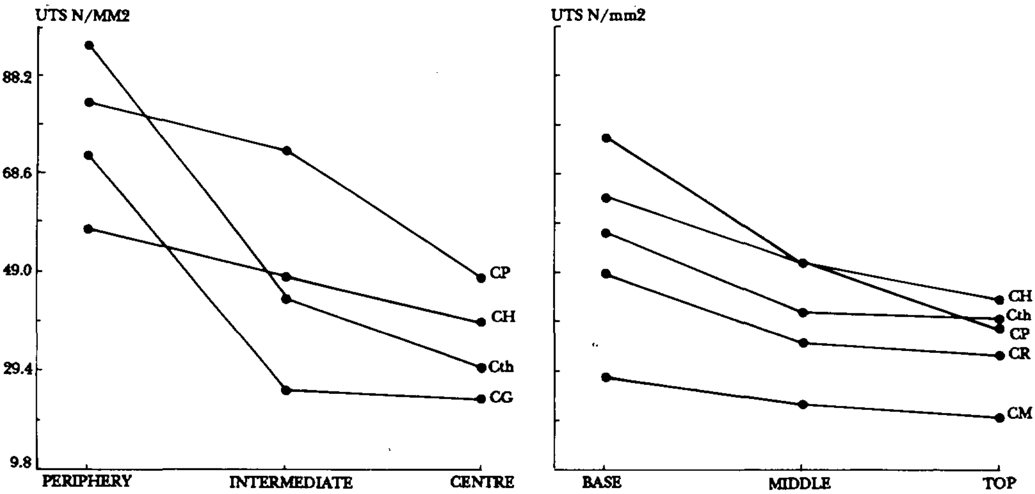


**Figure 1.** Ultimate tensile stress in relation to stem position in five rattan species (CG = *Calamus gamblei*, CH = *C. hookerianus*, CM = *C. metzianus*, CP = *C. pseudotenuis*, CR = *C. rotang*, C.Th = *C. thwaitesii*)

## Age

The comparison of strength values in young and mature stems of two species, *C. thwaitesii* and *C. hookerinus*, reveals that strength properties improve with age (Table 3). This is also evident within the stem as strength decreases from the older basal position to the younger top internodes (Figure 1).

**Table 3.** Mean strength values (base, middle and top positions) of young *versus* mature stems in two species

| Species | Young | | | | Mature | | | |
|---|---|---|---|---|---|---|---|---|
| | Stem length, (*m*) | Stem length, (Number of) internodes | MOR ($N\ mm^{-2}$) | UTS ($N\ mm^{-2}$) | Stem length (*m*) | Stem length (Number of) internodes | MOR ($N\ mm^{-2}$) | UTS ($N\ mm^{-2}$) |
| *C. thwaitesii* | 10.7 | 43 | 42.3 | 37.5 | 27.0 | 80 | 75.2 | 67.8 |
| *C. hookerianus* | 7.1 | 47 | 49.2 | 57.2 | 15.8 | 90 | 56.6 | 53.1 |

## Moisture content

Testing of bending and tensile strengths at different moisture contents in two species indicates that generally strength improves with the moisture loss as is the case in timber (Table 4).

**Table 4.** Strength values of two species with different moisture contents

| Species | Property | Green | | | | A.D. | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Base | Middle | Top | Mean | Base | Middle | Top | Mean |
| **Static bending** | | | | | | | | | |
| *C. thwaitesii* | | | | | | | | | |
| | Sp. gr. | 0.679 | 0.53 | 0.426 | 0.545 | 0.65 | 0.512 | 0.457 | 0.539 |
| | MC (%) | 56.1 | 78.2 | 83.8 | 72.7 | 21.7 | 17.4 | 29 | 22.7 |
| | MOR ($N mm^{-2}$) | 95.6 | 46.6 | 38.8 | 60.3 | 98.8 | 83.2 | 48.8 | 76.9 |
| | MOE ($N mm^{-2}$) | 6496 | 2557 | 2922 | 3991 | 4886 | 3938 | 2370 | 3731 |
| *C. hookerianus* | | | | | | | | | |
| | Sp. gr. | 0.641 | 0.556 | 0.458 | 0.551 | 0.62 | 0.503 | 0.446 | 0.523 |
| | MC (%) | 55.9 | 71.7 | 88.9 | 72.1 | 24.0 | 47.0 | 17.0 | 29.3 |
| | MOR ($N mm^{-2}$) | 43.3 | 35.5 | 31.1 | 36.6 | 63.3 | 55.4 | 51.3 | 56.6 |
| | MOE ($N mm^{-2}$) | 1605 | 1196 | 2080 | 1627 | 1822 | 1351 | 1651 | 1608 |
| **Tension parallel to grain** | | | | | | | | | |
| *C. thwaitesii* | | | | | | | | | |
| | Sp. gr. | 0.714 | 0.522 | 0.567 | 0.601 | 0.656 | 0.498 | 0.457 | 0.537 |
| | MC (%) | 56.0 | 75.7 | 83.0 | 71.5 | 40.0 | 20.3 | 20.4 | 26.9 |
| | UTS ($N mm^{-2}$) | 81.8 | 62.7 | 55.4 | 66.7 | 101.8 | 57.1 | 44.4 | 67.8 |
| *C. hookerianus* | | | | | | | | | |
| | Sp. gr. | 0.679 | 0.523 | 0.479 | 0.56 | 0.671 | 0. 555 | 0.459 | 0.561 |
| | MC (%) | 52.7 | 56.5 | 84.5 | 64.5 | 42.0 | 20.8 | 75.3 | 46.0 |
| | UTS ($N mm^{-2}$) | 70.6 | 50.9 | 30.9 | 50.8 | 72.0 | 49.9 | 37.4 | 53.1 |

A.D. = Air dry, Sp.gr. = Specific gravity, MC = Moisture content, MOR = Modulus of rupture, MOE = Modulus of elasticity, UTS = Ultimate tensile stress

## Specific gravity

With the range of correlation coefficients being 0.790-0.990 for all the relevant species except for *C. metzianus*, MOR and UTS values are significantly positively correlated with the specific gravity (Tables 2 and 5). In general, specific gravity of rattan is therefore a fairly good indicator of its strength as noted in Indian timbers (Shukla & Rajput 1989).

## Fibre content

Generally the specific gravity depends on the percentage of fibres that constitutes the total stem tissue of rattans (Bhat *et al.* 1990, Bhat & Varghese 1991). Therefore, the species having the highest proportion of fibres (39%) shows the

**Table 5.** Correlation coefficients for the relationships of modulus of rupture (MOR) and ultimate tensile stress (UTS) with specific gravity in different rattan species (n = 15)

| Species | Specific gravity *versus* MOR | Specific gravity *versus* UTS |
|---|---|---|
| *C. thwaitesii* | 0.843 | 0.759 |
| *C. gamblei* | 0.834 | 0.791 |
| *C. hookerianus* | 0.793 | 0.800 |
| *C. pseudotenuis* | 0.790 | 0.836 |
| *C. metzianus* | 0.611 | 0.196 |
| *C. rotang* | 0.801 | 0.772 |
| *C. travancoricus* | - | 0.990 |

greatest strength and that having the lowest fibre content (14%) the weakest (Table 2). The positive correlation of strength with fibre proportion observed among the species is in agreement with the results of Yudodibroto (1985) in Indonesian rattans.

## Conclusion

Of the ten species studied from the Western Ghats, *C. nagbettai* and *C. gamblei* appear to be the strongest canes (strength Class I) while *C. metzianus* and *C. lacciferus* are the weakest species (Class III). Majority of the species are moderately strong (Class II). The strength properties of Indian canes are not necessarily inferior to those of Southeast Asian canes. Species, age, stem position, fibre proportion, specific gravity and moisture content are the important factors that influence the strength behaviour of canes. As in timber, specific gravity is a fairly good indicator of strength properties of rattans.

## Acknowledgements

This work was carried out with the aid of a grant from the International Development Research Centre, Ottawa, Canada. We wish to gratefully acknowledge the cooperation received from A.C. Lakshmana, Conservator of Forests, Bellari, Karnataka in field collection and C. Renuka in taxonomic identification of new species from Karnataka. Thanks are due to K. M. Mohamed Nasser for technical help and S. Kuriakose for drawing the figures.

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