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Development of Basic Mechanical Tests for Malaysian Bamboos

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RINGKASAN

Buluh mempunyai banyak kegunaan, terutama bagi masyarakat desa. Tetapi oleh kerana kurang kefahaman tentang sifat-sifat kekuatan buluh, maka potensi buluh sebagai satu bahan kejuruteraan belum lagi disedari. Dalam ketiadaan satu piawaian bagi ujian mekanik terhadap buluh yang diterima umum, proseduir bagi ujian kekuatan asas telah dimajukan. Keputusan-keputusan ujian tentang sifat-sifat kekuatan Bambusa vulgaris, dengan nama tempatan Buluh Minyak dibentangkan dalam kertas ini.

SUMMARY

Bamboo has found various applications, especially to the rural people, but its potential as an engineering material has not been fully realised because of a lack of knowledge of its strength properties. In the absence of a commonly accepted standard for the mechanical testing of bamboo, a procedure for basic strength tests was developed. Results for the strength properties of Bambusa vulgaris, locally known as Buluh Minyak, are presented.

INTRODUCTION

At present there is no Malaysian standard for mechanical testing of bamboo. Reference was thus made to various British standards on testing of timber and metals, and the Indian standard on method of tests for round bamboos. Existing standards for timber are not directly applicable due to the tubular nature of bamboo. While it is possible to adopt the machine test speeds used for timber, specimen sizes have to be developed specially for bamboo.

Bamboo is essentially made up of two fibrous layers which contribute to its high tensile strength. The outer layer contains 40 to 60% fibre while the inner portion contains 15 to 30% fibre, Fang, H.Y. and Fay, S.M. (1978). It is these fibres that make the exterior hard and gives the bamboo stem a tough characteristic. The sectional properties of bamboo resemble that of a steel hollow circular section but with a difference in that nodes are present at regular intervals along the bamboo stem. The pripheral bamboo fibres placed appropriately away from the central axis of the bamboo stem make the structural make-up of bamboo a particularly promising material for construction but its strength properties must be understood and the problem of structural jointing overcome.

In this project the strength properties of *Bambusa vulgaris* were studied. *Bambusa vulgaris* is found in all states of Peninsular Malaysia, which has about 70 different species of bamboo. The culm is strong and has found various applications; from basket making to house construction. The length of the internode varies appreciably along the tree, while the wall may be up to 13 mm thick. It has a wide ecological tolerance, can withstand severe harvesting and was chosen for study because of its plentiful supply. Stronger species are found in the northern states of Peninsular Malaysia. Bamboo is known to possess a good strength to weight ratio and a fast growth rate. It takes only about one quarter of the time taken by trees to reach maturity and with the present rate of deforestation, may become an increasingly important subsitute for timber in the near future. With suitable treatment and proper

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application in moisture-free areas of building structures, the problem of durability can be minimized.

TEST PROCEDURES

The bamboo specimens tested were obtained from Jeram, in the Kuala Selangor district. The bamboo trees were felled in October and were estimated to be between two and three years in age. The test specimens were taken from about 75 percent of the entire length of the trees, avoiding the lowest and highest portions. The external diameters of the bamboo culm varied between 38 mm and 75 mm. The lengths of internode ranged from 220 mm to 380 mm. The specimens were taken to the laboratory in lengths of about 1.5 m. Their moisture content determined three days after felling was around 65%. The specimens were air-dried in the laboratory without end coating protection.

The mechanical test procedures adopted for prepared specimens were based on similar tests for timber or metal described in British Standards B.S. 131 and 373. The Indian Standard IS : 6874 (1973) for tests on round bamboo was used as a guide for whole bamboo specimens. Machine test speeds and specimen dimensions specified in the above standards were followed as closely as possible to enable direct comparison of test values. All mechanical tests were performed in a universal testing machine, except for the impact tests which were carried out on an impact test machine using a 250 kpcm pendulum. The test procedures for prepared and whole bamboo specimens developed in this project are summarised in Tables 1 and 2. Tests on whole bamboo specimens are necessary in addition to prepared specimens because of its tubular structure.

Moisture content and specific gravity tests were carried out using specimens with the actual thickness of the bamboo and 10 mm x 20 mm and 20 mm x 30 mm sample sizes respectively. Attempts to develop a tension test procedure for whole bamboo specimens were unsuccessful due to high slippage and early splitting of the specimens in the machine grips. In fatigue tests using a standard fatigue testing machine, the bamboo specimens exhibited progressive failures and the exact moment of fatigue failure could not be detected. The fatigue test programme was therefore abandoned.

RESULTS AND DISCUSSION

The results of the mechanical tests on prepared and whole bamboo specimens are summarised in Tables 3 and 4. The average moisture content and specific gravity of the specimens at test were 16% and 0.82 respectively. The strength values presented are average and are a range of values from six test specimens.

The average test values for compressive strength parallel to the grain for prepared and whole bamboo specimens were 44.6 Nmm^{-2} and 42.4 Nmm^{-2} respectively. The close values suggest that the simpler test based on a 180 mm whole bamboo specimens would give a sufficient indication of the compressive strength

TABLE 1
Mechanical Test Procedures for Prepared Bamboo Specimens

Type of test	Specimen dimensions (mm)	Machine test speed (mm/min)	Remarks
1. Static bending	6 x 15 x 300	500	280 mm test span, Three point loading
2. Compression;			
i. Parallel to grain	9 x 15 x 25	0.63	–
ii. Perpendicular to grain	10 x 10 x 10	0.63	–
3. Tension	–	1.32	Specimen dimension follow BS373: 1957
4. Impact Izod & Charpy	–	–	Test follow BS131 : 1961 Part 1 and 2

TABLE 2
Mechanical Test Procedures for Whole Bamboo Specimens

Type of Test	Specimen length (mm)	Machine Test speed (mm/min)	Remarks
1. Static bending	300	5.0	280 mm test span, Three point loading
2. Compression;			
i. Parallel to grain	180	0.63	–
ii. Perpendicular to grain	127	0.63	–

of bamboo for material control purposes. The comparessive strength value for *Bambusa vulgaris* is thus comparable with Malaysian timber as reported by Abdulrahman, E. (1975) and Lee Y.H., Abdulrahman E. and Chu Y.P. (1974), particularly with those in strength group C.

The average ultimate tensile strength of the prepared bamboo specimens was 34.3 1 Nmm^{-2}. This suprisingly high value is comparable with that of mild steel. The yield strength of mild steel is normally specified at 250 Nmm^{-2}, although the ultimate strength can be as high as 480 Nmm^{-2}. The high ultimate tensile strength of bamboo enables its use as a reinforcement for concrete slabs as reported by Ali Z. and Pama R.P. (1979). The average modulus of rupture and modulus of elasticity for prepared bamboo specimens based on the static bending test was 102.1 Nmm^{-2} and 9600 Nmm^{-2} respectively.

The modulus of elasticity values in compression of prepared specimens were found to vary between 2300 Nmm^{-2} to 4200 Nmm^{-2}. These values are relatively low compared to other engineering materials and would have a bearing on the deformation characteristics of bamboo structures.

TABLE 3
Mechanical Test Results for Prepared Bamboo Specimens

Type of test	Ultimate Strength (Nmm^{-2}; Joule for impact test) Range	Average
1. Static bending;		
i. Modulus of rupture	77.3-118.9	102.1
ii. Modulus of elasticity	4800-13700	9600
2. Compression;		
i. Parallel to grain	32.7-51.3	44.6
ii. Perpendicular to grain	21.5-39.8	31.6
iii. Modulus of elasticity	2300-4200	3400
3. Tension	264.8-388.0	343.1
4. Impact;		
i. Charpy	7.6-11.4	9.6
ii. Izod	5.3-8.6	6.2

TABLE 4
Mechanical Test Results for Whole Bamboo Specimens

Type of test	External Diameter (mm)	Tickness (mm)	Ultimate Load (KN) (Ultimate Stress, Nmm^{-2} for compression parallel to grain) Range	Average
1. Static Bending				
i. Internodal	56.7	7.0	2.3-4.5	3.3
ii. Node at centre	57.1	9.4	3.5-14.5	8.9
iii. Node near both ends	58.6	11.5	5.4-13.8	9.0
2. Compression				
i. Parallel to grain	59.7	9.2	24.7-50.7	42.4
ii. Perpendicular to grain	58.2	9.3	1.2-4.7	3.5

TABLE 5
Typical Basic Strength Values of Bambusa vulgaris†, Mild Steel, Concrete and Timber

Material	Ultimate Strength (Nmm^{-2}) Compression Parallel to grain	Tension	Modulus of Elasticity ($KNmm^{-2}$)
Bambusa vulgaris	32.7-51.3	264.8-388.0	2.3-4.2
Mild steel	–	480.0	210.0
Concrete	25.0-55.0	–	10.0-17.0
Timber	50.0-100.0	20.0-110.0	8.0-13.0

† Moisture content 16%

The energy absorbed values during impact tests on bamboo specimens were compared with values for standard steel specimens. Energy absorbed values of about 25% and 76% of that for steel were recorded for the Izod and Charpy tests respectively.

For the purpose of comparison, the strength values of bamboo obtained in this project is reproduced in Table 5 together with typical equivalent values for mild steel, concrete and timber. The basic strength properties of *Bambusa vulgaris* are comparable to timber except in tension. The tensile strength of *Bambusa vulgaris* is eight times the compressive strength. On the other hand timber and concrete are stronger in compression than tension. The tensile strength of concrete is normally only about one-tenth of the compressive strength. Like timber, bamboo has low modulus of elasticity. Despite this low elastic modulus, bamboo can be successfully utilized in building structures as reported by Janssen, J.J.A. (1980).

CONCLUSION

Before further investigations into the engineering characteristics of bamboo can be carried out, it is necessary to standardize the basic mechanical test procedures for bamboo. The test procedures reported in this paper have been adopted successfully as material control tests for subsequent structural behaviour tests of bamboo. Machine test speeds and specimen sizes are important parameters in the mechanical

tests, to ensure that the test values can be used for the analysis and design of bamboo structures. The results of the tests reported show that the strength properties of bamboo compare favourably with other common engineering materials and further investigation on the behaviour and potential of bamboo as an engineering material should be encouraged to enable its efficient use in building structures.

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REFERENCES

ABDULRAHMAN, E. (1975): Basic and grade stresses for strength groups of Malaysian timbers. Malaysian Forest Service. Trade Leaflet No.38. Ministry of Primary Industries.

ALI Z., PAMA R.P. (1978): Mechanical Properties of Bamboo-reinforced slabs. *Proc. of the International Conf. on Materials of Construction for Developing Countries,* Bangkok, Thailand. 22-24 August.

B.S. 131 : Part 1 (1967): The Izod Impact Test on Metals, British Standards Institution.

B.S. 131 : Part 2 (1972): The Charpy V-Notch Impact Test on Metals. British Standards Institution.

B.S. 373 : (1957): Standard Methods of Testing Small Clear Specimen of Timber: British Standards Institution.

FANG H.Y. and FAY, S.M. (1978): Mechanism of bamboo water concrete interaction. *Proc. of the International Conf. on materials of Construction for Developing Countries,* Bangkok, Thailand. 22-24 August.

I.S. 6874 (1973): Method of Tests for Round Bamboos. Indian Standards Institution.

JANSSEN, J.J.A. (1980): Bamboo in Building Structures, Doctorate Thesis. Eindhoven University of Technology, Netherlands.

LEE Y.H., RAHMAN E.A., CHU Y.P. (1974): The Strength properties of some Malaysian Timbers. Malaysian Forest Service. Trade Leaflet No. 34. Ministry of Primary Industries.

ABULLAH, A.A.A. (1983): Utilization of bamboo as a low cost structural material. *Proc. of the Symposium on Appropriate Building Materials for Low Cost Housing, Nairobi.,* Kenya. 7-14 November.

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