UNIVERSITI PUTRA MALAYSIA

APPLICATION OF BAMBOO AND OIL PALM CLINKER IN LIGHTWEIGHT REINFORCED CONCRETE BEAMS

REZUWAN BIN KAMARUDDIN

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by

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LIST OF NOTATIONS FOR BAMBOO

A	Average cross-sectional area of test specimen in mm^2.
A_s	Total shearing areas in mm^2.
d_i	Inner diameter of test specimen in mm.
d_o	Outer diameter of test specimen in mm.
E	Modulus of elasticity.
L	Distance between supports in mm.
m	Mass of test specimen in gm.
m_o	Oven-dry mass of test specimen in gm.
M	Percentage moisture content (dry weight basis).
P	Maximum load in Newton.
P^1	Load in Newton at limit of proportionality.
S_g^1	Specific gravity at test condition.
S_g	Adjusted specific gravity.
t	Average wall thickness of test sample in mm.
v	Volume of test specimen in cm^3.
δ	Change in gauge length as measured with an extensiometer.
Δ	Mid-span deflection in mm at limit of proportionality.
σ_b	Ultimate bending stress.
σ_c	Compressive stress at limit of proportionality.
σ_m	Crushing strength per unit wall thickness.
σ_s	Ultimate shearing stress.
σ_t	Ultimate tensile stress.
σ_t^1	Tensile stress at limit of proportionality.

LIST OF NOTATIONS FOR REINFORCED CONCRETE

A_s	Area of steel
A_b	Area of bamboo
b	Width of rectangular beam
E	Modulus of elasticity
F_c	Applied compressive load
M_u	Ultimate moment of resistance
f_y	Characteristic strength of steel
f_b	Characteristic strength of bamboo
f_{cu}	28 day cube crushing strength of concrete
Z	Lever arm
d	Effective depth of beam
F_{mc}	Maximum compressive load
A_c	Nominal cross sectional area of specimen
P_t	Indirect tensile strength
M	Moment
y	Distance from controid
I	Moment of inertia
F	Maximum load
D	Diameter of specimen
1	Length of specimen
x_i	Sample length
F_u	Ultimate load
P_c	Concrete cube compression strength
$\bar{x}$	Mean value

σ_n	Standard deviation
σ_{n-1}	Refinement standard deviation
V	Coefficient of variation
n	Number of samples
w/c	Water-cement ratio
%	Percentage
°C	Degree celsius
KP_a	Kilopascals
e	deformation

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by

Rezuwan bin Kamaruddin

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Supervisor: Professor Dr. Sk. Abdus Salam

Faculty: Faculty of Engineering

This study presents the results of the structural properties of lightweight oil palm clinker concrete beams reinforced with bamboo. The variables used in case of lightweight concrete were water-cement ratio and mix proportion. The hardened concrete was tested for compressive strength, tensile strength, modulus of elasticity, shrinkage and creep. So far as the reinforcement is concerned the results of mechanical and physical properties of Dendrocalamus asper bamboo in terms of specific gravity, moisture content, tensile strength of nodal and internodal specimens, compression strength parallel and perpendicular to the grain, static bending test and modulus of elasticity are presented.

Twelve beams with different reinforcement ratios were casted and tested under the two-third point loading to abtain service load, propagation of cracks, deflection, mode of

failure and the failure loads. Four of these beams are lightweight oil palm clinker concrete reinforced with split bamboo and another four beams are reinforced with steel while the rest are normal concrete beams reinforced with split bamboo. Reinforcement percentages of 0.5, 1.0, 1.5 and 2.0 were tried in these experiments.

Based on the strength of properties obtained, it can be concluded that the selected bamboo species can be used as reinforcement in concrete while oil palm clinker concrete is comparable to those of the control normal concrete specimen.

Of the twelve beams tested, it was found that the composite action of oil palm clinker concrete and bamboo reinforcement is reasonably exhibited. The British Standards Code of Practice BS8110 could be used in designing the lightweight clinker concrete beams reinforced with bamboo. In conclusion, clinker concrete beams reinforced with split bamboo as main reinforcement and as stirrups can be viable so long as the durability of the biological material is ensured.

Abstrak tesis yang dikemukakan kepada Senat Universiti Pertanian Malaysia bagi memenuhi sebahagian daripada syarat-syarat untuk memperolehi Ijazah Master Sains.

PENGGUNAAN BULUH DAN KLINKER KELAPA SAWIT DI DALAM RASUK KONKRIT RINGAN BERTETULANG

oleh

Rezuwan bin Kamaruddin

Mei 1991

Penyelia : Professor Dr. Sk. Abdus Salam

Fakulti : Fakulti Kejuruteraan

Kajian makmal ini mengemukakan keputusan sifat-sifat struktur rasuk konkrit ringan klinker kelapa sawit yang bertulangkan buluh. Angkubah yang digunakan di dalam konkrit ringan ini ialah nisbah air-simen dan nisbah campuran konkrit. Konkrit ringan yang matang telah diuji untuk menentukan kekuatan mampatan, kekuatan tegangan, keanjalan modulus, pengecutan dan kejalaran. Pengkajian terhadap sifat-sifat mekanikal dan fizikal tetulang bebuluh Dendrokalamus asper adalah daripada sudut graviti tentu, kandungan lembapan, kekuatan tegangan bagi sampel mempunyai buku dan antara ruas, kekuatan mampatan selari dan tegak dengan ira, lenturan statik dan keanjalan modulus dikemukakan.

Sejumlah 12 rasuk telah disediakan dan diuji sehingga gagal dengan menggunakan mesin ujian lenturan untuk mendapatkan beban perkhidmatan, perjalanan keretakan, pesongan, ragam

kegagalan dan beban muktamad. Empat batang rasuk daripada jumlah itu ialah rasuk konkrit klinker kelapa sawit bertetulangkan buluh dan empat yang lain bertetulangkan keluli alah tinggi. Selebihnya ialah rasuk konkrit biasa yang bertulangkan buluh. Setiap rasuk konkrit tersebut mempunyai peratus luas keratan rentas tetulang yang berbeza-beza, iaitu 0.5, 1.0, 1.5 dan 2.0.

Berdasarkan sifat-sifat kekuatan yang diperolehi,jenis buluh yang dipilih boleh digunakan sebagai tetulang di dalam struktur konkrit klinker kelapa sawit adalah setanding dengan konkrit biasa.

Ujian terhadap kesemua rasuk tersebut menunjukkan ikatan konkrit kelapa sawit dengan tetulang adalah menggalakkan. Praktis bagi kod Piawaian British, BS 8110 boleh digunakan untuk merekabentuk rasuk konkrit klinker kelapa sawit bertetulangkan buluh. Kesimpulannya, rasuk konkrit klinker kelapa sawit bertetulangkan buluh dan juga links buluh boleh jadi berdaya maju setelah kepastian kebolehtahanan bahan biologikal ini ditentukan.

CHAPTER 1

INTRODUCTION

Bamboo Utilization

Bamboo is one of the indigenous forestry products found in Malaysia. Its abundant availability and good strength properties contribute largely to a number of applications for domestic and commercial uses. It has been used commonly as one of the oldest construction materials by villagers of isolated communities in tropical or sub-tropical regions.

The demand for new low-cost construction materials in the developing world is tremendous, due to the increased need for housing resulting from the fast growing of population in both urban and rural areas. Attempts are being made in various parts of the world to find ways in utilizing local materials as cheap low-cost construction materials. For this, bamboo is one of the most common raw materials that has the potential in becoming a cheap construction material in future.

Mechanical and physical properties of bamboo depend mainly on its species, growth performance, moisture content and other factors. The two important properties of engineering materials are strength and durability. Bamboo has both these properties. For this reason, bamboo has been identified as a

potential material to be used as reinforcement in concrete. Bamboo can be used in the form of bars or fibres.

Research on the application of bamboo as reinforcement in cement matrix has been carried out since early 1920. During the second world war, American and Japanese armies used bamboo as reinforcement in concrete structures to overcome the shortage supply of steel in the construction of temporary army barracks.

At present, research is being carried out to determine the structural and mechanical properties of bamboo. It is necessary to exploit the use of bamboo as a substitute for conventional steel reinforcement. Bamboo can be used as a reinforcement material in concrete structures because of its high tensile strength. The tensile strength of one of the common Malaysian species (Dendrocalamus asper), tested in the internodal region is found to be 440.6 N/mm^2 (Abang Abdullah, 1984).

Phyllostacys bambusoides is a widely spread species in Japan, with tensile strength of 198.9 N/mm^2 compared to steel (ASTM A36) of 151.7 N/mm^2 strength (Herbert, 1979). Although bamboo is a potential material in term of strength, it has certain problems in long term durability, where it is easily attacked by fungus or insect. A proper study is required to overcome these problems.

Naturally, split bamboo bar is formed by two layers of fibres which give rise to its tensile strength property. The outer layer contains 40 to 50% fibres while the inner layer contains 15 to 30% fibres (Fang and Fay, 1978). This gives the outer layer, stronger than the inner layer.

In addition to various advantages of using bamboo in construction for its high tensile strength, bamboo is also one of the fastest growing, and highest yielding renewable natural resources. It can be cultivated commercially if needed, as in Japan and India (Renganathan, 1981). Bamboo matures in shorter period compared to timber. In addition, it can be grown to prevent erosion in soil conservation.

General Introduction to Oil Palm Clinker Lightweight Concrete

Lightweight concrete has become very popular, therefore research has been geared towards finding methods of producing lighter, good structural properties and cheaper concrete. For heavy structures, like long span bridges, the dead load occupies 60% to 70% of the total load. A reduction in dead load can result in overall economy.

An American Concrete Institute reported that, in many areas, supplies and reserves of naturally occurring aggregates have become depleted, and an increased emphasis will therefore be placed on manufactured aggregates, many of which are