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Evaluation of the strength of concrete slabs using bamboo-mesh in place of iron rod mesh with palm-kernel shells as additives

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ABSTRACT

Bamboo was used in the form of a mesh and placed within the concrete slab mold. The cement, sand and stone mixture were varied with the addition of palm kernel shells. Usually, the main mixtures for the production of concrete slabs are cement, sand, stones and water with iron rod mesh in-between the mixture. Due to high production cost, it was suggested that, if some waste material, in this case palm-kernel shell, is used to argument or supplement the amount of stones used and bamboo-mesh used to replace the costly iron rods, production cost as well as environmental issues would be addressed. The concrete slabs produced with this new mixture gave the compressive strength, after 28days of curing an average compressive strength of 60.0 KN/m^2. This value fell within the range of type A, B and C blocks with respective values of 4.0 KN/M ^{2}, 3.0 KN/M ^{2} and 2.5 KN/M ^{2}.

INTRODUCTION

Bamboo has a unique property such as strength, elasticity and lightness due its cavity. The reinforcement by diaphragms and its physical conditions provides its enormous superiority compared to other building materials (wood). There are about 1200 different species of bamboo and in Colombia about 25 different giant bamboos are used for construction [1]. It is considered as a composite material because it consists of cellulose fibres imbedded in a lignin matrix. Cellulose fibres are aligned along the length of the bamboo providing maximum tensile flexural strength and rigidity in that direction [2]. The importance of bamboo extends across various sectors of the economy some of which are for ecological (stabilization of the soil, uses on marginal land, hedges and screens, minimal land use), agro-forestry (Natural stands, Plantations, Mixed agro-forestry systems), local industries (Artisanal, Furniture, variety of utensils), wood and paper industries (Strand boards, Medium density fiberboard, laminated lumber paper and rayon, parquet; ceiling, flooring, walls, window, doors), energy (charcoal, pyrolysis, gasification).

The chemical composition of bamboo is similar to that of wood. The main constituents of bamboo culms are Cellulose, Hemi-cellulose and Lignin, which amount to over 90% of the total mass. The minor constituents of bamboo are resin, tannins, waxes and inorganic salts. Compared with wood, however, bamboo has higher alkaline extracts, ash and silica contents [3, 4]. Bamboo contains other organic composition in addition to cellulose and lignin such as 2 – 6% starch, 2% deoxidized Saccharide, 2 – 4% fat, and 0.8 – 6% protein. The carbohydrate content of bamboo plays an important role in its durability and service life. Bamboo is known to be susceptible to fungal and insect attack. The natural durability of bamboo varies between 1 and 36 months depending on species and climate condition [5]. The presence of large amount of starch makes bamboo highly susceptible to attack by staining fungi and powder-post beeths [6]. Higher benzene-ethanol extractive of some bamboo species could be an advantage for decay resistance [7]

The ash content of bamboo is made up of inorganic minerals, primarily silica, and Potassium. Manganese and Magnesium are two other common minerals. Silica content is the highest in the epidermis with very little in the nodes and is absent in the internodes. Higher ash content in some bamboo species can adversely affect the processing industry. Bamboo intended for use in construction should be treated to resist insects which may lead to rot [8].

Considering the mechanical properties of bamboo, with respect to compressive strength, the unlimited longitudinal cleavability of the bamboo tube wall inside of the inter-nodium is caused by strictly parallel directed fibres. Inside the nodium they cross each other in each direction. This amplification of knots with its strongly buckling diaphragms increases the cleavability strength and the buckling strength of the tubes. Cylindrical tube as compared to solid round bar possesses a much higher flexural strength. The portion of lignin affects the compressive strength. Similarly, with elastic modulus, the accumulation of highly strong fibres in the outer parts of the tube wall contributes positively to its elastic modulus like it does for the tension shear and bending strength. There exist a perfect relation between the cross section of the tube, the elastic modulus of the bamboo and the quality of the bamboo. Like the elastically modulus of solid wood, that of bamboo decreases to 10% with growing stress. The enormous elasticity makes bamboo a very useful building material in areas with high risk of earth quake. Shear strength reveals the behavior of breaking of common building wood differs clearly from the breaking conditions of bamboo. There is no spontaneous break though the whole material after the tearing of a single bamboo fibre like wood does. The appearing cletts are fed off immediately in direction of the fibre and so they impair the critical region less. The energy transfer is delayed by diffusion. The distribution of appearing longitudinal cracks all over the tube length is stopped by the enforcing knots (nodes). Especially the pressure, shearing and inter-laminar strength are raised by the knots. Those symptoms are titled as increasing factor of the fracture toughness. In the research of modern compound material it is less important to prevent the formation of cracks than to counteract the distribution of the clefs by finding a suitable material construction.

The concern of resources depletion and global pollution has challenged many engineers to seek and develop new materials. These include the use of by-product as well as waste material in building construction. Many of these by-products are used as aggregates for the production of light weight concrete. Experimental investigation of the beams of buildings shows that, the moment capacity of Palm Kernel Shells Concrete (PKSC) beam was higher than Aggregate Water Cement (AWC) beams by about three percent. In addition, the mode of failure observed in PKSC was ductile compared to the brittle failure of AWC beams. Thus, PKSC beams showed a ductile failure, giving ample warning before failure happened. PKSC beams also exhibited a lot of cracking but the crack width and crack spacing was small. The other advantage for PKSC beams was in its deflection which shows that PKSC beam exhibited higher deflection under constant load until failure, compared to AWC beams that failed in brittle manner without warning. Higher concrete strains from the reinforcement in the PKSC shows stronger bond between PKSC and the reinforcement.

MATERIALS AND METHODS

Equipment / Apparatus

Cutter	Trowel
Spatula	Crucible
Knife	Water-Resistant ink
Rectangular Moulds (140mm x 140mm x 100mm)	Measuring balance (Libror 3200S)
Measuring cylinder	Plastic plate
Pliers	Hacksaw
Plastic bowl	

Operating Conditions

Curing temperature	45^{o}C
Temperature in preparation room	25^{o}C
Average humidity level not less than	30%

Temperature for testing area	25^0C
Temperature for curing	37^o C – 46^o C

Raw Materials Used

Portland limestone cement	Sand	Bamboo
Binding wire	Water	Palm kernel shell
Water	Stones	

Parameters for preparing the bamboo mesh:

Thickness of the bamboo frame used	= 10mm
Thickness of bamboo mesh with polystyrene material used	= 50mm
Thickness of polystyrene used	= 30mm
Thickness of the bamboo sticks used	= 5mm
Length of the bamboo sticks used	= 100mm
Width of the bamboo sticks used	= 100mm

Composition of concrete slabs in their definite proportion

Preparation of the bamboo frame

The bamboo frame (Mesh) of the thickness 5mm was formed using a binding wire (iron) and bamboo sticks. The binding wire (iron) was used in tying the bamboo to give it a firm structure.

Mixing of concrete

Each batch of concrete was mixed in a big crucible. Measured quantities of cement, stones and sand were poured into the bowl. The mixture was stirred immediately for effective mixing of the product. This mixing was done at a period between 40 and 60 seconds respectively. The mixing was continued after adding a measurable amount of water until a period of 120 seconds. After that mixing was stopped and during the first 15 second, the mortar adhering to the wall and bottom part of the bowl were removed by means of a trowel and placed in the middle of the bowl. Finally, mixing was continued at high speed for 60 seconds.

Preparation of the concrete (with additive)

Composition of the concrete

Each batch of 5 (five) test specimens consists of cement, sand and water with additives of Palm Kernel Shell in varying proportions in each sample A,B,C.

Batching concrete (with additive)

The cement, sand, additive (PKS) were kept at a temperature range of (25^0C) whereas the weighing was carried out using a balance of accuracy of + 1g.

Mixing of concrete (with additive)

Each batch of concrete containing Palm Kernel shell (PKS) was mixed in a crucible. The quantities of cement, sand and additive were poured into the bowl. Mixing was started at low speed for 30 seconds and then water was added steadily. Mixing continued for 90 seconds and during the first 15 seconds, the concrete adhering to the walls and bottom part of the bowl were removed by means of a trowel and placed in the middle of the crucible. Finally mixing was continued at high speed for 60seconds.

Preparation and moulding of test specimens

Size of bamboo mesh specimen = (100 x 100 x 30) mm

The specimens were molded immediately after the preparation of the mortar. At this stage, a (140mm x 140 mm x 50mm) mold was filled with the paste using a trowel and the concrete was compacted manually by shaking for effective settling of the concrete compacted and the excess concrete was stroked-off with the edge of the trowel held horizontally and moved slowly with a transverse sawing motion once in each direction. The surface of the mould containing the paste was smoothened using the trowel. The mould was then labeled for easy identification of the specimens.

Casting of the specimens
The concrete mixture was molded into a rectangular shape using a wooden mould with an inner perimeter of 140mm x 140mm x 50mm by volume. The mould was placed in dry and sunny place without delay. The dry air was made to have access to all sides of the mould. After a suitable time (30 minute), demolding of the slab was done to ensure proper curing of the slabs.

Demoulding of specimens
The mold was carefully dismantled and the specimens removed. To make way for easy identification, the selected specimen were marked with water-resistant ink and cured in the sun.

Curing of test specimens
Curing of the various specimens was carried out for twenty eight (28) days under normal environmental condition outdoor. The concrete specimen was watered every morning to enhance the strengthening process of the material. The slabs were weighed and its final mass was recorded after 28 days of curing.

Density of cured specimens
Density is defined as the mass per unit volume of the specimen
Mathematically; **Density, P = mass (m) / Volume (v)**

In determining the density of the cured specimen, the mass of the cured specimen was measured and recorded using mass balance. The volume of the cured specimen was also calculated as:

Volume of standard specimen (V) = (70mm x 70mm x 70mm)

Volume of standard specimen (V) = $(3.43 \times 10^{5})\ mm^3$
= $(3.43 \times 10^{-4})\ m^3$

(a) The measured mass of slab was then divided by the volume of the slab to get its density That is, mathematically

$$Density, \qquad P = \frac{Mass, M\ (kg)}{Volume\ of\ cube, V\ (m^3)}$$

Testing the specimen for compressive strength
Compressive strength is the maximum load sustained by a sheet of materials when subjected to a crushing force. In this test, the cubed specimens were centered laterally to the platens of the machine and the load was increased smoothly at the rate of about 2600N/S over the entire load application until fracture. Thus compressive strength, Cs was calculated as:

$$\mathbf{Cs = Fc/\ A\ (N/mm^2)}$$

[Where Fc is the maximum load at fracture (N) and $14000mm^2$ = 140mm x100mm is the area of (A) the cube.]

Water absorption of specimen:
The water absorption, (W_A) of a cured specimen was calculated as:

$$\boldsymbol{W_A = [(W_F - W_I)/W_I] \times 100}$$

Where W_F is the final weight after curing, and W_I is the initial weight before curing

- Testing the compressive strength of the bamboo mesh.
- Testing the compressive strength of the sand wished bamboo materials.

Table 1: Composition of concrete slabs produced using bamboo mesh to replace iron mesh

Reduction of cement quantity ↓

CONTROL			Slabs with Bamboo-mesh	EXPERIMENTAL (MASSES OF SLABS)				
Material	%	W/g		1st/g	2nd/g	3rd/g	4th/g	5th/g
Water	10	300.0	A1	√	√	√	√	√
Sand	10	569.0		√	√	√	√	√
Cement	30	310.8	Variation of 5%	√	√	√	√	√
Stone	50	549.84		521.5	494.9	467.4	439.8	438.8
Shell	-	-		27.5	54.9	82.4	111.0	137.41
Water	10	300.0	B1	√	√	√	√	√
Sand	10	569.0		√	√	√	√	√
Cement	25	258.9g	Variation of 5%	√	√	√	√	√
Stone	55	6047.7g		574.5	544.2	514.0	483.7	453.4
Shell	-	-		30.3	60.5	90.7	121.0	151.3
Water	10		C1	√	√	√	√	√
Sand	10	569.0		√	√	√	√	√
Cement	20	207.0	Variation of 5%	√	√	√	√	√
Stone	60	659.0		626	593.0	560.0	527.0	494.0
Shell	-	-		33.0	66.0	99.0	132.0	165.0

PICTURES SHOWING PREPARATION OF SLABS

Pictures showing samples of the raw materials used in the production of the slabs. This follows in the order, sand preparation, slab- mold, stone and bamboo mesh and concrete slab.

RESULTS AND DISCUSSION

TABLE 2: Slabs/blocks with bamboo frame

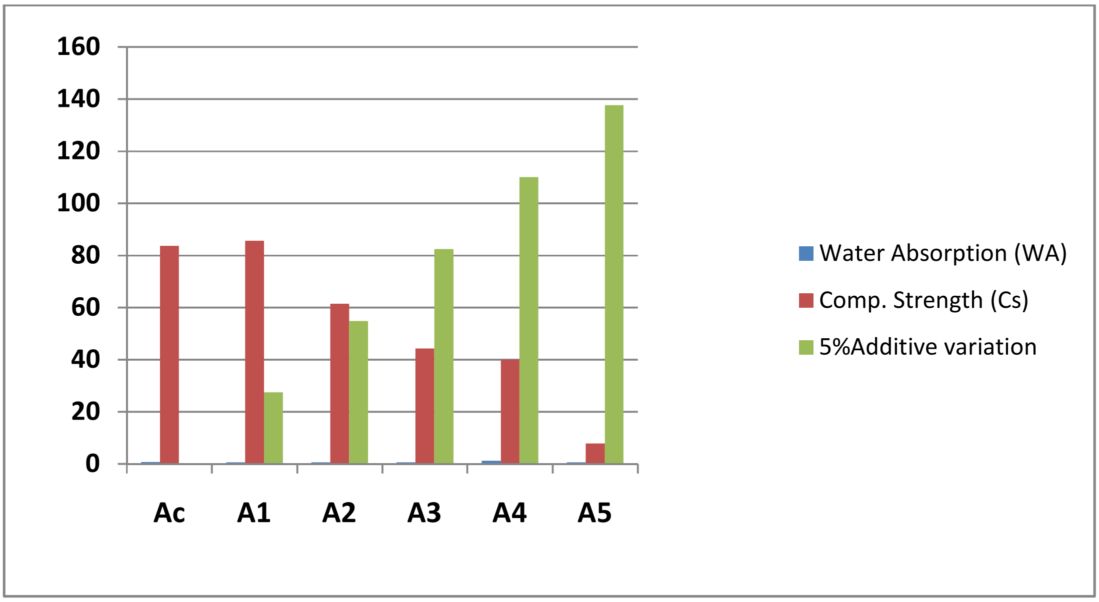
Sample	MB_1 (kg)	MA_2(kg)	MD(kg)	WA (%)	FDA(kg/m^3)	MLA (KN)	CS (KN/m^2)	5% ADDITIVE VARIATIONS
A_C	1.73	1.74	0.01	**0.57**	0.0888	1100	**78.6**	**NIL**
A_C	1.73	1.75	0.02	**1.14**	0.0892	1110	**79.3**	**NIL**
A_C	1.73	1.74	0.01	**0.57**	0.0888	1300	**92.9**	**NIL**
A_1	1.73	1.74	0.01	**0.57**	0.0888	1200	**85.7**	**27.5**
A_2	1.73	1.74	0.01	**0.57**	0.0888	860	**61.4**	**54.9**
A_3	1.73	1.74	0.01	**0.57**	0.0888	620	**44.3**	**82.4**
A_4	1.74	1.76	0.02	**1.14**	0.0897	560	**40.0**	**110.0**
A_5	1.74	1.75	0.01	**0.57**	0.0892	110	**7.90**	**137.4**
B_C	1.74	1.75	0.01	**0.57**	0.0892	1600	**114.3**	**NIL**
B_C	1.74	1.76	0.02	**1.14**	0.0897	1200	**85.7**	**NIL**
B_C	1.74	1.75	0.01	**0.57**	0.0892	1000	**71.4**	**NIL**
B_1	1.74	1.75	0.01	**0.57**	0.0892	1001	**71.5**	**30.3**
B_2	1.74	1.76	0.02	**1.14**	0.0897	1000	**71.4**	**60.5**
B_3	1.74	1.75	0.01	**0.57**	0.0892	920	**65.7**	**90.7**
B_4	1.74	1.75	0.01	**0.57**	0.0892	860	**61.4**	**121.0**
B_5	1.74	1.74	0.02	**1.14**	0.0888	700	**50.0**	**151.3**
C_C	1.74	1.75	0.01	**0.57**	0.0892	1100	**78.6**	**NIL**
C_C	1.74	1.75	0.01	**0.57**	0.0892	1100	**78.6**	**NIL**
C_C	1.74	1.76	0.02	**1.14**	0.0897	980	**70.0**	**NIL**
C_1	1.74	1.76	0.02	**1.14**	0.0897	920	**65.7**	**33.0**
C_2	1.74	1.75	0.01	**0.57**	0.0892	900	**64.3**	**66.0**
C_3	1.74	1.75	0.01	**0.57**	0.0892	880	**62.9**	**99.0**
C_4	1.74	1.75	0.01	**0.57**	0.0892	800	**57.1**	**132.0**
C_5	1.74	1.75	0.01	**0.57**	0.0892	750	**53.6**	**165.0**

where

MB_1 (kg)	*Initial mass before curing*
MD (kg)	*Mass difference after curing*
FDA (kg/m^3)	*Final density after curing*
CS-(L/A)	*Compressive strength*
WA (%)	*Water absorption*
MLA	*Maximum load at fracture*

Table 3 showing the Various Samples and their Water absorption, Compressive strength with additive variations

SAMPLE	Water Absorption (WA)	Comp. Strength (Cs)	5% Additive variation
A_c	0.76	**83.6**	**0**
A_1	0.57	**85.7**	**27.5**
A_2	0.57	**61.4**	**54.9**
A_3	0.57	**44.3**	**82.4**
A_4	1.14	**40.0**	**110.0**
A_5	0.57	**7.90**	**137.7**
B_C	0.76	**90.5**	**0**
B_1	0.57	**71.5**	**30.3**
B_2	0.57	**71.4**	**60.5**
B_3	0.57	**65.7**	**90.7**
B_4	0.57	**61.4**	**121.0**
B_5	1.14	**50.0**	**151.3**
C_C	0.76	**75.7**	**0**
C_1	1.14	**65.7**	**33.0**
C_2	0.57	**64.3**	**66.0**
C_3	0.57	**62.9**	**99.0**
C_4	0.57	**57.1**	**132.0**
C_5	0.57	**53.6**	**165.0**



Fig,1; Graph of samples A slabs showing their various measurements in mass against their water absorption, compressive strength and additive variations.

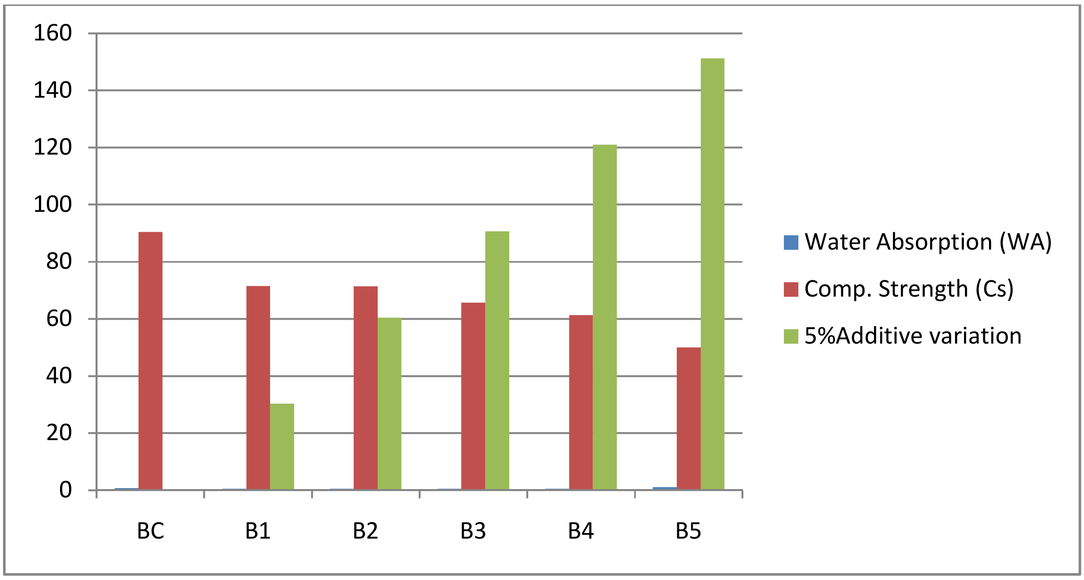


Fig. 2; Graph of sample B slabs showing their various measurements in mass against their water absorption, compressive strength and additive variations.

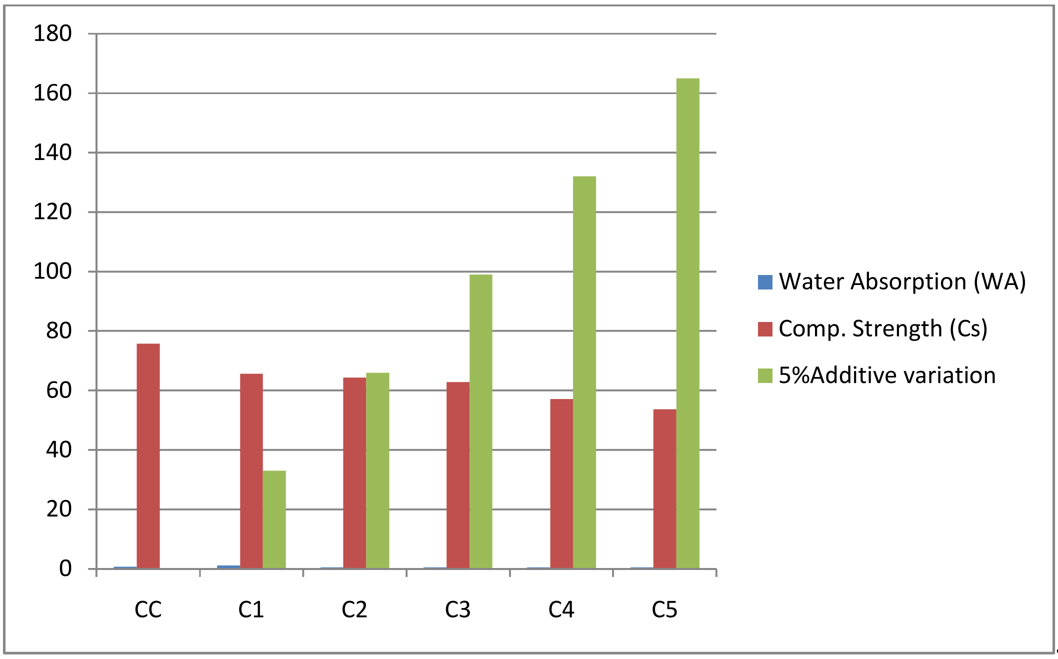


Fig.3; Graph of samples C showing their various measurements in mass against their water absorption, compressive strength and additive variations.

DISCUSSION

The concrete slabs made from bamboo frame showed high compressive strength as compared with those without the bamboo in terms of the control (M.A Anang et al).

Considering table 3, Sample A recorded compressive strengths of 85.7, 61.4, 44.3, 40.0, and 7.9 for 5 % additives additions of 27.5, 54.9, 82.4, 100.0 and 137.7 respectively for the 5% replacement levels in sample A slabs. Similarly, slab B recorded compressive strengths of 71.5, 71.4, 65.7, 61.4 and 50.0 for additives 5% additive additions of 30.3, 60.5, 90.7, 121.0 and 151.3 respectively

It showed an increase in the compressive strength with the amount of additive added (stones and shells) to some level and reviewed downwards due to the amount of the additive. As the amount of additive increases, there is a decrease in the amount of concrete mixture and this gave a reduced compressive strength.

From the results obtained from this experiment, it was observed that, the compressive strength of the slabs obtained were all within the standard values as required by the Ghana Standards Board It was also realized that, the results of the final masses and densities of concrete slabs after the 28 days curing were almost the same.

The water absorption levels of the slabs were almost the same and it contributed significantly to the settling process of the concrete slab.

The compressive strength of slabs made using bamboo to replace the often used iron mesh is on the averagely 10 – 12 times stronger than the type A, B, C blocks of compressive strength of 4.0KN/m^2, 3.0KN/m^2 and 2.5KN/m^2 respectively.

Considering the results obtained, the idea of reducing environmental pollution can to a large extent be addresses. This would also reduce the cost of production of concrete slabs since the usually expensive iron-rods could be replaced with a bamboo mesh and the quantities of stones reduce by adding palm kernel shells. Such a product can be used as covers for septic tanks, gutters or areas of less pedestrian patronage or where heavy load to some extent would not be exerted.

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