

# **Analysing the Characterisation of Alkali Treated Coir Fibre Composites**

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**ABSTRACT:** Polymeric materials reinforced with synthetic fibres such as glass provide advantage of high stiffness and high strength to weight ratio. Despite these advantages, the widespread use of synthetic fibre-reinforced polymer composite has a tendency to decline because of their high-initial cost and most importantly their adverse environmental impact. In this work, four different composites are prepared with untreated coconut fibres, NaOH mercerized coconut fibres, KOH mercerized coconut fibres and CSM – glass fibres. Lot of studies is done earlier on NaOH mercerized coconut fibre composites. But, no studies are done specifically on KOH mercerized coconut fibre composites. So, KOH mercerized coconut fibre composites are prepared in this study. General purpose polyester resin is used for preparing all the composites. The mechanical properties of composites are studied using flexural test, impact test and tensile test. The mechanical properties of KOH mercerized coconut fibre composites are studied and compared with the mechanical properties of NaOH mercerized coconut fibre composites, untreated coconut fibre composites and CSM – glass fibre composites.

**KEYWORDS-** Untreated coconut fibres, NaOH mercerized coconut fibres, KOH mercerized coconut fibres, CSM – glass fibres, General purpose polyester resin

## **1. INTRODUCTION**

There is an increasing environmental consciousness and awareness of the need for sustainable development, which has raised interest in using natural fibres as reinforcements in polymer composites to replace synthetic fibres. The advantages of natural fibres include low cost, low density, unlimited and sustainable availability, and low abrasive wear of processing machinery. Several investigations have been carried out to assess the potential of natural fibres as reinforcement in the polymers. The results have shown that natural fibres present potential to be used as reinforcement for plastics, but generally they do not attain the full mechanical performance levels of glass fibres reinforced plastics. However, composite materials need a better understanding of their failure mechanisms. Recently, however the natural fibres reinforced composites have attracted substantial attention as a potential structural material for low cost applications.

Because of their biodegradable nature, natural fibres have been increasingly adopted to replace synthetic polymers in the industrial applications. Among the various natural polymers, coir fibre has shown a great potential for use in composite structures. Coir fibres are derived from the coconut husks, they may be classified according to the peeled off time from the husks. The husks of fully ripened coconuts yield brown coir fibre, it is highly resistance to abrasion Coir fibres may be decomposed in 20–30 years in the nature; it may be regarded as an environmentally friendly material. To develop its industrial employ, thorough understanding of the coir fibre is necessary [1]. Coir fibers received three treatments, namely washing with water, alkali treatment (mercerization) and bleaching. Treated fibers were incorporated in starch/ethylene vinyl alcohol copolymers (EVOH) blends. Mechanical and thermal properties of starch/EVOH/coir bio composites were evaluated. The best results were obtained for mercerized fibers where the tensile strength was increased by about 53% as compared to the composites with untreated fibers, and about 33.3% as compared to the composites without fibers. [2]

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The coir fibers which are soaked in 5% sodium hydroxide solution at room temperature (RT) for 72 hours showed the highest IFSS with 55.6% higher than untreated coir fibers. The mechanical properties of alkali-treated coir fiber/PBS composites are significantly higher than those of untreated fibers. The best mechanical properties of alkali-treated coir fiber/PBS composite were achieved at fiber mass content of 25% in this study, which showed an increase of tensile strength by 54.5%, tensile modulus by 141.9%, flexural strength by 45.7% and flexural modulus by 97.4% compared to those of pure PBS resin. [3]

## II. EXPERIMENTAL

### 1.1. Materials

#### 2.1.1 Fibers

Coconut fibres were extracted from exocarp and dried at air for 24 hr. After being ground in a mill and sieved. To remove the soluble extractives and to facilitate adhesion between fibres and matrix, the untreated coconut fibres were modified by pre-treatment with alkaline solution 1% (w/v). Furthermore the fibres were filtered in a vacuum filter and fibres were washed with distilled water. Then, fibres were dried in an oven at 100 °C for 24 hr.

#### 2.1.2 Chopped Strand Mat

Chopped strand mat or CSM is a form of reinforcement used in fibre glass. It consists of glass fibres laid randomly across each other and held together by a binder. The properties of CSM is E-type glass is used. The penetration rate of glass is <180 s, width  $\pm 5$  mm and the moisture content is <0.20%. The area weight of the glass is about  $300 \pm 10\%$ , its breakage strength  $\geq 120$  N/150mm and loss on ignition 4.2~4.8%.

It is typically processed using the hand lay-up technique, where sheets of material are placed in a mould and brushed with resin. Because the binder dissolves in resin, the material easily conforms to different shapes when wetted out. After the resin cures, the hardened product can be taken from the mould and finished. Using chopped strand mat gives a fibre glass with isotropic in-plane material properties.

#### 2.1.3 Methyl Ethyl Ketone Peroxide (MEKP)

Methyl ethyl ketone peroxide (MEKP) is organic peroxide, a high explosive similar to acetone peroxide. MEKP is a colourless, oily liquid, MEKP is slightly less sensitive to shock and temperature, and more stable in storage. The first to be reported was a cyclic dimer,  $C_8H_{16}O_4$ , in 1906. Later studies found that a linear dimer is the most prevalent in the mixture of products typically obtained, and this is the form that is typically quoted in the commercially available material from chemical supply companies.

#### 2.1.4 Cobalt (II) Napthanate

Cobalt (II) naphthenate is a mixture of cobalt (II) derivatives of naphthenic acids. These coordination complexes are widely used as oil drying agents for the autoxidative cross linking of drying oils. Metal naphthenates are not well defined in conventional chemical sense that they are mixtures. They are widely employed catalysts because they are soluble in the non polar substrates, such as the alkyd resins or linseed oil. The fact that naphthenates are mixtures helps to confer high solubility. A second virtue of these species is their low cost. A well-defined compound that exhibits many of the properties of cobalt naphthenate is the cobalt (II) complex of 2-ethylhexanoic acid.

#### 2.1.5 Polyester Resin

Polyester resin tends to have pale yellowish tint, and is suitable for most backyard projects. Its weaknesses are that it is UV sensitive and can tend to degrade over time, and thus generally is also coated to help preserve it [4]. The viscosity, specific gravity, gel time at 25°C is about 500-600 cP, 1.120-1.140 gm/m<sup>3</sup>, 15-25 min. The amount acid value is 23-27 mg KOH/gm and the volatile content 33-37% is available.

Its hardener is a MEKP, and is mixed at 14 drops per oz. MEKP is composed of methyl ethyl ketone peroxide, a catalyst. When MEKP is mixed with the resin, the resulting chemical reaction causes heat to build up and cure or harden the resin.

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## 2.2 Alkali Treatment

For 5% NaOH aqueous solution and 5% KOH aqueous solution, mix 5 gms of Sodium hydroxide pellets with 95 gms /ml of water and mix 5gms of Potassium hydroxide pellets with 95 gms /ml of water. The 5% NaOH aqueous solution and 5% KOH aqueous solution are usually white before the fibres are dipped in the solution [5].

First of all coir fibres were treated with 5% NaOH solution in a glass beaker for soaking time of 72 hr, at room temperature (RT). Next the fibres were taken out of the solution, and then washed several times with fresh water and subsequently with distilled water. Finally, the coir fibres were air-dried for next 48 hr. 5% alkali-treated coir fibres for 48 hr which will be shown in next section is higher than that of untreated and other alkali-treated coir fibres [6]. Therefore, another series of treatment with the same procedure were followed for KOH solution. The 5% NaOH aqueous solution and 5% KOH aqueous solution will change its colour to dark brown, after the coir fibres are dipped for 72 hours.

## 2.2 Composites Preparation

The composites were manufacture in a wooden mould (180 mm x 160 mm x 10 mm). For the preparation of composites were used: polyester resin and treated, un-treated coconut fibres, CSM. The composites were prepared by compression molding technique. The components of the polyester resin were mixed manually. Furthermore, the fibres were added.

Four different types of composites has been fabricated with four different fibres – untreated coir fibres, NaOH treated coir fibres, KOH treated coir fibres and Chopped Strand Mat (CSM) glass fibres as shown in Table I. The weight of fibre in a composite is 7.14% of the total weight of the composite. Non-woven fibre mats were used for composite fabrication with polyester resin in a close mould.

TABLE I  
DESCRIPTION OF PREPARED COMPOSITES

S.No.	Composites
1	Untreated Coir fibre Composite
2	5%(w/v) NaOH treated Coir Fibre Composite
3	5%(w/v) KOH treated Coir Fibre Composite
4	CSM - Glass Fibre Composite

First, the mould was polished and then mould releasing agent was applied on the surface. General purpose polyester resin was mixed with 1 wt. % cobalt naphthenate (accelerator) and 1 wt. % methyl ethyl ketone peroxide (catalyst). The resin mixture was degassed in vacuum desiccators and then poured on to the fibre mat placed in the mould. When the mat was completely wet by the resin, the mold was closed, pressed and cured at room temperature for 24 hours. The cast of each composite is cured under a load of about 50 kg for 24 hours before it removed from the mould. Then this cast is post cured in the air for another 24 hours after removing out of the mould. Specimens of suitable dimension are cut using a diamond cutter for mechanical testing. Utmost care has been taken to maintain uniformity and homogeneity of the composite.

## 2.3 Impact Tests

The Charpy impact test, also known as the Charpy v-notch test, is a standardized high strain-rate test which determines the amount of energy absorbed by a material during fracture. This absorbed energy is a measure of a given material's toughness and acts as a tool to study temperature-dependent ductile-brittle transition. It is widely applied in industry, since it is easy to prepare and conduct and results can be obtained quickly and cheaply. A major disadvantage is that all results are only comparative. According to ASTM A370, the standard specimen size for Charpy impact testing is 10mm×10mm×55mm.

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## 2.4 Flexural Test

Flexural properties as determined by these test methods are especially useful for quality control and specification purposes. Most commonly the specimen lies on a support span and the load is applied to the centre by the loading nose producing three point bending (Fig.1.) at a specified rate. The parameters for this test are the support span, the speed of the loading, and the maximum deflection for the test. These parameters are based on the test specimen thickness and are defined differently by ASTM and ISO. For ASTM D790, the test is stopped when the specimen reaches 5% deflection or the specimen breaks before 5%. For ISO 178, the test is stopped when the specimen breaks. Of the specimen does not break, the test is continued as far as possible and the stress at 3.5% (conventional deflection) is reported [7].

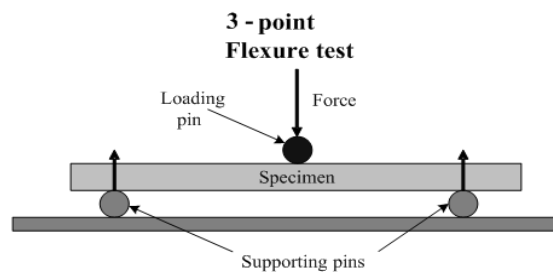


Fig.1. - Three point bending load

A variety of specimen shapes can be used for this test, but the most commonly used specimen size for ASTM is 3.2mm x 12.7mm x 125mm (0.125" x 0.5" x 5.0") and for ISO is 10mm x 4mm x 80mm.

## 2.5 Tensile Test

ASTM D3039 tensile testing is used to measure the force required to break a polymer composite specimen and the extent to which the specimen stretches or elongates to that breaking point [8]. Tensile tests produce a stress-strain diagram, which is used to determine tensile modulus. Specimens are placed in the grips of a Universal Test Machine at a specified grip separation and pulled until failure. For ASTM D3039 the test speed can be determined by the material specification or time to failure (1 to 10 minutes). A typical test speed for standard test specimens is 2 mm/min (0.05 in/min). An extensometer or strain gauge is used to determine elongation and tensile modulus. The most common specimen for ASTM D3039 has a constant rectangular cross section, 25 mm (1 in) wide and 250 mm (10 in) long.

## 2. RESULTS

### 3.1 Impact Test

Impact strength is measured using Charpy test. The impact energy absorbed by different fibre composites are illustrated and compared in Table II.

TABLE II  
IMPACT PERFORMANCE OF COMPOSITES

S.No	Composites	Impact Strength (J)
1	Untreated Coir fibre Composite	1.679
2	5%(w/v) NaOH treated Coir Fibre Composite	2.638
3	5%(w/v) KOH treated Coir Fibre Composite	2.236
4	CSM - Glass Fibre Composite	3.755

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It is observed that CSM – glass fibre composite has got the highest impact strength, followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite (Fig.2.).

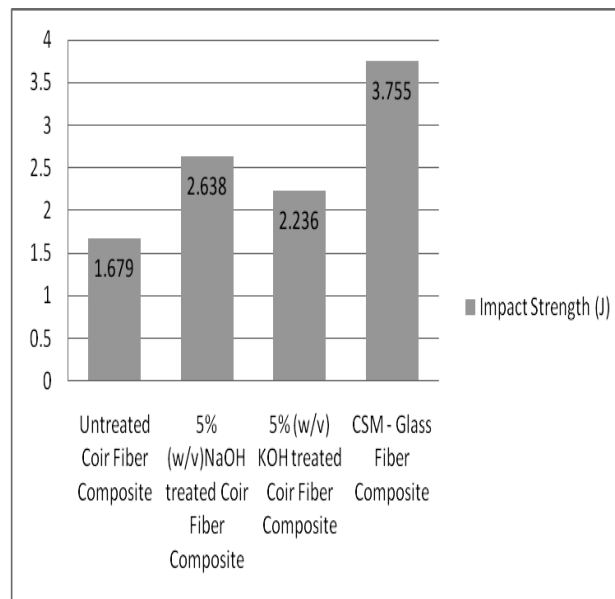


Fig.2. - Graphical representation of the Impact Strength of different fibre composites

But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior impact strength than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

## 3.2 Flexural Properties of Composites

Flexural properties of different fibre composites are gauged by calculating the flexural strength and flexural modulus of the composites.

### 3.2.1 Flexural Strength

Flexural strength, also known as modulus of rupture, bend strength, or fracture strength, a mechanical parameter for brittle material, is defined as a material's ability to resist deformation under load. The flexural strength of composites is prescribed in Table III. The flexural strength represents the highest stress experienced within the material at its moment of rupture. It is measured in terms of stress, here given by the symbol  $\sigma$ .

$$\text{Flexural Strength } (\sigma) = 3FL / 2(bh^2)$$

Where,  $F$  = Normal force  
 $L$  = Specimen length  
 $b$  = Specimen width  
 $h$  = Specimen thickness  
 $Y$  = Deflection at load point

TABLE III  
FLEXURAL STRENGTH OF COMPOSITES

S.No.	Description	Flexural Strength ( $\sigma_1$ ) Mpa	Flexural Strength ( $\sigma_2$ ) Mpa
1	Untreated Coir fibre Composite	9.525	230.446
2	5%(w/v) NaOH treated Coir Fibre Composite	54.3108	126.023
3	5%(w/v) KOH treated Coir Fibre Composite	19.563	50.885
4	CSM - Glass Fibre Composite	81.606	239.0205

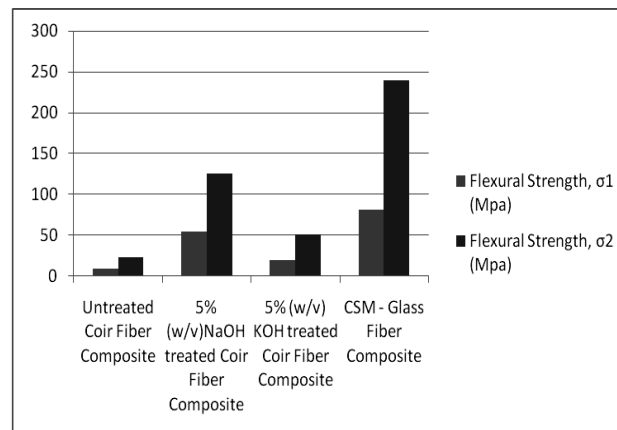


Fig.3. Graphical representation of the Flexural Strength of different fibre composites

It is observed that CSM – glass fibre composite has got the highest flexural strength, followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite (Fig.3). But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior flexural strength than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

### 3.2.2 Flexural Modulus

Flexural modulus is the ratio of stress to strain in flexural deformation, or the tendency for a material to bend. The data in the Table IV determined from the slope of a stress-strain curve produced by a flexural test (such as the ASTM D 790), and uses units of force per area.

$$\text{Flexural Modulus, } (E) = (L^3) * F / (4bh^3) * Y$$

Where,  $F$  = Normal force

$L$  = Specimen length

$b$  = Specimen width

$h$  = Specimen thickness

$Y$  = Deflection at load point

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TABLE IV  
FLEXURAL MODULUS OF COMPOSITES

S.No.	Description	Flexural Modulus ( $\sigma_1$ ) Mpa	Flexural Modulus ( $\sigma_2$ ) Mpa
1	Untreated Coir fibre Composite	15.2409	7.3287
2	5% (w/v) NaOH treated Coir Fibre Composite	74.488	74.2918
3	5% (w/v) KOH treated Coir Fibre Composite	46.9538	46.9538
4	CSM - Glass Fibre Composite	233.620	235.357

It is observed that CSM – glass fibre composite has got the highest flexural modulus, followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite (Fig.4).

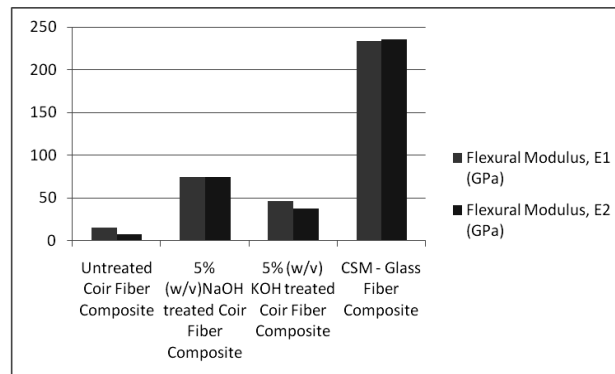


Fig.4 - Graphical representation of the Flexural Modulus of different fibre composites

But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior flexural modulus than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

## 3.3. Tensile Properties of Composites

Tensile properties of composites are determined by calculating the tensile strength and elongation (%) of the composites.

### 3.3.1. Tensile Strength

Tensile strength is used to measure the force required to break a polymer composite specimen. The data in Table V is often used to specify a material, to design parts to withstand application force and as a quality control check of materials.



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TABLE V  
TENSILE STRENGTH AT YIELD AND BREAK OF COMPOSITES

S.No.	Description	Tensile Strength at Yield, Mpa	Tensile Strength at Break, Mpa
1	Untreated Coir fibre Composite	2.019	2.5235
2	5% (w/v) NaOH treated Coir Fibre Composite	5.2005	6.5
3	5% (w/v) KOH treated Coir Fibre Composite	4.0625	5.078
4	CSM - Glass Fibre Composite	13.2573	22.0955

It is observed that CSM – glass fibre composite has got the highest tensile strength at yield and break points, followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite (Fig.5). But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior tensile strength at yield and break points than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

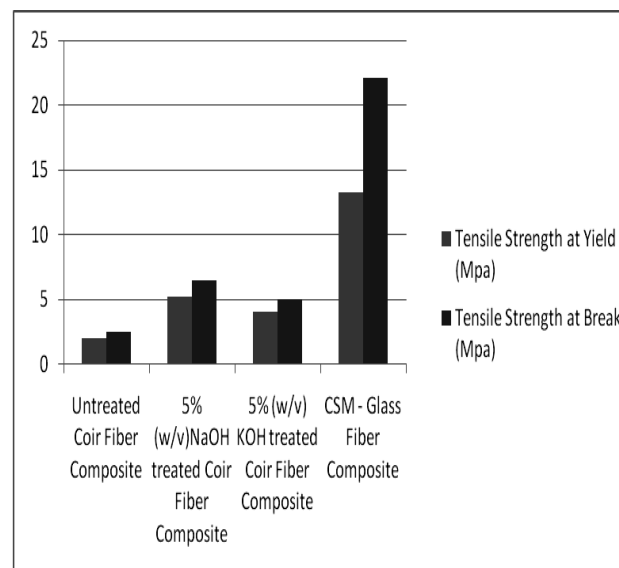


Fig.5 -Graphical representation of the Tensile Strength of different fibre composites

## 3.3.2. Elongation (%)

Elongation of the specimen is used to determine the extent to which the specimen stretches or elongates to that breaking point. Elongation (%) is determined during the tensile test is shown in Table VI. An extensometer or strain gauge is used to determine elongation.



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TABLE VI  
ELONGATION OF COMPOSITES

S.No.	Description	Elongation (%)
1	Untreated Coir fibre Composite	0.68
2	5%(w/v) NaOH treated Coir Fibre Composite	1.475
3	5%(w/v) KOH treated Coir Fibre Composite	0.925
4	CSM - Glass Fibre Composite	2.32

It is observed that CSM – glass fibre composite has got the highest elongation (%), followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite (Fig.6). But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior elongation (%) than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

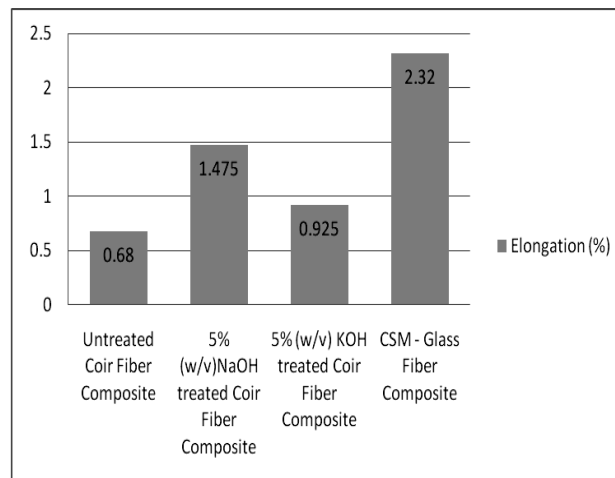


Fig. 6 - Graphical representation of the Elongation (%) of different fibre composites

## III. CONCLUSION

From the results of flexural test, impact test, tensile test it is evident that CSM – glass fibre composite has got superior flexural properties, impact strength and tensile properties followed by 5% (w/v) NaOH treated coir fibre composite, 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite. But, among the natural fibre composites, 5% (w/v) NaOH treated coir fibre composite has got superior flexural properties, impact strength and tensile properties than 5% (w/v) KOH treated coir fibre composite and untreated coir fibre composite.

It is also concluded that, 5% (w/v) KOH treated coir fibre composite has got superior mechanical properties than untreated coir fibre composite. But, its mechanical properties are inferior to 5% (w/v) NaOH treated coir fibre composite and CSM – glass fibre composite.

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