THE PROPERTIES OF *RATTAN CALAMUS CAESIUS* (*RATTAN SEGA*) AND ITS APPLICATION IN SPRING FORM

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ABSTRACT

THE PROPERTIES OF RATTAN CALAMUS CAESIUS (RATTAN SEGA) AND ITS APPLICATION IN SPRING FORM. Rattan is one of the natural resources in the Peninsular of Malaysia, Indonesia, etc. The lack of information of the properties of rattan is a reason why this material is not known as engineering materials. The flexibility or the plasticity of the rattan is actually a strong point to develop it as an engineering materials such as a reinforced of the cement to resist the earthquake or as a spring. This paper therefore shows the properties of rattan calamus caesius (Rattan Sega) and its application as spring. The determination of the properties of rattan was conducted according to ASTM standard with a suitable modification. This research shows the plasticity of the rattan which makes it remain in spring form. The stiffness coefficient of the spring was measured based on the relation of the force and displacement. The value of the stiffness of spring gained from measurement was compared with the analytical method which is valid in an elastic region.

Key words *:* Rattan, engineering materials, spring

ABSTRAK

SIFAT *RATTAN CALAMUS CAESIUS (RATTAN SEGA)* DAN PENGGUNAANNYA DALAM BENTUK PEGAS. Rotan merupakan sumber daya alam yang banyak diperoleh di semenanjung Malaysia , Indonesia dan negara lainnya. Kurangnya informasi tentang sifat mekanis dan fisik merupakan penyebab sehingga bahan ini tidak dikenal sebagai bahan teknik. Sifat keplastisan rotan sebenarnya merupakan faktor penting untuk mengembangkannya sebagai bahan teknik misalnya sebagai penguat semen untuk menahan gempa bumi atau digunakan sebagai pegas. Pada makalah ini, menunjukkan sifat *rattan calamus caesius* (Rattan Sega) dan penggunaanya dalam bentuk pegas. Penentuan sifat rotan dilakukan sesuai dengan standar ASTM dengan modikasi seperlunya. Penelitian ini memperlihatkan adanya sifat plastisitas rotan sehingga bisa dibentuk menjadi pegas. Koefisien kekakuan pegas diukur berdasarkan hubungan antara gaya dan perpindahan. Harga kekakuan pegas yang diperoleh dari pengukuran dibandingkan dengan metode analitik yang hanya berlaku pada daerah elastis.

Kata kunci : Rotan, bahan teknik, pegas

INTRODUCTION

Rattan is the name given to the entire or split stems of rattan palms. Rattan palms have strong, tough, flexible, and slender, many jointed stems of uniform diameter, which are usually 46 meter long, but may extend to 153 meter . It is relatively light (mean density range from 0.25 - 0.59 g/cm^3) but as strong as a medium-density wood. Rattans with different types or species will have different value of properties. Since the fiber dimension of rattan varies significantly with species, the length, diameter, lumen width and the wall thickness of the rattan's fiber will be different from each other [1]. Latif [2] conducted a test of five rattan species such as mantang, manau, jernang, dok and semambu. Sri Rulliyati [3] made a research on the anatomical structure of manau, senambu and sabut. There are no data on the plasticity of the rattan even though rattan can be formed in a different form due to its flexibility which therefore it is used as a furniture or a household. This paper therefore conduct the measurement tests the rattan up to its plastic region in order to show the plasticity properties of the rattan and its possibilities to form it into the spring form. This paper shows also the measurement of the physical and mechanical properties of Rattan Sega which is selected due to the idea of manufacturing it in spring form.

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EXPERIMENTAL

The Measurement of the Physical and Mechanical Properties

The measurement of physical properties include the moisture content, basic density and specific gravity and the measurement of the mechanical properties include MOE, MOR, Compression strength and shear modulus. The most important test in that case is the complete diagram of stress and strain up to failure. There is no ASTM standard to measure the physical and mechanical properties for rattan yet. Therefore, the standard for timber is used with a suitable modification [4]. The moisture content which required for each specimen test are 12-14% and bu using ASTM D 4442-92 is measured by Relative Humidity Hygrometer (RH Chamber). ASTM D 2395-83 method and weighing machine were used to measure the basic density. The Mechanical properties include tensile test, compression test, shear test and bending test using Apparatus Universal Test Machine (UTM) GOTECH. The tensile test is carried out one by using ASTM D 3500-90 with specimen, Gage length: 18 × diameter. The compression test is done by using ASTM D 3501-76 method with test specimen, Column: length/ diameter ratio d" 4. Shear Test uses ASTM D3044-76, specimen: Length, L H" 4 cm (d" 4 × diameter), portion H" 1 cm, Shear Tool (ASTM standard). Bending Test is carried out by using Preparatory Reading, ASTM D 4761-88 method with test specimen: Gage length : 10 × diameter, beam Supporter, Loading Block, Vernier Caliper. The number of specimen for each test is 25.

Spring Manufacturing and Test of its Spring Stiffness Coefficient

The manufacturing of spring was equipped with a spring mould with a different length and diameter, rattan with a specified length and blow torch. The determination of spring includes the coil pitch ($coil_{pitch}$), rise angle (θ), total number of coils (n) and total length of rattan required in spring forming (L_{rattan}) as well as the solid height of the spring (L_{solid}) for 3 spring sets. Set 1 (L= 20 cm, D= 5 inch), set 2 (L = 20 cm, D= 4 inch) and set 3 (L= 20 cm, D= 3 inch) . Each set of spring above mentioned consist of spring with different number of spring coils, which range from 5 to 10 coils. The mould, the length of the rattan and the dimension of rattan for each set of spring is shown at Figure 1.

The procedure to form the rattan into coil form as follows:

1. fix one end of the rattan to the edge of the spring according to the coil shape required
2. Use blowtorch to soften the rattan or to reduce its strength by giving the heat. Try to use this method to retain it in spring form, so that it would spring back after being released from the spring mould.

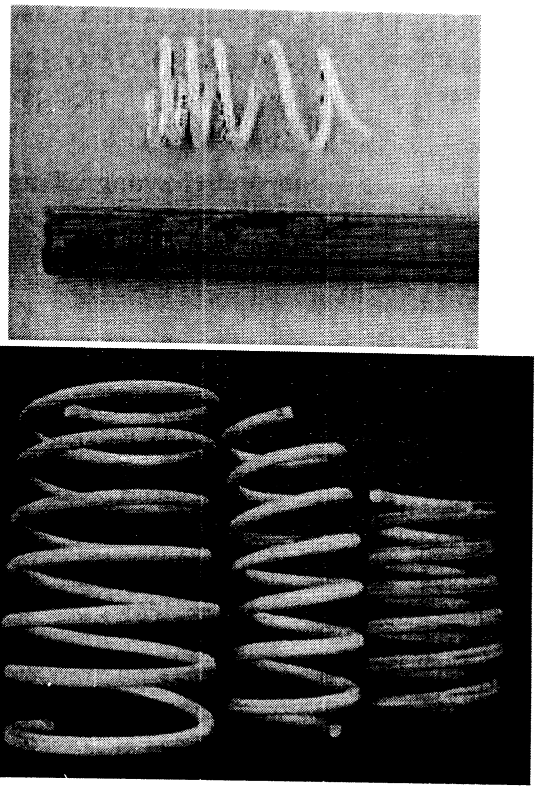

Figure 1. Basic function of spring mould to provide uniform diameter in coils form (above). The resulted spring (below).

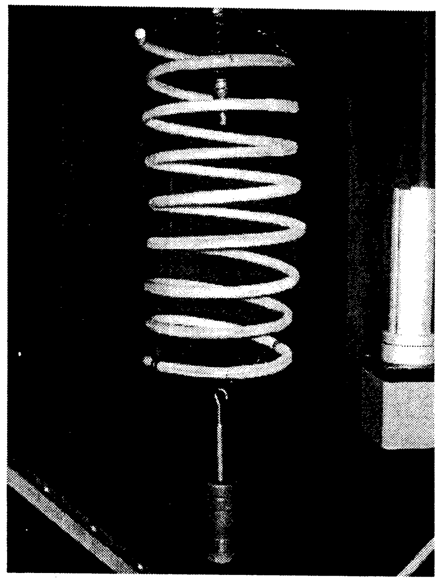

Figure 2. Test of the spring stiffness - Loads acted to spring

The test of the spring stiffness uses the simple relation of the force and deflection. The original of the length of the spring by excluding its inactive coils and the length of spring after elongation by increasing the load slowly and constantly are measured (Figure 2). Draw a load – displacement diagram for every spring based on the measured data. The spring stiffness is found from the slope of the load- displacement diagram.

RESULT AND DISCUSSION

The data have been reduced and assembled into normal distribution. The distribution commonly encountered in material testing is a bell – shaped curve resembling the theoretical normal frequency curve [5].

The Physical and Mechanical Properties of Rattan Sega

The mechanical properties of Rattan Sega were obtained through tensile , compression , bending and shear tests. 25 samples have been tested for each test. The date gained from each test had been gathered and analyzed using the normal distribution [5]. The bending test was not successfully done because of the setting problem of the equipment. The summary of the physical and mechanical properties of the Rattan Sega is tabulated in Table 1.

Table 1. The physical and mechanical properties of Rattan Sega

Name of Cane		Sega		
		Mean	Range	Mean
Average Diameter (mm)		8.75	8.25 - 9.59	
Basic Density (kg/m^3)		580.9	539 - 553	104.40
MOE (MPa)	Bending			-
	Tensile	915	837.1 - 993	198.73
MOR (MPa)		54.60	50.5 - 58.7	10.60
Compression Strength (MPa)		31.00		
Shear Modulus, G (MPa)		3.41	3.1 - 3.74	0.85

Though all samples are placed and dried in the same oven under the same temperature, but there are occurring a different of moisture content. The moisture content is in the range of 8-9% and 12-14%. Within this range of moisture content, the value of basic density and specific gravity can be seen through the normal distribution. The density of rattan, of course, is greatly influenced and determined principally by two factors: the amount of rattan substance per unit volume and the moisture content. Other factors, such as the content of extractives and minerals, have minor effects on density. The density of rattan, exclusive of water, differs greatly within as well as between species.

Many characteristics of rattan are affected by density. Since it is the rattan substance in the fibers that imparts strength and stiffness, rattan of high density is stronger and stiffer than those of low density, other factors such as moisture content being equal. Rattans of high density typically shrink and swell more with changes in moisture content than do rattan of low density. The weight density of water is used as the basis for such comparisons. Therefore, this property is also varying from different species. In this work has not found the relationship between moisture content and strength or specific gravity and compressive strength because the data is scatter.

The Plasticity and Fracture of the Rattan Sega

The test of tensile stress and the study of the fracture were conducted for 25 samples. The plasticity and fracture of the rattan was done by the tensile test. The proper gripping of the specimen should be given attention because it brings great effect to the performance of the result. The most important objective of this work is to find out the plasticity properties of rattan. There is plasticity region in the force-displacement diagram for Rattan Sega (Figure 5). It is the difference of the rattan properties compared to the wood properties. It indicates that the rattan can be formed into a spring form due to its plasticity properties. It proves that the rattan has ability to be transformed into spring form without any fixture. The forming of the rattan into a spring form is based on these properties. The question is the rattan can be given a load to reach the plastic region.

Figures 3, 4 and 5 show the fracture of rattan based on the tensile test and its relation to the diagram of stress and strain. Generally, the tensile fractures can be classified into two major groups, they are tensile fractures with partial breaking and full breaking. In partial breaking, there are two types of fractures.

1. Failure Mode A: Specimen splits irregularly at middle.
2. Failure Mode B: Specimen splits regularly at middle.

For tensile fractures with full breaking, five types of fracture could be seen among the 25 samples.

1. Failure Mode C: Specimen breaks at middle with skin peeled off.
2. Failure Mode D: Specimen breaks at middle irregularly.

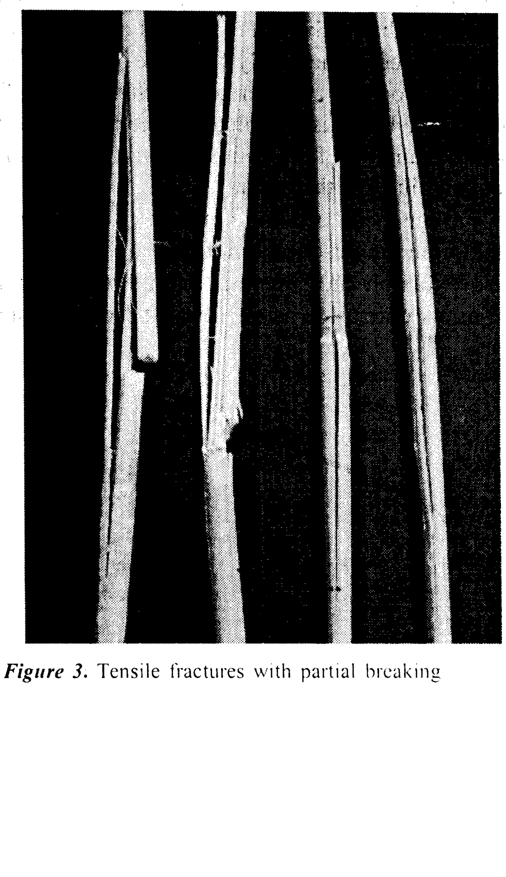

Figure 3. Tensile fractures with partial breaking

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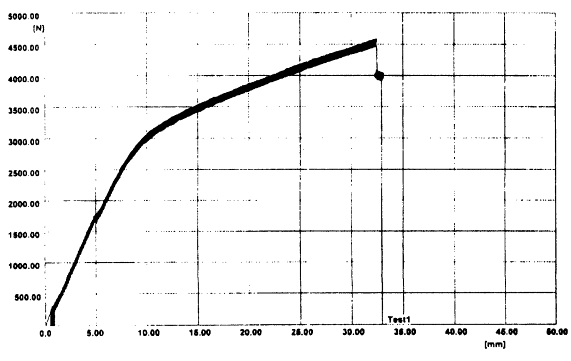
Figure 4. Typical tensile fractures with full breaking

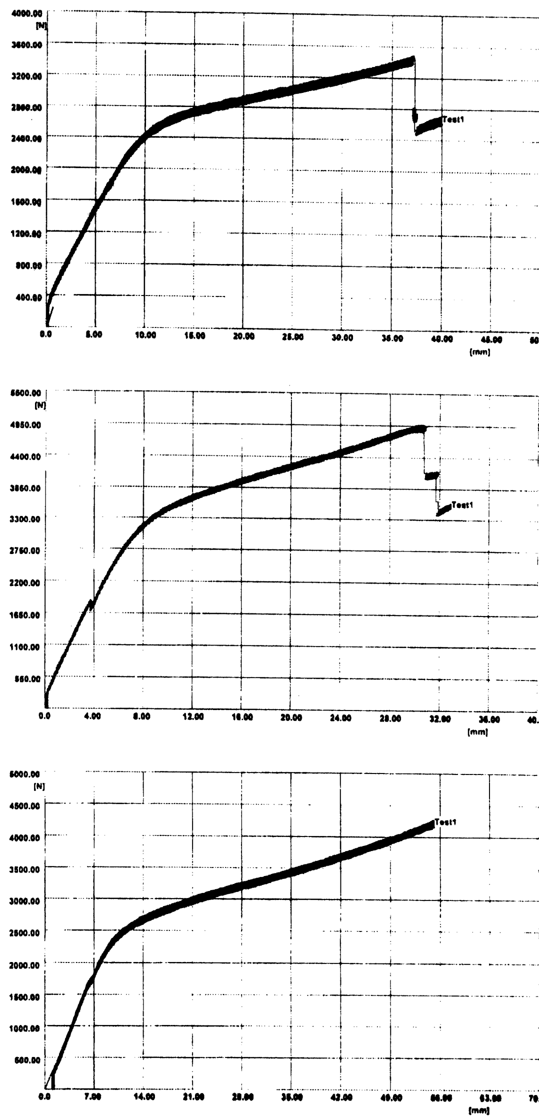
3. Failure Mode E: Specimen breaks at middle with even and flat surface.
4. Failure Mode F: Specimen breaks at connection with fibrous surface.
5. Failure Mode G: Specimen breaks at connection with even breaking.

From the observation through force-displacement diagrams, it can be differentiated the fractures type between partial breaking and full breaking. Figures 5.a, 5.b and 5.c are the force-displacement diagram for partial breaking, while Figure 5.d is for full breaking. The main difference is the rupture region. For partial breaking, there are stages in the rupture. As the specimens do not break completely, but part of its fiber break when a certain amount of load is acted. Therefore, the force acted drops vividly and start to increase again as load is acted on the other parts that are still connected. It can be concluded here that every drop in the force-displacement diagram shows the breaking of the fiber. For full breaking, the force stopped immediately when the test fail. There is no further dropping and increasing after rupture. This means that the break is completely. The relation of the stress and strain until failure shows that it is difficult to predict the failure of the rattan.

Various types of failure of rattan loaded parallel with the grain are described in Figure 6. The types of failure are torsion and crushing. Sample A has torsion failure as its outer skin is peeling off from the stem.



(a)



(b)

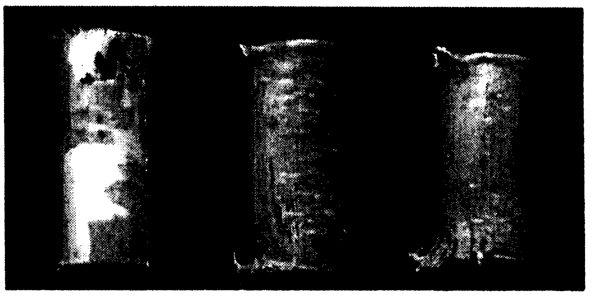
(c)

(d)

Figure 5. Force-displacement diagrams for tensile wich one partial breaking and wich one full breaking

Sample B and C are crushing at both ends with splitting surfaces.

Figure 7 shows typical fracture due to shear stress. A shearing stress acts parallel to a plane, as distinguished from tensile and compressive stresses, which act normal to a plane. Direct shear and torsion.



A B C

Figure 6. Types of failures of Rattan Sega under compression parallel tothe grain

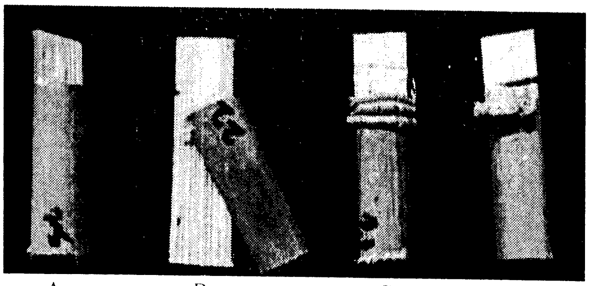


Figure 7. Typical shear stress fractures of Rattan Sega

shear are the loadings causing shear conditions that are of principal interest in materials testing. However, only direct shear test was conducted. Sample A indicates the specimen for shear test with a portion before tested. The types of the failure among the 25 sample are:

1. Failure Mode B: This failure mode occurred in most of the specimens in shear test. It splits off accurately at the mid plane
2. Failure Mode C: The portion under loading is being compressed instead of shearing.
3. Failure Mode D: In this failure mode, the sample seems to tear off from the partial line of portion.

Figure 8 shows some failure due to bending. Since the tensile strength of rattan parallel to the grain is usually greater than its compressive strength, the neutral axis shift toward the tensile face so as to maintain equality than in compression forces. Therefore, the first visible sign of failure may be in the tensile face even though the rattan is stronger in tension than in compression

The failure of the rattan in bending are as follows:

1. It may fail in direct compression at the concave compression surface.
2. It may break in tension on the convex tension surface

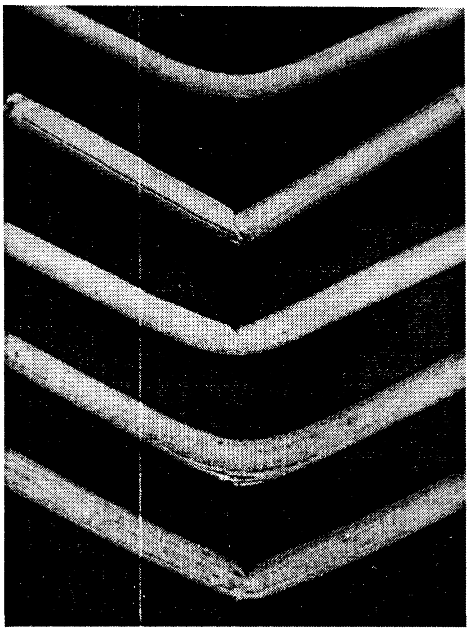


Figure 8. Failure of bending

3. It may fail by lateral deflection of the compression fibers acting as column.
4. It may fail in horizontal shear along the grain near the neutral axis
5. It may fail in compression perpendicular to the grain at points of concentrated load.

The Spring Stiffness-Theoretical and Experimental

The achievement of forming the rattan into a spring form without spring back indicates that the load has reached the plastic region. Plain type of springs has been produced with different length, coil's diameter and also the number of spring coils. These springs had been tested under continuous loading to obtain its spring stiffness, k. The spring stiffness was calculated based on the slope of the lines of the linear lines of the force-deflection graph. Table 2 shows the spring stiffness based on experimental. The test of the spring stiffness is conducted only in compression condition.

Table 2. Experimental Spring Stiffness

Spring Set	Spring Stiffness, $e_{xperimental}$					
	5 coils	6 coils	7 coils	8 coils	9 coils	10 coils
Set 1	0.67	1.11	1.0	0.462	0.692	0.75
Set 2	4	4	4	2.33	4	2.00
Set 3	5	4	4.5	4	3.6	2.86

The theoretical equation of helical spring stiffness has been derived as :

$$k = \frac{Gd^4}{8D^3 n_a}$$

according to the spring geometry which is valid in elastic region [1]. The spring stiffness is affected by the diameter of coils and also the number of spring coils. It can be seen from the equation that the spring stiffness is higher with the increasing of the shear modulus and the diameter of the material. The theoretical spring stiffness is calculated after insertion of shear modulus of 3.41 MPa. Through the comparison of experimental and theoretical stiffness, the absolute errors for different spring set are shown in Table 3.

Table 3. The comparison of the spring stiffness between experimental and theoretical

Set	Dimension	Absolute Error
1	L = 20 cm; D = 12.70 cm	431.14%
2	L = 15 cm; D = 10.16 cm	23.16%
3	L = 15 cm; D = 7.96 cm	36.49%

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The spring stiffness for spring set 1 varies a lot from theoretical result. The result from set 2 and 3 shows that spring made of rattan has better performance in smaller diameter. For bigger diameter of spring coils, such as spring set 1, it could have exceeded the elastic region and causes unstable displacement when continuous load is added. The moment formed at the torsion area in the spring has caused the load exceeds the elastic limit. This shows that the equation is only valid within elastic region for spring with smaller diameter. It could be caused by the presence of moment at the torsion part with exceeded load to the spring.

CONCLUSION

Through this study, the properties of Rattan Sega have been successfully obtained from a few tests, for both the physical and mechanical properties. It is a contribution to the rattan-based industry with the presence of a new rattan species with its properties. Another achievement in this study is to prove the plasticity region of Rattan Sega through tensile test. The stem would not spring back when the force used to form over a certain limit. Therefore, fixture is needless to fix or tied the rattan stem as what have been used in today's rattan furniture manufacturing. Because of the forming ability of rattan, it has been applied in spring manufacturing. Unlike the other products, both ends of the stem are free from any fastening.

This work will be extended in future by conducting of measurement of fatigue, the effect of the temperature to the yield strength and the anatomical characteristics and chemical properties as well as its microstructure in order to fulfill both the physical and to know the reason of the different failure breaking.

REFERENCES

[1]. ABD.LATIF and SITI NORRALLAKMAN YAHAYA, *Anatomical Characteristic of five Malaysian Canes and Their Relationship with Physical and Mechanical Properties*, Rattan Management and Utilization (1992)

[2]. ABD. LATIF MAHMOD, K.C. KHOO and JAMALLUDDIN KASIM, *Physical Properties, Fiber Morphology and Chemical Constituent of Five Malaysian Rattan*, Journal of Tropical Forest Product, **2** (1997)

[3]. SRI RULLIYATI, *The anatomical Structure of Manau, Senambu, Sega and Sabut*, Bulletin Penelitian Kehutanan, **1** (1996)

[4] NN, *American Society of Testing Material, Standard test Methods for Physical and Mechanical Properties of Lumber and Wood-Base Structural Material*, (ASTM D 4761-88), (ASTM D 4442-92), (ASTM D 4442-92), (ASTM D 3044-76), (ASTM D 3500-90) (1986)

[5]. E.P.POPOV, *Engineering Mechanics of Solid*, Englewood Cliffs, New Jersey, Prentice – Hall (1990)