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COMPUTER SIMULATION TO STUDY DEFORMATIONS AND STRESSES DISTRIBUTION ON SOME SUDANESE LOCAL WOOD MATERIALS UNDER CONSTANT EXTERNAL LOAD

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Abstract:
A computer simulation was conducted to study the resultant deformation, Von-Mises stress distribution, and stresses distribution in X, Y and Z axes as well as shear stresses on X-Y, Y-Z and X-Z planes on some wood materials under constant external load. A finite element program (ANSYS 11) was used for simulation. Tested wood materials were Faidherbia albida, Acacia nilotica and Tamarindus indica. Wood materials were modeled in ANSYS and were then defined, the mechanical properties of each model were used as inputs, meshed and constrained then a load of 10kPa was applied and the solution was run. The results showed that Von-Mises stress for for Acacia nilotica wood was 167.76kPa as the highest value of Von-Mises stress and for Faidherbia albida wood was 161.76kPa as the lowest value. In case of stresses in coordinates, in X, Y and Z axes, Faidherbia albida recorded 205.76kPa and 90.07kPa (in Y and Z axes) as the highest values while Acacia nilotica recorded 204.77kPa and 75.05kPa (in Y and Z axes) as the lowest values. It was found that the highest values of shear stress on X-Y, Y-Z and X-Z planes were 43.01kPa, 4.65kPa and 26.93kPa, respectively, and they were shown by Faidherbia albida wood while the lowest values were 42.46kPa, 4.27kPa and 24.65kPa and they were recorded by Acacia nilotica. Computer simulation could be an effective tool for wood materials selection optimization.

Key words: *computer simulation; Von-Mises stress; wood materials.*

INTRODUCTION

Wood has been considered an important renewable resource due to its sustainability in production, abundance and universal use such as building, energy, transportation structures and various wood industries (Nasroun 2005, USDA 2010). The good mechanical behavior (strength) of wood expresses the efficiency and ability of wood to resist external loads that change its dimensions and/or shape (Nasroun 2005). Green *et al*. (1999) stated that, mechanical properties are commonly measured and represented as "strength properties" for design include modulus of rupture in bending, maximum stress in compression parallel to grain, compressive stress perpendicular to grain, and shear strength parallel to grain (Green *et al*. 1999). Desch and Dinwoodie (1983) found that wood density is of practical importance in its utilization and a good indicator of strength properties. Evans (1991) concluded that the pattern of wood density variations have impact on the variations of most strength properties. While Izekor *et al*. (2010) reported that density and mechanical properties decreases from the tree base to the top whereas it increases from the inner wood to the outer wood at any particular height and the density has a strong positive correlation with the mechanical properties of wood and can therefore be used in predicting its strength properties. As described by Kretschmann (2010a), wood may be considered as an orthotropic material that has unique and independent mechanical properties in the directions of three mutually perpendicular axes: longitudinal (L), radial (R), and tangential (T). He further explained that there are twelve constants are needed to describe the elastic behavior of wood. These constants are three moduli of elasticity E, three moduli of rigidity G, and six Poisson's ratios µ. When wood material is able to resist against extreme external load without deformation in the shape, therefore, this wood material can be classified as solid material otherwise brash and in all cases wood elasticity is measured by modulus elasticity (MOE) while the wood resistance against failure is measured by modulus of rupture (MOR) (Rammer 2010, Kretschmann 2010b, Nasroun 2005). Information regarding mechanical properties of wood can be obtained through either laboratory experiments or directly during common circumstances of wood uses (Nasroun 2005). Recently, computer simulation has been widely used in various disciplines and becoming practical tool for studying and development of material properties (Turner 1986, Sibani 2005). The objective of the present work is to conduct a computer simulation to study the mechanical behaviors of selected some local types of wood in Sudan when subjected to external load.

MATERIALS AND METHODS

Materials used in this study include a desk top computer, ANSYS software, and wood model with mechanical properties shown in Table 1.

Table 1

Some mechanical properties of some local Sudanese wood under study

Wood species	Density, g/cm3	Poison's ratio	Modulus of Elasticity MOE, GPa
Faidherbia albda	0.59	0.330	6600
Acacia nilotica	0.93	0.297	9400
Tamarindus indica	1.05	0.318	10100

Source: (Nasroun 2005).

Wood materials

For the purpose of this study, mechanical properties of three local Sudanese woods were adapted from Nasroun (2005). These wooden species were represented by *Faidherbia albida*, *Acacia nilotica* and *Tamarindus indica*. According to Sahni (1968), *Faidherbia albida* Del. (local name: *Haraz*, family: leguminaceae) is a large tree up to 25m height and 5m in girth with spreading crown. It is widely distributed in Sudan from latitude 100 – 2500m above sea level (a.s.l). The timber of *Faidherbia albida* is soft, very liable to blue stain and is readily attacked by borers. It has common uses in construction and furniture. *Acacia nilotica* (L.) Wild. (local name: *Sunt* or *Garad* (fruit); sub family: mimosaideae) is a tree up to 14m high spread all over Sudan in the flooded areas. The timber of this species is heavy, hard and naturally durable, and widely used for railway sleepers but also for many other purposes such as structural members in buildings. *Tamarindus indica* L. (local name: *Arabiab*) is a large tree up to 16m high with stout pole and compact rounded crown with drooping branches. The timber is very hard and used in local building constructions and is considered a potential furniture species where extreme hardness is required.

Mesh generation

Solid Tet 10 nodes 187 was used for element type and structural isotropic with mechanical properties demonstrated in Table 1 were used as material models for wood. For boundary conditions wood model with dimensions 1.2m×0.2m×0.2m was constrained at right and left ends. A distributed load of 10kPa was applied on upper surface of the model. The solution of linear problem was run to investigate the response of wood material to the applied load.

Post-processing

Calculation control and result processing were accomplished within POST1. Deformed and un-deformed shapes, Von-mises stress, stresses in X axis, and shear stresses on XY, YZ and XZ planes were displayed and animated within PlotCtrls button. The flowchart of the program is shown in Fig. 1.

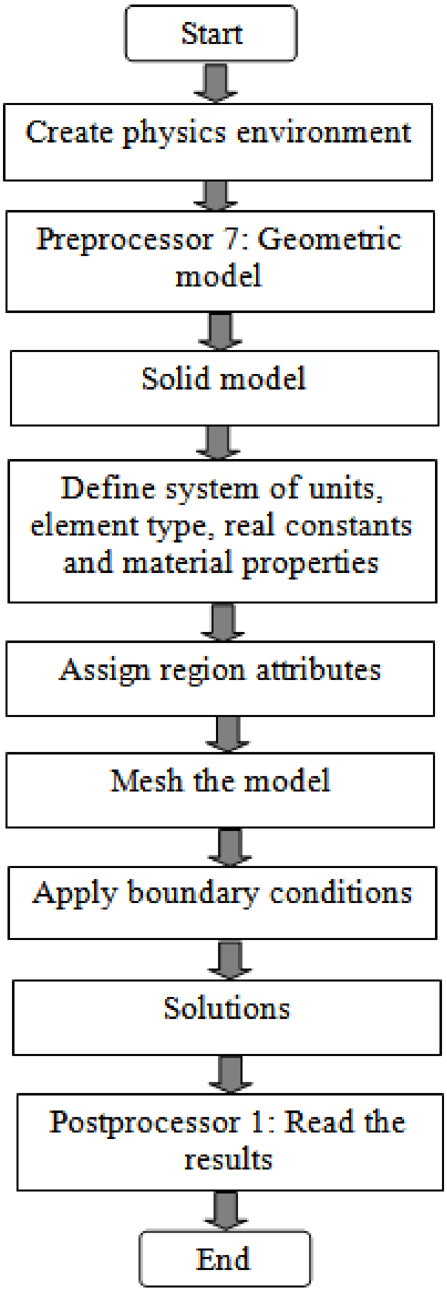

Fig. 1
Flow chart of structural analysis.

RESULTS AND DISCUSSION

The Dimensions of sampled wood model under study was shown in Fig. 2. The meshed model, deformed and un-deformed shapes and Von-Mises stress for *Faidherbia albida*, *Acacia nilotica* and *Tamarindus indica* were shown in Fig. 3 while stress distributions for the coordinates were depicted in Fig. 4. Table 2 shows the summery of stresses distributions for different types of wood materials. Results in Table 2 showed that the Von-Mises stress for Faidherbida albida wood was 161.76kPa, for Acacia nilotica wood was 167.76kPa and for Tamarindus indica wood was 164.01kPa. Acacia nilotica demonstrated the highest value of Von-Mises stress while Faidherbia albida wood showed the lowest value of Von-Mises stress. In case of stress distribution in coordinates, in X axis (longitudinal direction) the values were 206.59kPa, 204.77kPa and 205.86kPa for Faidherbia albida, Acacia nilotica and Tamarindus indica woods, respectively. In Y and Z axis, the values of stresses are equal for the same wood and they are 90.07kPa, 75.05kPa, 84.27kPa for Faidherbia albida, Acacia nilotica and Tamarindus indica woods, respectively. The highest values of stresses in X, Y and Z axis were recorded by Faidherbia albida wood while the lowest values were shown by Acacia nilotica. It was found that shear stress on XY plane was 43.01kPa for Faidherbia albida wood, 42.46kPa for Acacia nilotica wood and 42.62kPa for tamarindus indica wood and Faidherbia albida wood showed the highest value while Acacia nilotica demonstrated the lowest shear stress in XY plane. In case of shear stress on YZ plane, for Faidherbia albida wood the value was 4.65kPa, for Acacia nilotica wood was 4.27kPa while it was 4.51kPa for Tamarindus indica wood. The highest shear stress value in this plane was shown by Faidherbia albida wood while the lowest value was shown by Acacia nilotica wood. In case of shear stress on XZ plane, the highest value was 26.93kPa and it was demonstrated by Faidherbia albida wood while the lowest value was 24.65kPa and it was shown by Acacia nilotica. The differences between all values of stresses for three types of wood were found to be significant at P≤0.01.

Table 2

Stresses distribution on surfaces of different types of wood

Source of wood	Stresses distribution, k Pa						
	Von-Mises	X-axis	Y-axis	Z-axis	XY-shear stress	YZ-shear stress	XZ-shear stress
Faidherbia albda	161.76a	206.59a	90.07a	90.07a	43.01a	4.65a	26.93a
Acacia nilotica	167.76b	204.77b	75.05b	75.05b	42.46b	4.27b	24.65b
Tamarindus indica	164.01c	205.86c	84.27c	84.27c	42.62c	4.51c	26.12c

Values in the same column not share a common superscript letter show significant differences at P≤0.01 as separated by Bonferroni test.

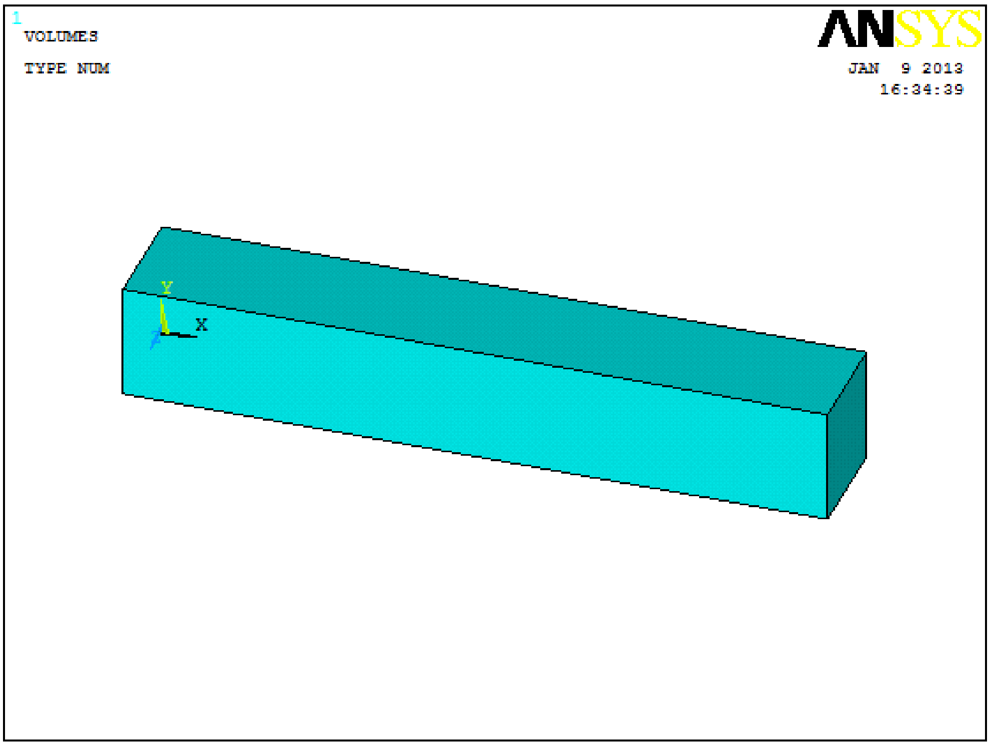

Fig. 2
Dimensions of sampled wood under study.

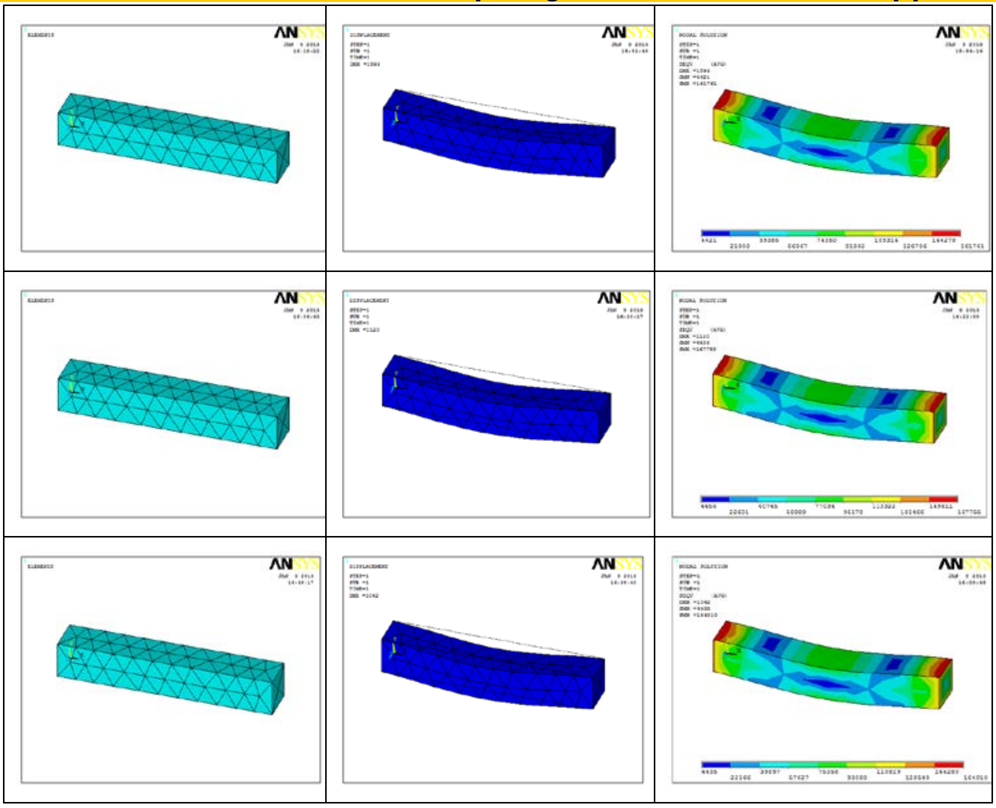

Fig. 3
Meshed Block (left), deformed shape (middle) and Von-mises stress distribution (right) of Faidherbia albida, Acacia nilotica and Tamarindus indica wood.

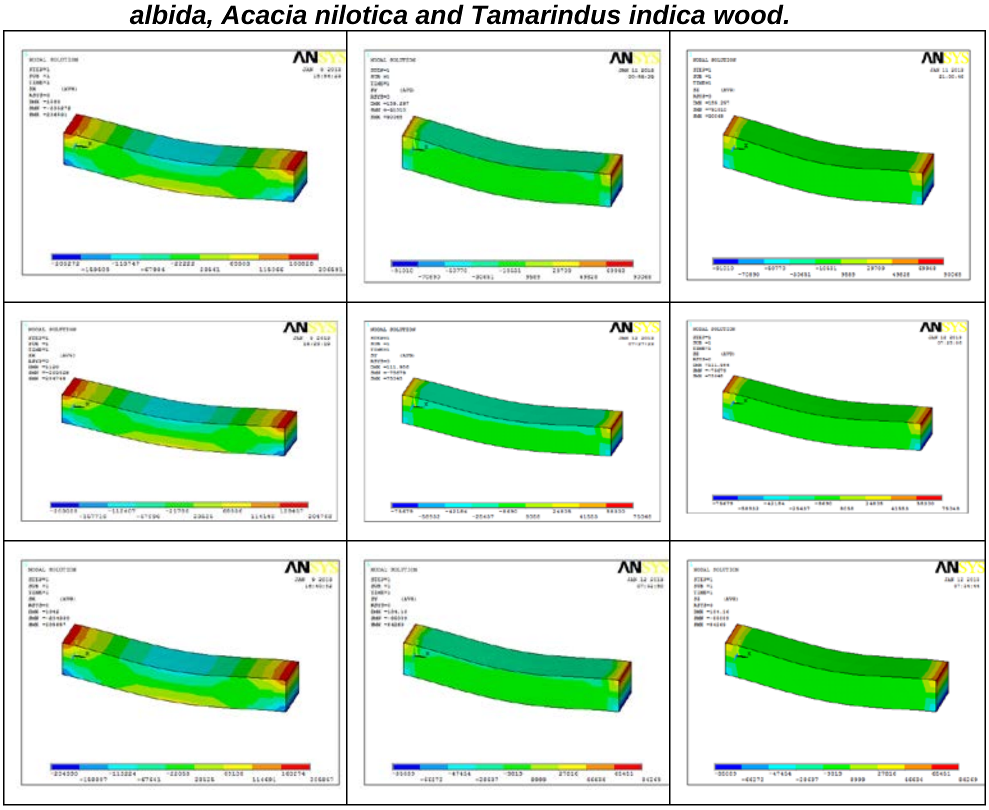

Fig. 4
Stress distribution in X axis (left) longitudinal direction, Y-axis (middle) and Z-axis (right) on wood of Faidherbia albida, Acacia nilotica and Tamarindus indica.

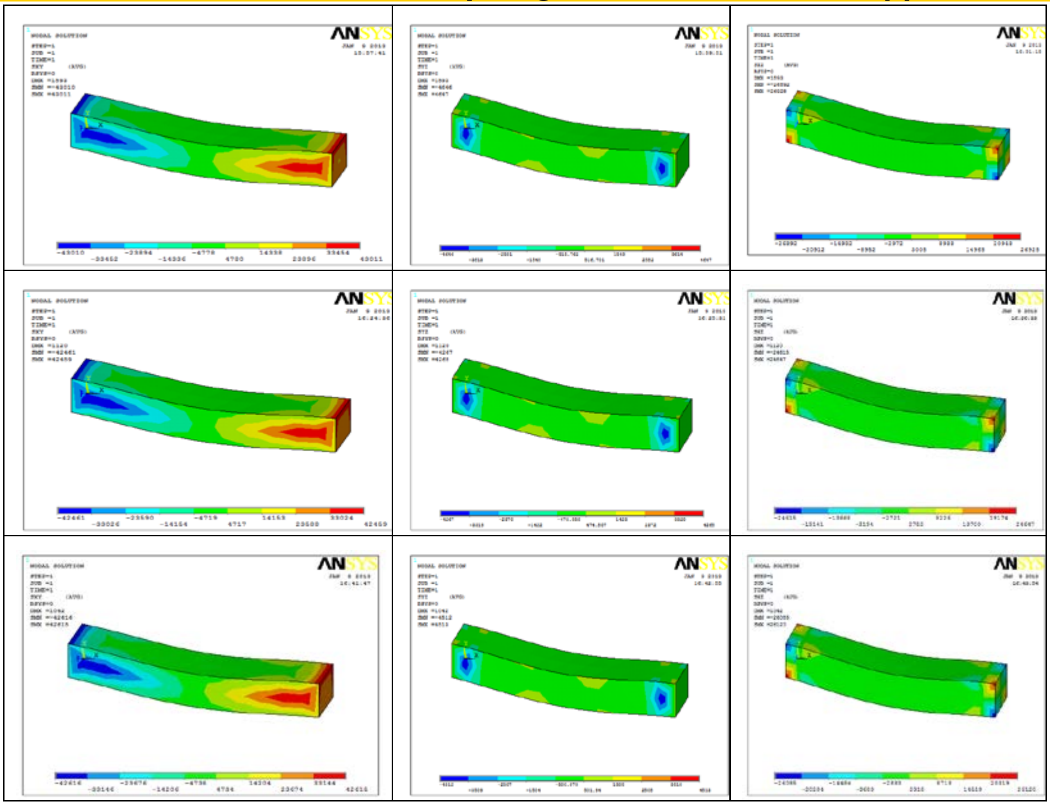

Fig. 5
Shear stress XY-plane (left), YZ-plane (middle) and XZ-plane (right) on wood of Faidherbia albida, Acacia nilotica and Tamarindus indica.

CONCLUSION

Acacia nilotica characterized by highest Von-Mises stress, while Faidherbida albida has highest stresses in X, Y and Z axis as well as shear stresses on XY, YZ and XZ planes. Computer simulation could be an effective tool for testing the stresses and displacements of wood materials when they are subjected to different external loads, forces or moments. This may enhance the optimum selection of material type at the virtual level before executing structure.

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