Engineering Properties of Date Palm Trunk Applicable in Designing a Climber Machine

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ABSTRACT

The objective of this research was to determine some important engineering properties of date palm trunk to be utilized in the designing of a machine that will be directly connected to the trunk and uses it as a support. The moisture content and average density of trunk were 228.98% (d.b.) and 1.16 g/cm^3, respectively. Results of flexural strength showed that the average flexural strength and flexural modulus of trunk were measured as 7.166 and 273.4 MPa, respectively. The modulus of elasticity and yield stress in parallel compressive strength tests were 281.3 and 4.458MPa, respectively, while stress at proportional limit was measured as 1.124MPa in perpendicular compressive strength test. The strength in perpendicular compressive strength test was lower than in parallel compressive strength test. The maximum load in hardness test was 0.7319 kN and the toughness was measured as 1.61 kg.m in impact test. Flexural strength test, compressive strength tests; parallel and perpendicular to trunk fibers, and hardness test were carried out with using Instron testing machine while impact strength test was carried out with Amsler. These results are useful for designing of a climber machine or robot which is directly connected to the tree trunk and uses it as a support.

Keywords: Date palm, flexural, compressive, hardness, impact, strength, climber, Iran

1. INTRODUCTION

The growth habit of date palm *(Phoenix dactylifera* L.*)* is cylindrical, without any branching stem, and relatively tall. The trunk of date palm composes of vascular bundles held together with connective tissues. Towards the periphery, where the leaf bases are embedded, the tissue tends to become more lignified and tough (Barreveld, 1993). The date palm tree commonly grows to a height of about 10 to 15m and has a slender trunk of more or less constant diameter from the base to the crown. Overall length of a date palm depends on variety and region, and in some cases like Shahani variety in Jahrom becomes 20 meters and more (Hashempour, 1999). The date palm may reach an age of over 100 years. Each year the old leaves are cut off at the base of the leaf stem. If the bases of the leaves are cut off, the trunk becomes smooth, much smaller in diameter, and more difficult to climb (Al-Suhaibani et al., 1988). Date palm lengthwise growth is upward and is provided by means of leaf growth from apical meristem and is a function of fertilization, irrigation, pruning and so on.

In order to prepare reinforced concrete with date palm fibers, Kriker et al. (2005) examined four types of date palm surface fibers and determined the properties of palm fibers and concrete reinforced with the fibers. Also Abdel-Rahman et al. (1988) carried out an experimental investigation of physical and mechanical properties of date palm frond stalks and their durability in concrete.

During the past decades, increasing interest in mechanization of date palm services has led to the development of date palm harvesting aids and machines (Perkins and Brown., 1964, 1967; Sarig et al., 1971; Sarig, 1989; Al-Suhaibani et al 1988, 1992; Shamsi, 1998; Loghavi and Abounajmi, 2001; Abunajmi and Loghavi, 2003).

The objective of this research was to determine some engineering properties of date palm trunk (cv. Shahani) applicable in designing a machine which will be directly connected to the tree trunk in order to do some special operations such as pollination, thinning, bagging, harvesting and spraying for insect control at the top. There were no detailed literatures on mechanical properties of date palm trunk to be utilized in designing of date palm services machines.

2. MATERIALS AND METHODS

2.1. Sampling

The trunk specimens were prepared in Jahrom which is one of the most important horticultural centers in the south of Iran. The selected palm tree cultivar was Shahani which is the most popular cultivar in Jahrom. The prepared specimens with approximately 1 m in length and 45cm in diameter were transported to wood mechanical laboratory of Wood and Paper Science Faculty, University of Tehran as soon as was possible after cutting (The day after). Trunk specimens were covered with nylon in Jahrom to reduce its moisture evaporation during transportation (Fig.1). All experiments were carried out at a temperature range of 25–30 °C.

Fig.1. Trunk sample of palm covered by nylon

2.2. Moisture Content and Density of Trunk

Moisture content is important because wood strength is reduced with losing moisture (Parsapajouh, 1988). Trunk specimens of date palm were transported to Woodcraft Unit to prepare standard specimens for each experiment. In order to measure moisture content and density of trunk, some cube shaped specimens were prepared. Trunk density for cubic samples was determined by using mass-volume relation. In measuring moisture content, specimens were kept in an oven for 3 days at 105^{o}C. Weight loss on drying to a final constant weight was recorded as moisture content by AOAC (1984) recommended method and using the following equation (1):

$$MC = \frac{M_0 - M_d}{M_d} \times 100 \qquad (1)$$

where MC is moisture content (d.b.), M_0 is initial mass and M_d is the final mass of samples(g).

2.3. Flexural Strength Test

Flexural strength test, compressive strength tests; parallel and perpendicular to trunk fibers, and also hardness test were done by using Instron testing machine (model 4486). Its minimum and maximum load cell capacity was 10 kN in flexural strength and hardness tests and 300 kN in compressive strength tests, respectively. Impact strength test was carried out with Amsler testing machine having 10 kg-m capacity. All mechanical experiments were carried out according to ASTM143-Secondary method.

In order to determine the flexural strength, 10 cubic specimens were prepared with dimensions of 2×2×28 cm^3. Each specimen was placed on two Instron supports of distance 24 cm apart and loaded at the middle (Fig.2).

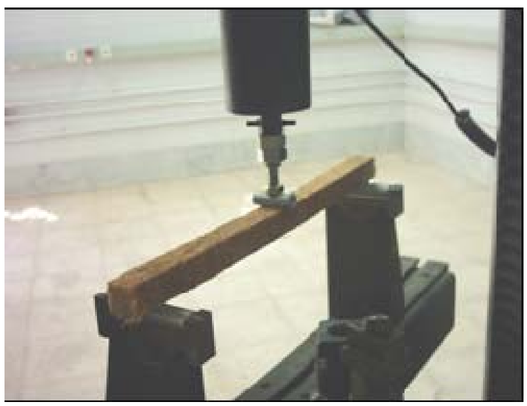

Fig.2. Flexural strength test

Loading rate was exatly10mm/min for each specimen. Loading was stopped when the load-displacement diagram was horizontal. At this moment usually a weak noise was heard because of rupture.

2.4. Compressive Strength Tests; Parallel and Perpendicular to Trunk Fibers

To determine the parallel and perpendicular compressive strength of trunk fibers, specimens were prepared with dimensions of 5×5×15cm^3. For compressive strength test; parallel to trunk fibers, specimens were placed in longitudinal position between Instron supports and were subjected to compressive load (Fig.3). Loading rate was adjusted to 1.2 mm/min.

Fig.3. Compressive strength test parallel to trunk fibers

For compressive strength perpendicular to trunk fibers, load was applied on 5×15 cm^2 section of specimen and the loading area was 5×5cm^2 (Fig.4). The loading rate was 0.3 mm/min. Both compressive strength tests were replicated 5 times each.

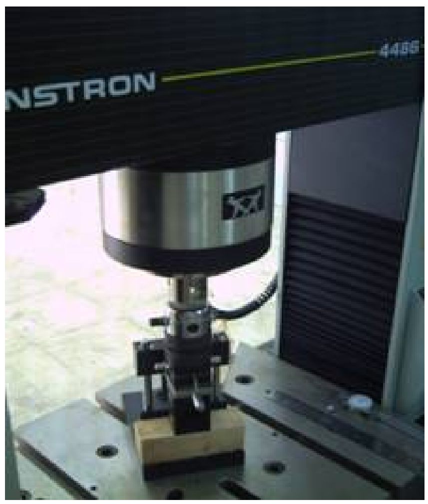

Fig.4. Compressive strength test perpendicular to trunk fibers

2.5. Hardness Test

In hardness test, specimens were prepared with dimensions 5×5×15cm^3. A metal shot with approximate diameter of 11.3 mm (its projected area is exactly 1cm^2) was used to penetrate the specimen, subjected to increasing load (Fig.5). The Penetration rate was 6mm/min. Test ended as shot penetrated into the specimen to its radius. At this moment loading stopped. This test was also replicated at 5 times.

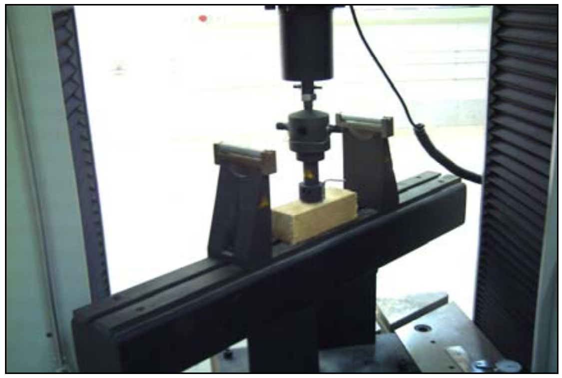

Fig.5. Hardness test

2.6. Impact Strength Test

Amsler testing machine with 10 kg-m capacity was used for impact strength test (Fig.6). Specimens' dimensions were 2×2×28cm^3. Support displacement of machine was as 24cm. Amsler has a scaled part which graduated as 0 to 10 (kg-m). At the first hammer lifted and locked at the top and then gauge adjusted on 10 (kg-m). Hammer was released to shatter the specimen at the middle of it. The number on the scaled part is presented impact strength of the specimens after dropping hammer. This test repeated 15 times.

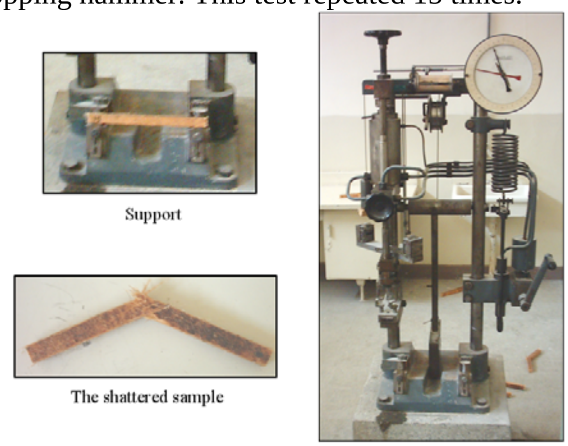

Fig.6. Impact strength test

3. RESULTS AND DISCUSSION

3.1. Moisture Content and Trunk Density

Moisture content and average density of trunk just after cutting were measured as 228.98% (d.b) and 1.16g/cm^3, respectively.

3.2. Flexural Strength

Results of Flexural strength from Table1 show that the averages of flexural strength and flexural modulus of palm trunk were 7.166 and 273.4MPa, respectively.

Table1. Results of flexural strength test of date palm trunk

Specimen	Displacement at Yield (mm)	Strain at Yield (mm/mm)	Load at Yield (KN)	Flexural Strength (MPa)	Modulus (MPa)
1	29.26	0.0344	0.2634	8.819	397.1
2	31.36	0.0363	0.2207	7.306	245.3
3	27.52	0.0331	0.2107	6.595	260.3
4	29.79	0.0354	0.2306	7.621	286.5
5	29.56	0.0354	0.2768	8.744	348.5
6	29.82	0.0356	0.1659	5.383	175.4
7	30.14	0.0352	0.1793	5.946	195.7
8	27.07	0.0319	0.2674	8.627	381.2
9	30.54	0.0366	0.2548	8.218	306.4
10	29.31	0.0336	0.1273	4.397	137.9
Mean	29.44	0.0348	0.2197	7.166	273.4
SD	1.29	0.0015	0.0494	1.54	87.4

Load-displacement diagram of flexural strength is shown in Fig. 7.

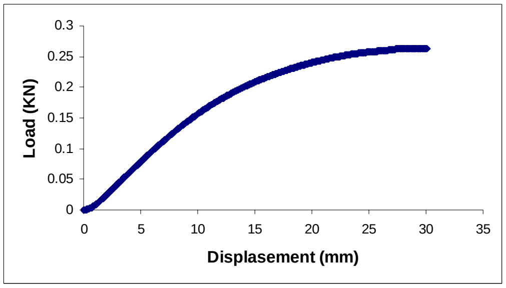

Fig.7. Load-displacement diagram of flexural strength test

3.3. Compressive Strength

Load-displacement diagram for compressive strength test parallel to trunk fibers is given in Fig. 8.

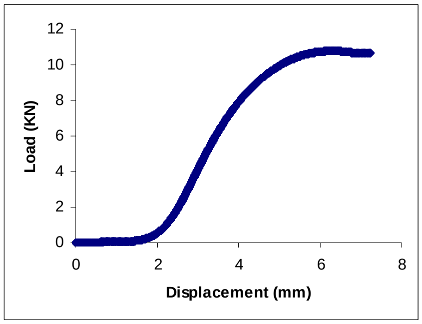

Fig.8. Load-displacement diagram for compressive strength test parallel to trunk fibers

Modulus and maximum strength were 281.3 and 4.458MPa in parallel compressive strength test according to Table2.

Table2. Results of compressive strength test parallel to trunk fibers

Specimen	Load at Maximum (kN)	Displacement at Maximum (mm)	Stress at Maximum (MPa)	Modulus (MPa)
1	10.78	4.309	4.229	265.1
2	14.53	3.7	5.655	429
3	10.2	3.247	4.014	271.4
4	10.95	5.428	4.351	244.1
5	10.24	6.179	4.04	196.8
Mean	11.34	4.573	4.458	281.3
SD	1.81	1.214	0.683	0.809

From Table 3, Strength at proportional limit (state what this means) was 1.124MPa in perpendicular compressive strength test. Load-displacement diagram for this experiment is given in Fig. 9. (Give the Table for compressive strength tests perpendicular to trunk fibers showing Load, Displacement, Max. Stress and Modulus. This will enable us assess Fig. 9 which should show the actual results obtained).

Table 3. Results of compressive strength test perpendicular to trunk fibers

Specimen	Load at Proportional limit (kN)	Stress at Proportional limit (MPa)
1	2.56	1.024
2	3.02	1.208
3	2.7	1.08
4	3.06	1.224
5	2.71	1.084
Mean	-	1.124
SD	-	0.087453

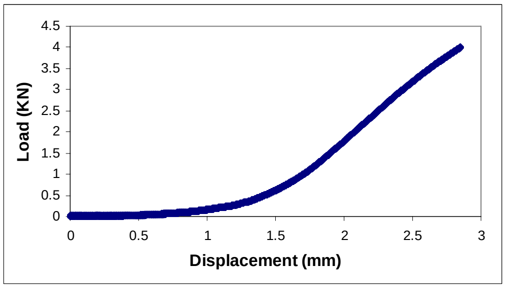

Fig.9. Load-displacement diagram for compressive strength test perpendicular to trunk fibers

Comparisons Figures 8 and 9 showed that the tangent of load-displacement diagram was horizontal when the parallel compressive strength tests were ended while the tangent of load-displacement diagram in perpendicular compressive strength test wasn't. Results showed that strength in perpendicular compressive strength test were lower than parallel compressive strength test.

3.4. Hardness Test

According to Table 4, the average of maximum load in hardness test was 0.7319 kN. The load- penetrate depth diagram is shown in Fig.10.

Table 4. Results of hardness strength test

Specimen	Load at Maximum (kN)
1	0.989
2	0.8448
3	0.6416
4	0.5554
5	0.6285
Mean	0.7319
SD	0.1795

(Show the penetration depths to enable us evaluate Fig. 10).

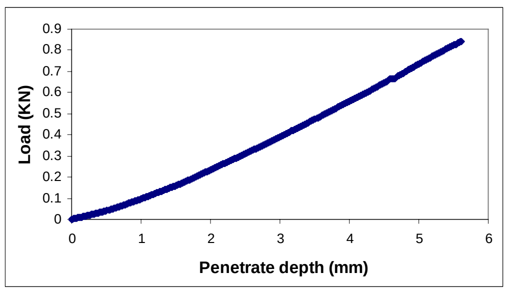

Fig.10. Load-displacement diagram for hardness test

3.5. Impact Test

Toughness was obtained as 1.61 kg.m, from Table 5 in impact test.

Table5. Results of impact strength test

Specimen	b (mm)	h(mm)	Energy (kg-m)	Standard Toughness (kg.m)
1	22.3	22.1	2	1.62
2	22.1	22.22	1.8	1.47
3	21.16	21.14	1.7	1.52
4	20.5	19.82	1.9	1.87
5	22.5	21.64	1.5	1.23
6	22	21.96	1.7	1.41
7	20.82	20.86	2.1	1.93
8	21.6	22.08	2	1.68
9	21.92	22.2	2	1.64
10	21.8	22.26	2.1	1.73
11	22.22	22.46	1.9	1.52

12	20.64	20.3	2	1.91
13	20.82	21.2	2	1.81
14	22.4	22.5	1.9	1.51
15	21.16	21	1.4	1.26
Average	-	-	-	1.61
SD	-	-	-	0.22

where b and h are accurate cross area dimensions of each specimen.

4. CONCLUSIONS

The moisture content and average density of trunk at wet condition (just after cutting) were measured as 228.98% (d.b) and 1.16g/cm^3, respectively. Results of Flexural strength showed that the average flexural strength and flexural modulus of trunk were 7.166 and 273.4 MPa, respectively. Modulus and stress at maximum (strength) were 281.3 and 4.458MPa in parallel compressive strength test, respectively. Stress at proportional limit (strength) was 1.124MPa in perpendicular compressive strength test. The load at maximum in hardness test was 0.7319kN and toughness was 1.61 kg.m in impact test, respectively. This information can be useful in designing palm service machines such as calculating the maximum weight of machine which the tree can suffer and also the maximum force to hold each grip on trunk grips in gripper date palm service machines.

(Most of the results obtained were just presented and not discussed. The authors need to show the importance of the measured parameters while comparing them with works of other researchers in the same or similar fields)

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