SOLID MECHANICS FOR ASH WOOD

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Abstract

Wood is an anisotropic material and, further, because of its natural origin the mechanical properties might significantly differ also between each sample which is tested. Ordinary methods for evalution of solid mechanic properties often destroy the tested specimen. It is therefore not common practice to evaluate more than one property, e. g. Young´s modulus for tension, at the same time and sample. Different tests also have different recommendations of how the test specimens should be designed in order to test the property of interest. When calculations shall be made by e. g. the Finite Element Method values for a number of properties must be included and when the resulting construction is after this examined it is not easy to know if discrepancies depend on unreliable input data. This paper therefore describes tension, compression and bending tests for one specific detail, a wood beam of ash wood. The applied forces are well under those where rupture occurs and hence the material is assumed to be intact under all testing procedures.

INTRODUCTION

Solid mechanics for wood is very difficult. This because of the natural origin of the material where the properties depend on the direction of the applied forces. Traditionally, three directions are studied, viz. longitudinal, radial and tangential, see Reference [1] page 293. When wooden structures are to be designed properties for all those different directions must be considered. However, different samples might also differ very much because of growth conditions etc. For building purposes this has been solved by setting a very low allowable stress for the wooden parts. Furniture, such as chairs, is not the subject for such hazardous consequenses if the construction breakes. Hence, higher allowable stresses could be used. In our earlier research we have made calculations by use of the so called Finite Element Method, FEM, for chairs. When the calculations are to be elaborated certain input data must be used, e. g. the Young´s modulus. For many construction materials this modulus is assumed to be the same for both tension and compression but for wood this might not always the case. The breaking strength in tension is about twice the strength during compression. When a beam is bent, e.g. during a three point bending experiment, the compressed side starts to breake for a lower strain than the tensed side. The so called neutral axis will therefore move and classic theory can no longer be used. The problem is to a part dealt with in Reference [1], page 361. In earlier work we have examined structures in the form of chairs. Input data in our FEM calculations have been both values found in literature and those found by own experiments with traditional testing equipment. The FEM calculations lead to internal forces in the structure and we have tried to validate these forces by strain gauge meters applied on the beam members in a chair. These experiments showed that large discrepancies sometimes occured between calculated and monitored values, see Figure 1.

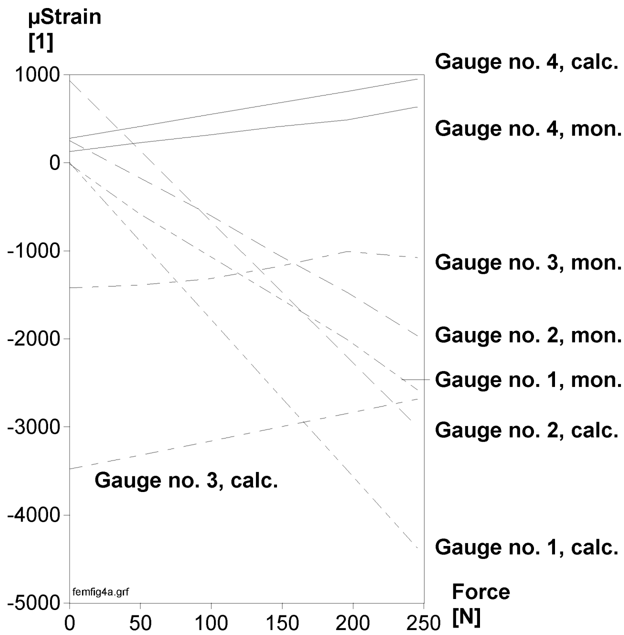

Figure 1: Monitored and calculated strain for different parts in a chair, see Reference [2].

For gauge No. 4 the discrepancies were relatively small while gauge No. 3 showed a much larger difference between monitored and calculated values. The question is now if these differences depends on the calculation process or if the material parameters are so inreliable that calculations must be used only for approximative purposes.

CASE STUDY

The problem with traditional testing of solid mechanical properties for wood is that there are large variations for different trees, diffrerent origin inside the same tree, different moisture contents, density and so on. Because of this many specimens of the same type must be examined and the average value is after this thought to reflect the conditions when e.g. FEM calculations are elaborated. It can therefore not be ascertained that the tested structure is built of wood with the same properties as shown by these average values. The situation is shown in Figure 2 and 3 which show some compression tests for ash wood, *Fraxinus excelsior.*

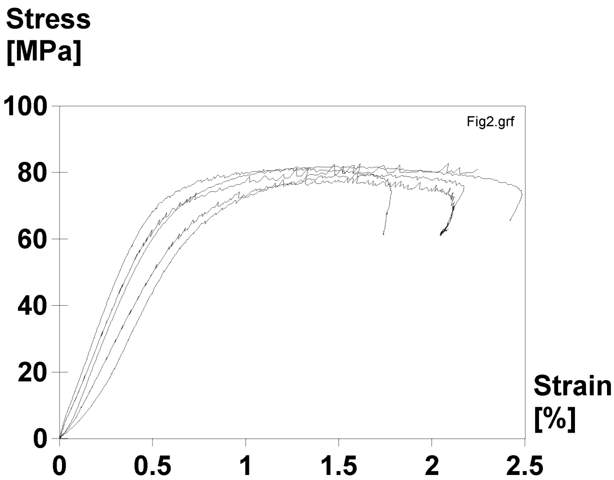

Figure 2: Compression tests for ash wood, *Fraxinus excelsior.*

In Figures 2 and 3 ten different tests are shown. The computerised monitoring system has calculated the Young´s modulii within the range of 10.1 to 17.9 GPa with an average of 13.3 GPa. The maximum compression strength varied between 76.7 to 83.4 MPa with an average of 80.5 MPa. The moisture content varied between 4.99 up to 6.95 % with an average of 6.25 %. In Reference [3] page 164 the same value is said to be only 51 MPa but then for air dry conditions which equals about 12 or 15 %, Reference [3] page 111. Compression strength for oven dry ash wood is shown in Reference [1] page 343 and the values varies from about 50 to 130 MPa depending on the specific gravity. There are no values for the Young´s modulus for ash under compression in [3] but in [1] page 295 a value of about 16 GPa is shown but then it is not mentioned if compression or tension is used, only that the load was applied in the longitudinal direction. The above discussion shows that there is a difficulty in choosing the right calculation data for a structure.

In order to study the situation for more constant conditions we have therefore manufactured a beam of ash wood with a length of 1 m and a cross sectional area of 0.04 × 0.04 m. Strain gauge meters have been applied on two sides with a distance of 0.2 m. The beam has after this been loaded with different weights both under tension and compression and further examined under bending. We have tried to use the most simple equipment for the tests in order to exclude all measuring errors. The load has been well under the level where rupture should occur and hence the internal structure of the ash wood material should not have been affected during the experiments. The result for tension is shown in Table 1.

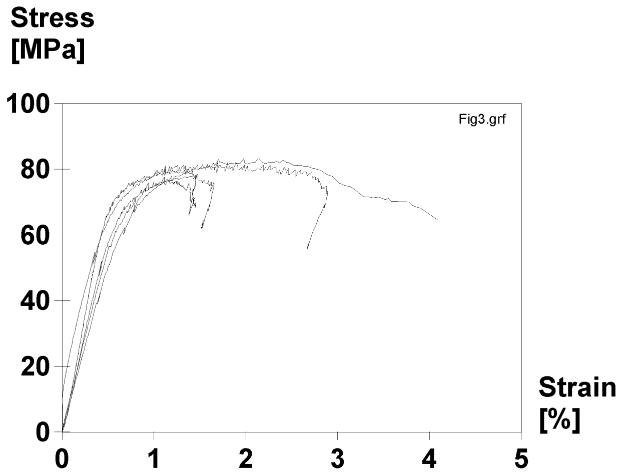

Figure 3: Compression tests for ash wood, *Fraxinus excelsior*.

The result in Table 1 is very discouraging. Even if a weight of 25 kg were lifted by the beam some of the strain gauge meters showed that compression actually occured. Meters no. 1 and 8 is located at the same level but on opposite sides of the beam and about 0.16 m from the hinge, see Figure 4.

For the next pair, no. 2 and 7 the first one showed tension and the other compression which is also valid for the pair no. 3 and 6. The meters applied about 0.16 m from the other hinge both showed tension but not exactely the same values, see no 4 and 5. When a high load, see the values for 170.62 kg, was applied almost all of the meters showed tension but differences are large between the metering devices. Meter no. 8 showed compression during the whole experiment and almost always to the same amount while meter no. 1 showed increasing values. This shows that only one side of the beam takes part

Strain gauge	Weight						
No.	26.57	51.75	76.89	102.06	127.17	145.51	170.62
1	-9	19	45	73	100	118	142
2	18	37	53	73	91	105	122
3	10	17	27	38	48	55	67
4	14	17	23	30	34	39	44
5	6	4	7	20	26	34	46
6	-15	-5	9	16	28	33	44
7	-12	-6	-5	9	16	18	23
8	-11	-13	-17	-15	-19	-16	-19

Table 1: Strain in μ-strain for varying weight in kg. Tension.

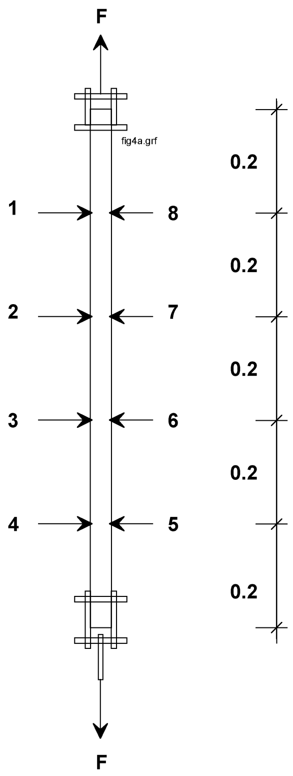

Figure 4: Experiment setup for tension of the ash wood rod.

of the work and further that a moment probably was introduced. The beam was therefore slightly bent during the experiment. The moment, however, declines for the lowest strain gauge meters i.e. no 4 and 5 and they show almost identical values, at least for the higher loads. In Figure 5 values for two opposite meters have been added and then divided by 2 in order to achieve an average.

The magnitudes are not equal but the slopes for the curves do not differ very much. By applying a straight line through the four curves in Figure 5, Young´s modulus for tension has been calculated to 13,100 MPa.

The result for compression is shown i Table 2.

During this experiment the load has been balanced on the ash rod while keeping it in a vertikal position. The data show, however, that tension occured, see the positive values, no matter the applied load. In Figure 6 average values are shown for opposite strain gauge meters and Young´s modulus for compression has been calculated to 12,300 MPa.

Unfortunately, the experiments above seems to be very unreliable. When the ash wood rod were used to lift weights up to 170 kg compression occurred at some points on the surface and when the rod were thought to be compressed some of the strain gauge meters showed tension. In spite of all these discrepancies the slope of the curves points to values for the Young´s modulus which coincide, at least to some extent, with those found in literature. If more reliable values are to be achieved much more emphasis should be laid upon the experimental setup and

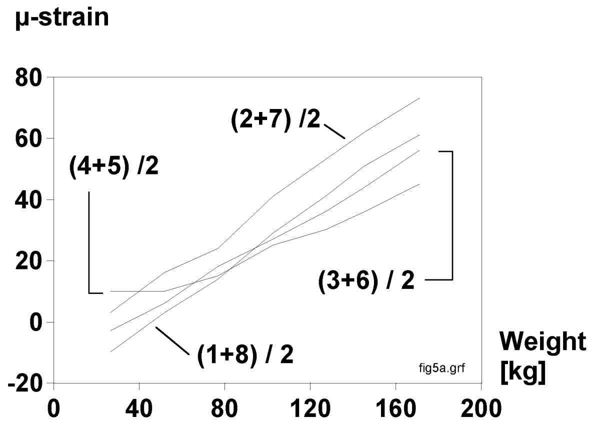

Figure 5: Average values for opposite strain gauge meters during tension.

Strain gauge No.	Weight 26.57	51.75	76.89	102.06	127.17	145.51	170.62
1	-13	-44	-75	-122	-117	-118	-110
2	-2	-13	-30	-89	-54	-45	-44
3	-4	-22	4	-25	19	28	26
4	2	-19	16	-50	49	54	22
5	-8	-18	-57	-28	-117	-136	-150
6	-17	-30	-50	-1	-77	-103	-133
7	-15	-21	-39	6	-51	-90	-107
8	-8	0	-8	17	-3	-37	-50

Table 2: Strain in μ-strain for varying weight in kg. Compression.

more strain gauge meters applied also on the two other sides. The experiments showed, however, that Young´s modulus for compression is somewhat lower than that for tension. The question is now if this could be detected when the rod is bent. The most simple bending experiment we found was the one of a loaded console beam firmly connected to a table, see Figure 7.

The strain for meter no. 1 and 8 , however, became so large that only three weights from our set could be tested, see Table 3.

For this experiment the strain gauge meters showed values that were more in coincidence with theory. On the upper side the rod was tensed while it was compressed on the lower side. The strain also increased for longer distances to the load. The fact is that all the meters, except for no. 2 and 7 showed that the strain was larger on the upper side than the corresponding values on the bottom. This must lead to the assumption that the compression Young´s module is larger than the tension ditto. This contradicts the result found for pure tension and compression where the opposite was valid. Interesting is also

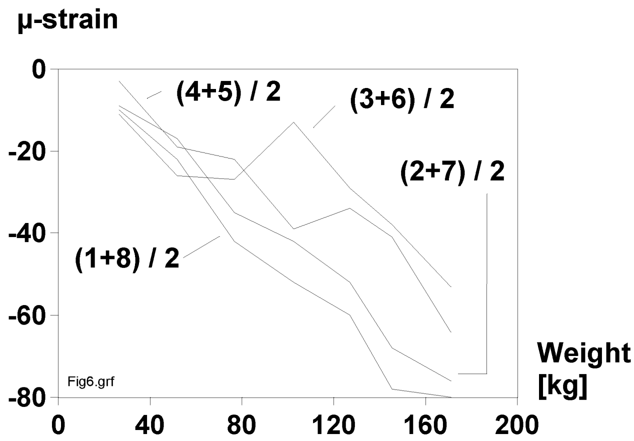

Figure 6: Average values for opposite strain gauge meters during compression.

Strain gauge	Weight [kg]		
Nr	26.57	51.75	61.75
1	1466	2960	3510
2	1020	1999	2385
3	608	1217	1437
4	289	570	680
5	-275	-541	-647
6	-573	-1104	-1329
7	-1028	-2008	-2413
8	-1323	-2610	-3134

Table 3: Strain in μ-strain for varying weight in kg. Bending.

to examine how the strain in Table 3 corresponds to theoretical values calculated by use of the Young´s modulii found above. The moment is calculated as F multiplied by the distance while the strain is calculated as:

$$\epsilon = \frac{M \times z}{E \times I}$$

where ϵ equals the strain, M the moment, z the distance from the neutral axis, E a Young´s modulus of 13,000 MPa and I the moment of inertia. The resulting strain values are shown in Table 4.

If Tables 3 and 4 are compared it is obvious that the rod had higher strain than expected only for gauge no. 1 while all other meters showed the opposite behavior. All monitored values seems, however, to follow straight lines, see Figure ??.

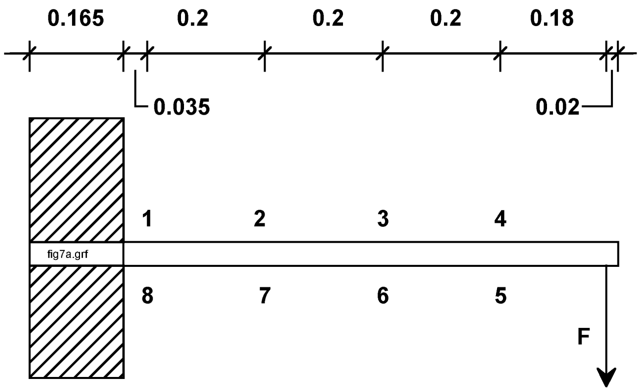

Figure 7: Bending experiment with a firmly fixed console.

Strain gauge	Weight [kg]		
Nr	26.57	51.75	61.75
1	1457	2837	3386
2	1081	2105	2512
3	705	1373	1638
4	329	641	765
5	-329	-641	-765
6	-705	-1373	-1638
7	-1081	-2105	-2512
8	-1457	-2837	-3386

Table 4: Calculated strain in μ-strain for varying weight in kg. Bending.

CONCLUSIONS

A rod of ash wood has been used for tension, compression and bending experiments. The measurements of Young's modulus showed slightly higher values for pure tension than for pure compression, 13,100 compared to 12,300 MPa. It seems, however, very difficult to predict the precise strain on specific spots on the rod if classic theory is used. The differences between the eight strain gauge meter values were large. This might depend on a poor experiment design but also on an inhomogeneous micro structure of the ash wood. The two modulii showed that the rod should show a higher strain on the compressed side when it was bent but the measurements contradicts this posture. For three of the comparable four points the strain gauge meters showed that the opposite occurred. When the rod was bent the meters showed a linear behavior for an increasing moment but the strain values did not perfectly follow classic theory when their magnitude were considered.

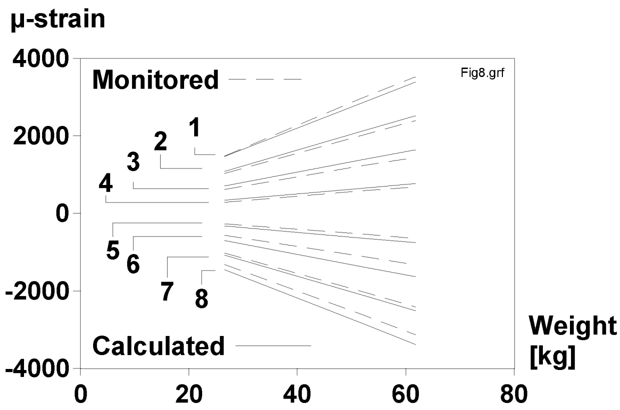

Figure 8: Monitored and calculated values for a bent console of ash wood.

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