EXPERIMENTAL INVESTIGATIONS ON THE BEHAVIOUR OF WOOD IN TRANSVERSE COMPRESSION

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ABSTRACT:

Experimental investigations were done to study the behaviour of wood in transverse compression. Three key variables were incorporated in the experiments to study their influence on the behaviour. These variables were the orthotropic ratio of the material, the geometry of loading and that of the specimen.

Deformation measurements were made at selected locations on test specimens by means of strain-gage based clip gages.

Results from the experimental measurements were compared to previous deformation predictions made by a finite element analysis(9). There is a very good agreement between measured values and those obtained from the finite element analysis thus verifying the validity of the finite element model.

The importance of the results relate to the development of more efficient designs in perpendicular to grain problems and in that segment of industry which relies on pressing wood in the transverse directions during manufacturing such as glulam, plywood and wood composite board.

1.0 INTRODUCTION

The behaviour of wood in transverse compression is very complex. Designs involving perpendicular to grain behaviour of wood are based on results obtained from such tests as the ASTM D 143 test method (1) which is considered very conservative. It is not known how the results of the standard test relate to inservice performance for various joint details since the actual stress distributions are difficult to relate to the standard test conditions. The test is only useful in contrasting different species (2) (3).

Studies on transverse compression in wood indicate that there are many factors which influence the behavior. Among these factors are geometry of loading, ring orientation, member size, anatomy of the wood, moisture content and rate of loading (4) (5) (6) (7) (8).

It should be recognized, however, that most of the important influencing factors can be taken into account by characterizing some fundamental properties of the problem in question. Key variables involve the relative modulus of elasticity perpendicular and in the direction of loading (orthotropic ratio), the geometry of the member and that of the loading (9). These three key variables were used as the basis for the experimental study.

2.0 EXPERIMENTAL INVESTIGATIONS

2.1 Specimen Selection and Preparations

Specimens were selected from three logs whose elastic properties had been determined from previous studies (10). The logs had been stored continuously in a conditioned room at a moisture content of about 12 percent.

Table 1 shows the species selected and their elastic properties. The specimens were selected so as to cover a wide range in the orthotropic ratio. This ratio ranged from 4.64 to 31.96.

Table 1: Species type and properties of samples selected

(From Bodig and Goodman (1972))

Species	Modulus of Elasticity (10^3 N/mm^2)			Shear Modulus (10^3N/mm^2)	Poisson's Ratio	Orthotropic Ratio: R = Ex/Ey
	E_L	E_R	E_T			
Engelmann Spruce (log No.2)	6.047	1.303	-	G_{LR}=0.958	ν_{LR}=0.494	4.64
Engelmann spruce (log No 30)	6.888	-	0.374	G_{LT}=0.625	ν_{LT}=0.338	18.40
Western hemlock (log No120)	10.335	-	0.323	G_{LT}=0.330	ν_{LT}=0.423	31.96

L,R,T = Longitudinal, radial and tangential directions

Fig. 1 shows the geometry and loading arrangement notations

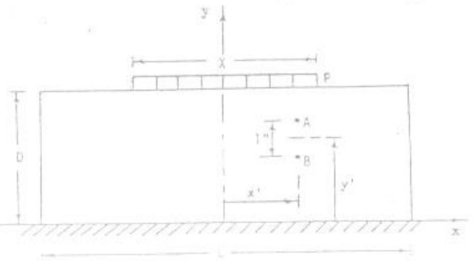


Fig.1: Geometry and Loading Notation

From each log three specimen sizes were cut as shown in Table 2. (See Fig. 1 for notation)

Table 2: Specimen sizes and Variations in Geometry of Loading

X/L	L/D	Specimen size (mm)	X (mm)
0.25	1.6	229x140(9"x5.5")	57.2 (2.25")
	2.0	229x114(9"x4.5")	57.2
	3.0	229x76 (9"x3")	57.2
0.5	1.6	229x140	114.3 (4.5")
	2.0	229x114	114.3
	3.0	229x76	114.3
1.0	1.6	229x140	229 (9")
	2.0	229x114	229
	3.0	229x76	229

2.2 Choice of Strain/Clip Gages and Calibration

Due to the small deformations expected within the elastic range electrical resistance strain gages were preferred over LVDT's. The problem of zero shift experienced in electrical resistance strain gages bonded straight on wood was avoided by the use of specially designed clip gages.

The calibration of the clip gages was done using an extensometer. To ensure the same deformation characteristics of the clip gage shoes during the test as during the calibration, the same species of wood and grain orientation were used in the calibration as for the test. (Fig.2)

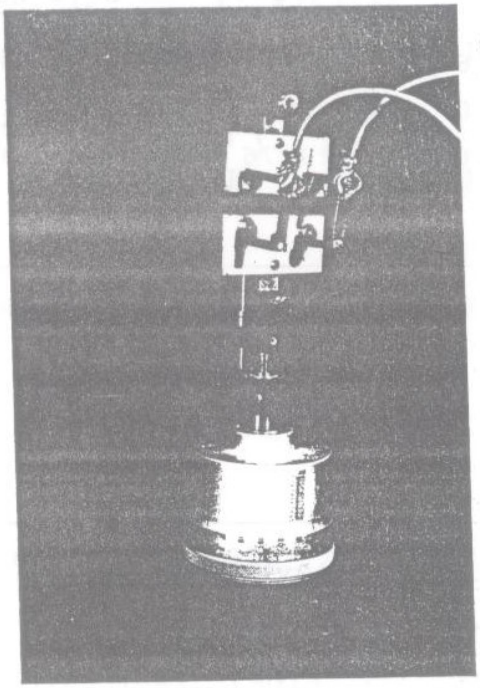
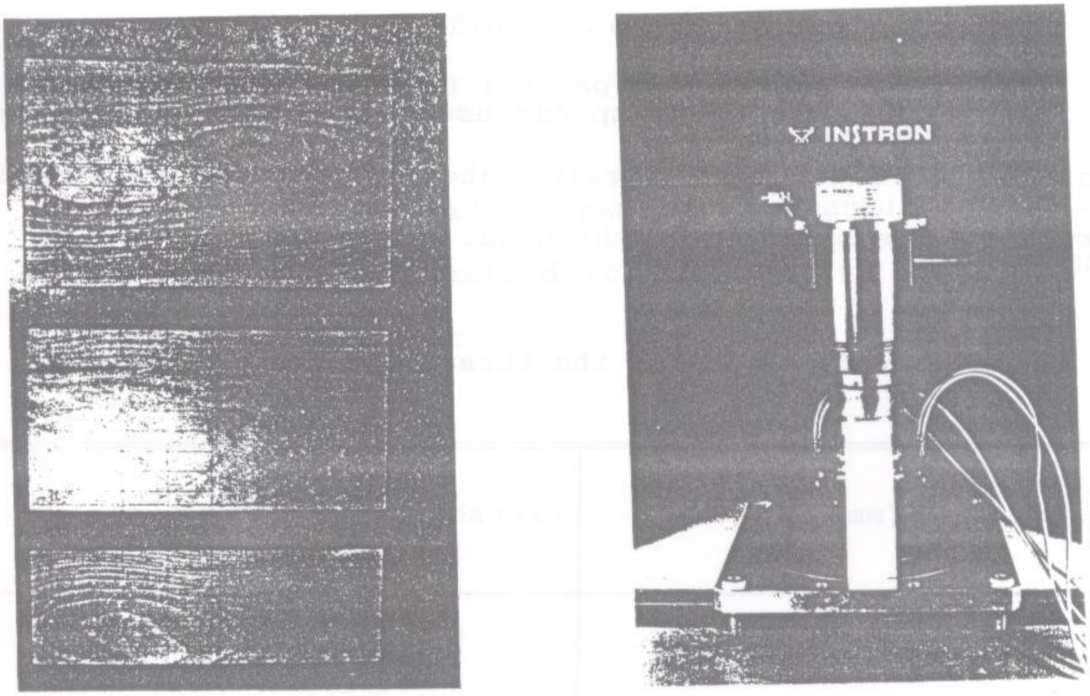


Fig. 2: Calibration of the Clip Gages by an Extensometer.

2.3 Testing Equipment and Test Arrangement

The loading was accomplished through an Instron testing machine model No.1137 with a 30,000 pound load cell. To ensure uniformity of loading on the specimen it was necessary to attach a spherical alignment loading head between the load cell and the loading plate. Fig 3(a) illustrates the location of the clip gage attachments on the three specimen sizes cut from each log. Measurements were made at designated points of interest: close to the boundary, at the line of symmetry and below the edges of the loading plate.



(a) (b)

Fig.3: (a)Location of clip gage attachments on three specimen sizes cut from each log.

(b)One of the clip gage arrangements during testing (side view).

Fig 3(b) illustrates a side view of one of the clip gage arrangements during testing.

During testing, the Instron testing machine was used to obtain a continuous record of the load-time curves for the specimen under test. These curves were related to corresponding continuous deformation curves obtained through the use of strip chart recorders. In order to produce the same strain rates, the cross head speed of the Instron machine was changed for different specimen depths.

Table 3 shows the cross head speeds used for the three specimen depths to ensure the same strain rates. These speeds were in proportion to the specimen depths used.

Table 3: Crosshead Speeds for the three specimen depths.

Specimen size (mm)	Crosshead Speed (in/min).
229 x 140 (9"x 5.5")	0.05
229 x 114 (9"x 4.5")	0.041
229 x 76 (9"x3")	0.027

3.0. EXPERIMENTAL RESULTS

Figure 4 shows the relative deformations at a location on the specimen with coordinates x = 0, y = 2" (50mm) (see Fig.1) as predicted by a finite element analysis (9) for the three species and for various geometric ratios L/D and loading ratios X/L.

The experimentally measured deformations for the three species at the same location are compared separately in Fig.5 to Fig. 7 to those predicted by the finite element analysis again for various geometric ratios L/D and loading ratios X/L.

Fig. 8 shows the measured deformations compared to those obtained by the finite element method for the species from log No. 2 at various height locations y.

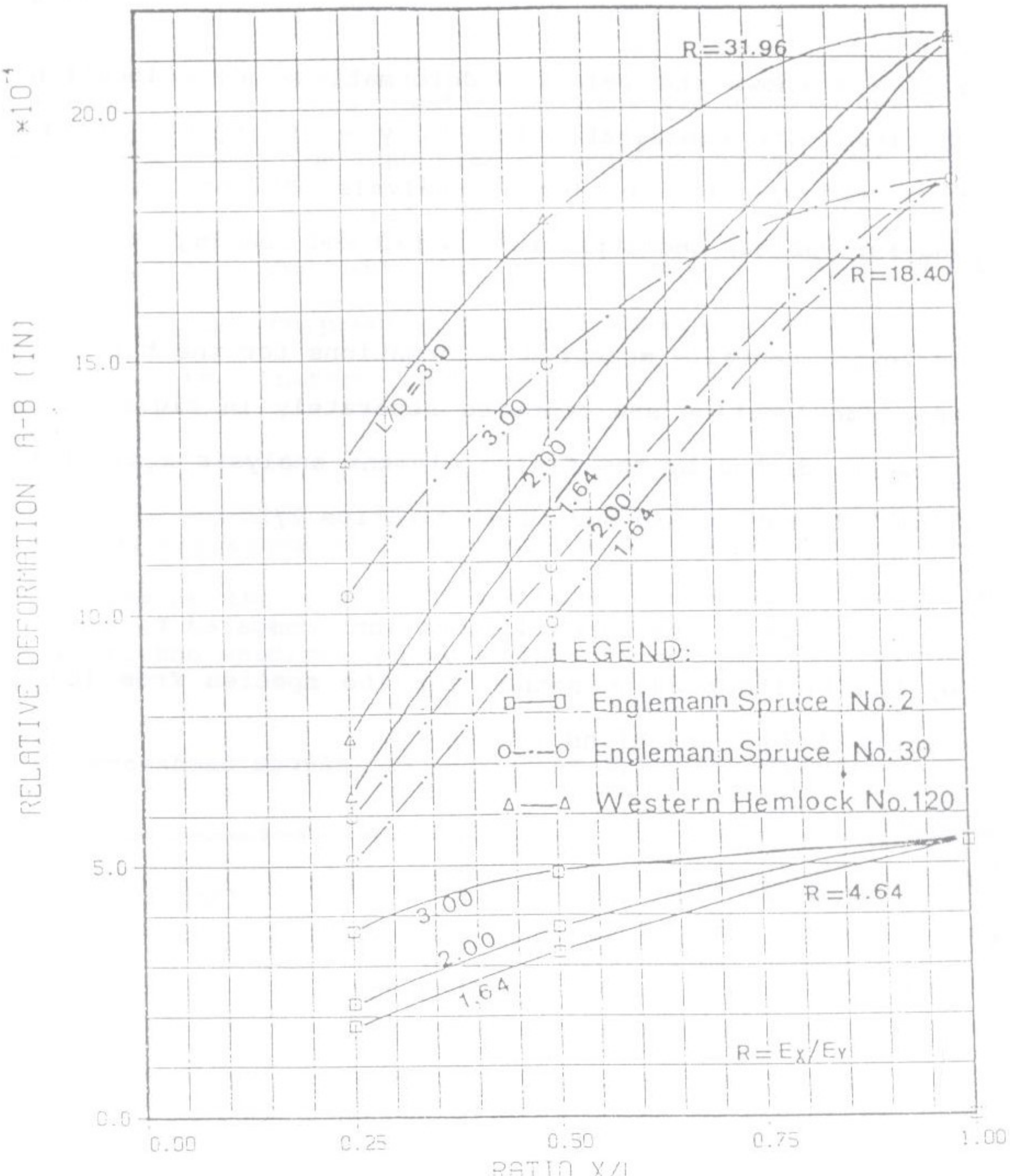


Fig.4: Relative deformations at x=0, y=2" by the finite element method

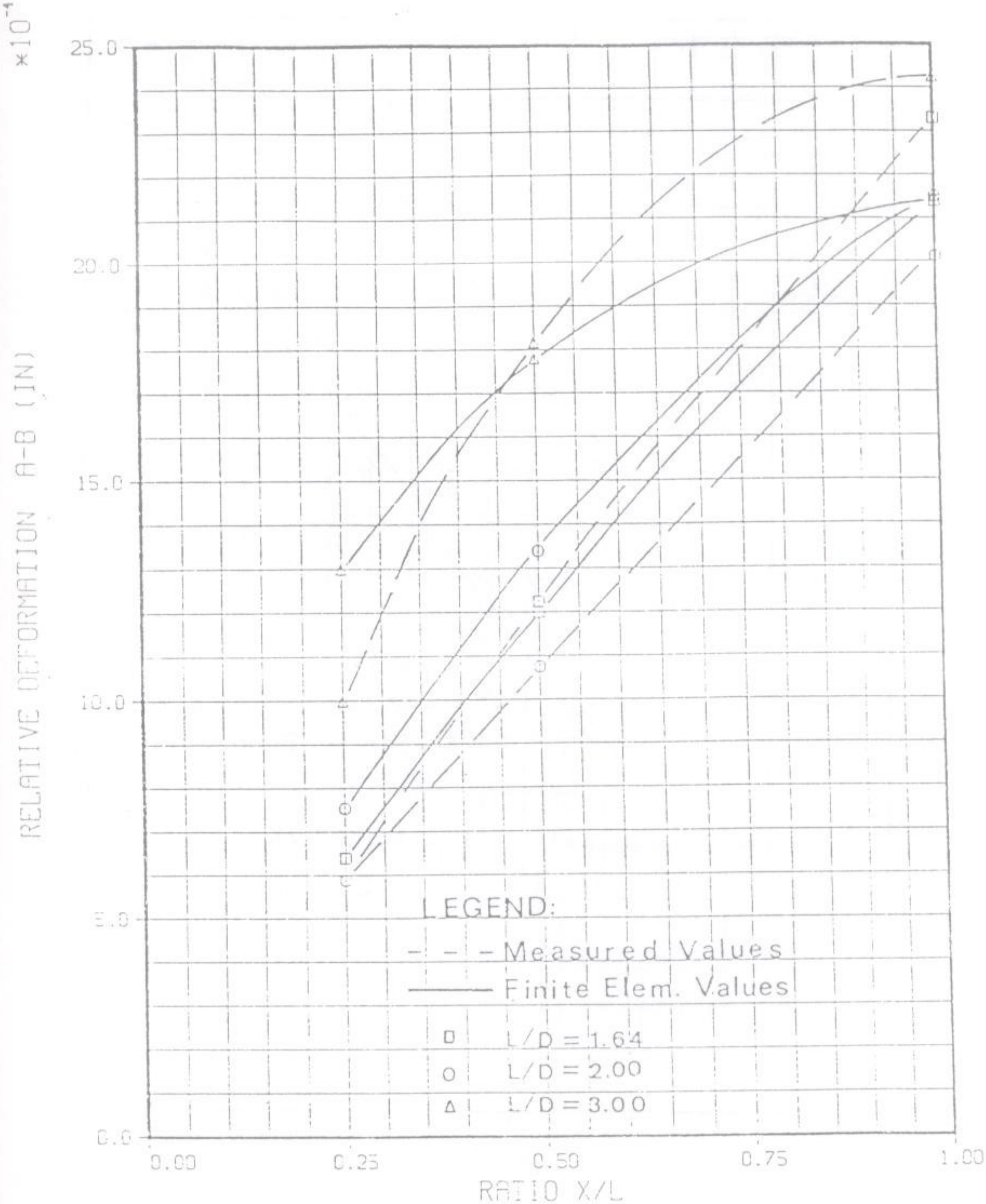


Fig. 5 : Comparison of relative deformations predicted by the finite element method and the experimental measurements (Western hemlock, log no.120)

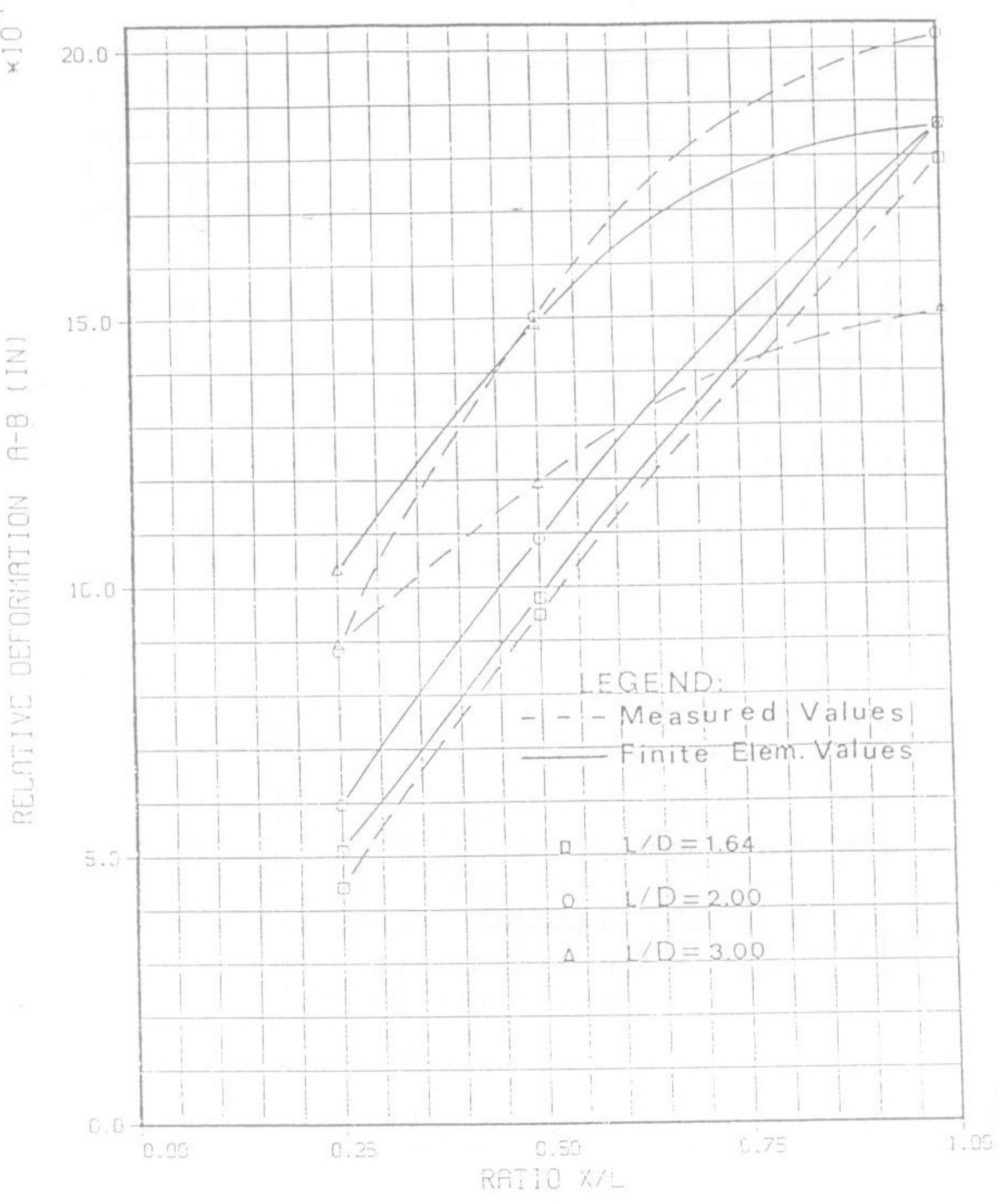


Fig.6: Comparison of relative deformations predicted by the finite element method and experimental measurements (Engelmann spruce, log no.30)

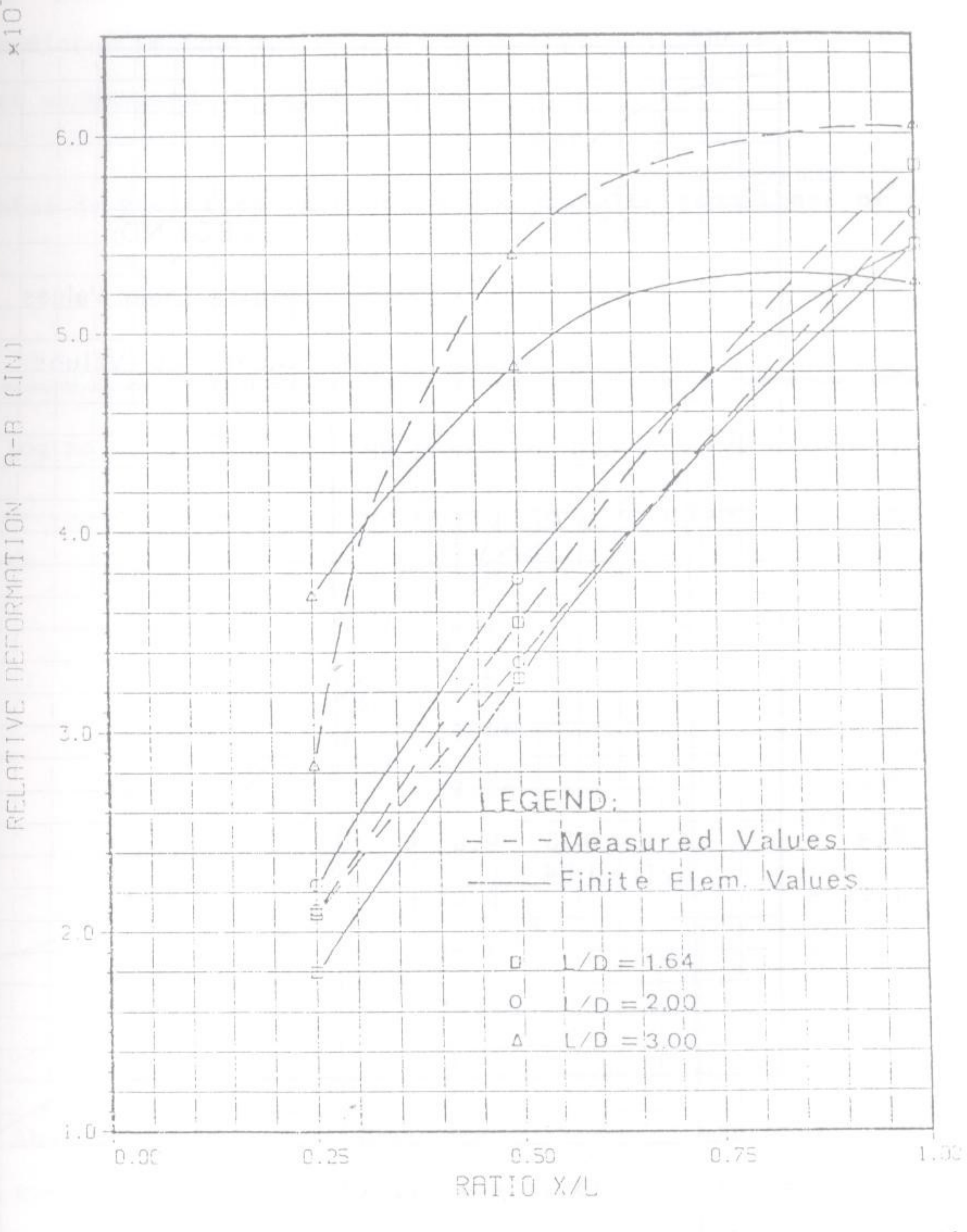


Fig.7: Comparison of relative deformations predicted by the finite element method and experimental measurements (Engelmann spruce log no.2)

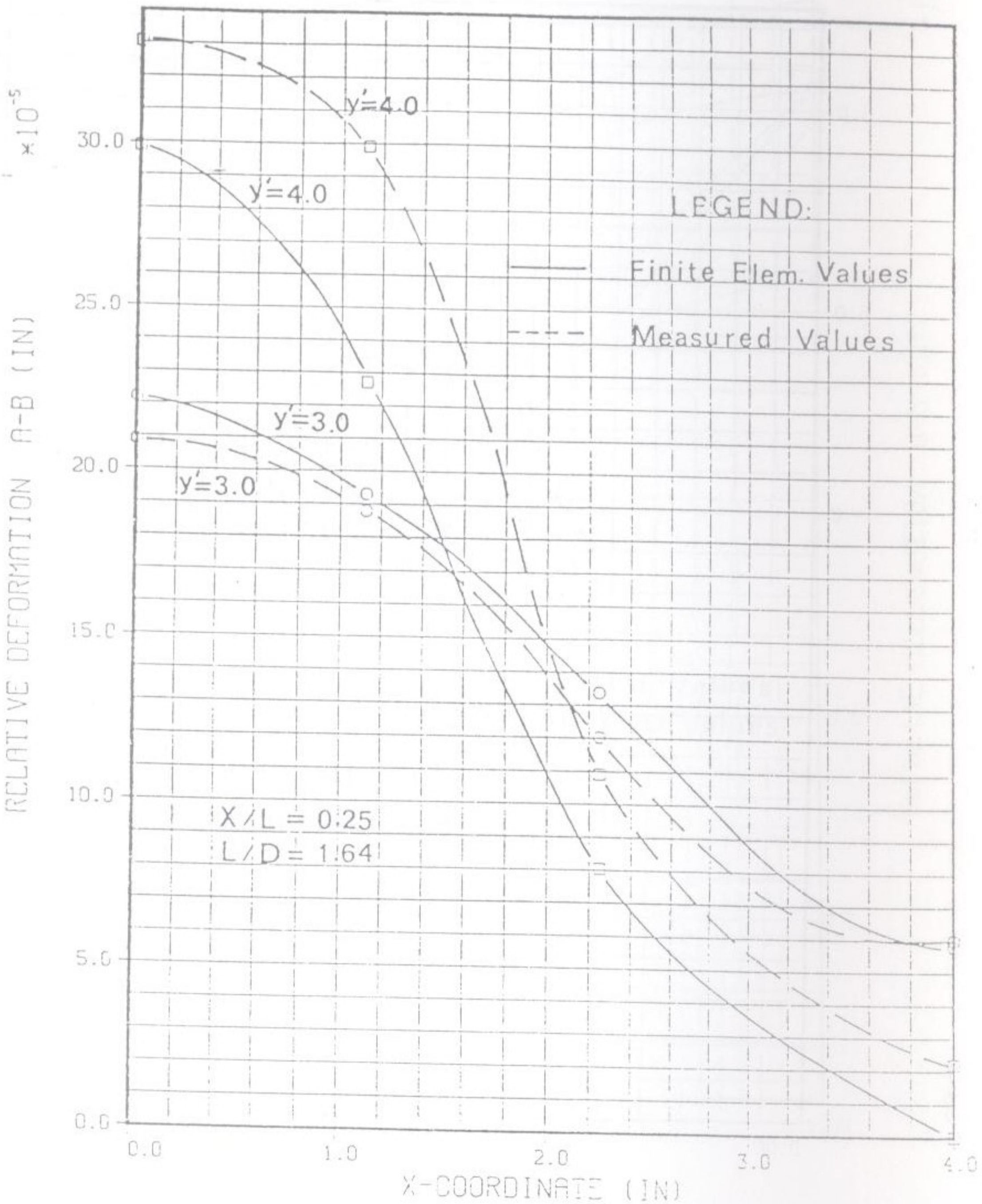


Fig. 8: Relative deformations for Engelmann spruce log no. 2 as functions of distance from the specimen center-line

The percentage deviation in experimental results from those predicted by the finite element analysis at the selected location are summarized in Table 4.

Table 4: Deviation in experimental results from those of finite element analysis (percent)

log no.2	log no.30	log no.120
+16.0	- 13.1	- 6.3
+ 8.4	- 3.2	- 2.0
+ 7.4	- 3.5	- 8.9
- 5.7	+ 47.9*	- 21.9
-11.1	+ 37.9*	- 19.7
+ 2.7	+ 8.9	- 6.5
-23.0	- 13.2	- 23.1
+11.5	- 19.8	+ 2.2
+15.0	- 18.4	+ 12.8
Absolute Average = 11.2%	Absolute Average = 11.4%	Absolute Average = 11.5%

* Values considered as outliers.

4.0 DISCUSSION OF RESULTS AND CONCLUSIONS

The difference in results between measured values and those obtained by a finite element analysis is on average about 10%. The author attributes this difference to errors in the experimental measurements rather than to inaccuracy of the finite element analysis.

A previous analysis by the author (9) using the finite element method showed that the maximum stress developed due to stress concentration can be obtained from the stress concentration factor as follows(See Fig. 1 for notation):

$$\text{Stress Conc. Factor} = 1.35 + 0{,}0993\log(E_y/E_x) \times 0{,}408\log(L/D) + 0{,}350\log(X/L) \quad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

(Correlation coefficient, $R = 0{,}958$ (adjusted for degrees of freedom))

The stress concentration factor is defined as the maximum stress developed within the material due to a unit imposed stress.

With the validity of the finite element analysis confirmed in this study, it is possible to predict, using equation (1) what maximum stresses (or deformations) are expected in compression perpendicular to grain problems if the three key variables i.e. orthotropic ratio (E_y/E_x), the geometry of loading (X/L) and that of the specimen (L/D) are known.

The loading situations covered in this study are for cases when the partial loading is symmetrically imposed on the member. More studies are necessary to cover situations in which the loading is at the end of the members. However with the proof of the validity of the finite element analysis here, such studies can easily be accomplished.

This study has addressed the elastic behaviour of wood only. Future research needs include the need to obtain information on the behaviour of wood beyond the elastic limit and strength.

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