AN INVESTIGATION INTO THE ENGINEERING PROPERTIES OF STRUCTURAL TIMBER IN HISTORIC BUILDINGS

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1. What is the problem and why is research required?

"Often, there is a perception that timber in older, derelict buildings is in poor condition and requires total replacement. In most cases, this is simply not the case"

(The Structural Engineer, 2006)

- Engineers involved with heritage projects often come across the problem of having to apply properties to historic timber in order to make an educated guess of its bending strength.
- The British Standard BS5268 requires the timber sub-species and the visual grade to be known before a strength classification and therefore values to use in design calculations for bending strength can be obtained.
- There is currently a lack of information available to engineers as to whether visually grading old timber is an appropriate way to obtain values for design, this can lead to unnecessary and often costly strengthening works.

Species identification

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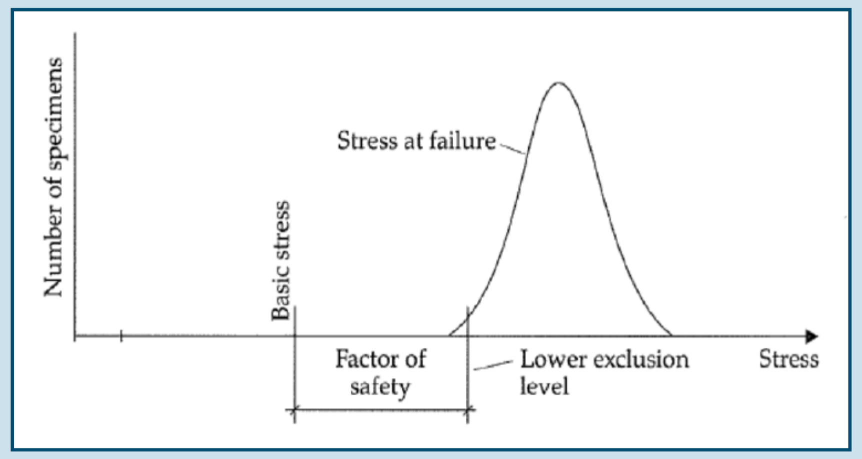
Visual grading

= Properties for Design

2. What have researchers found in the past?

- G.M.Lavers carried out thousands of three-point bending tests in accordance with BS373 on small clear specimens of many different timber species. Her results were collated and used to produce the basic bending stresses provided in BS5268.

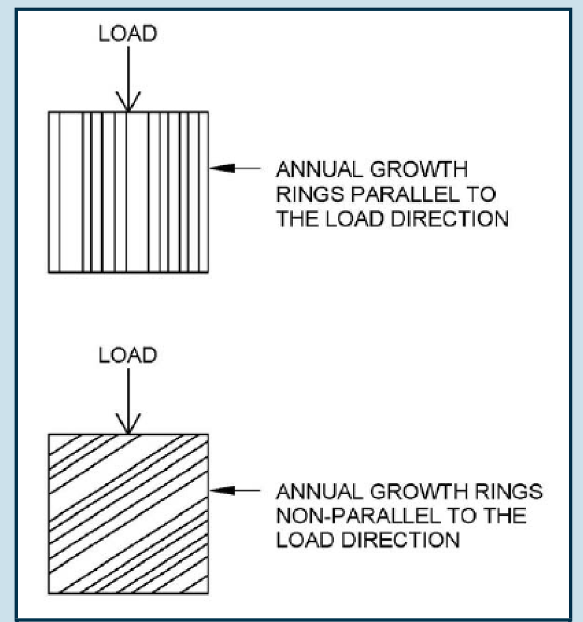


- R.Hoadley investigated how the species of a piece of softwood can be identified using relatively simple tools. He published guidelines on how this can be done even by people with limited knowledge of timber as a material.
- S.J.Record investigated possible failure modes of timber and categorised them into simple tension failure, cross-grain tension failure, splintering tension failure, brittle tension failure , compression failure and horizontal shear failure.

3. What was the testing procedure?

- A sample of old timber was obtained from a reclamation yard and its sub-species was identified using R.Hoadley's guidance.
- The sample was divided into 75 small clear specimens (20x20x300mm) and visually graded based on BS4978.
- The sub-species and visual grades allowed strength classifications to be distinguished using BS5268.
- Specimens were also grouped according to the direction of the load in relation to the orientation of the growth rings in section (note that this is different to orientation of slope of grain).
- The samples were put under a three-point bending test to BS373.
- Data was obtained to allow modulus of rupture values to be calculated for each specimen.
- The data was then used to produce graphical results to identify whether the results obtained were as would be expected based on the grade bending stress values given in BS5268.
- The way in which the specimens failed was noted and grouped into one of S.J.Record's possible failure mode categories.

All (75 specimens)	
C18 (26 specimens)	C24 (49 specimens)
Annual rings parallel to load (50 specimens)	Annual rings non-parallel to load (25 specimens)



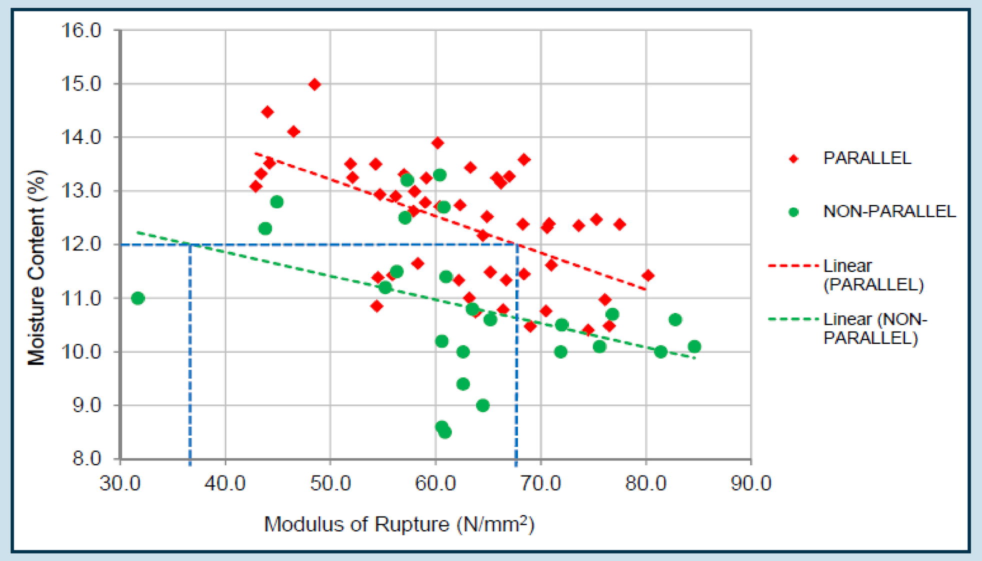
CROSS-SECTION THROUGH SPECIMEN

4. Which results were particularly interesting?

The timber was found to be Southern Yellow Pine and the results obtained from the testing varied greatly, however, a number of relationships between the timber properties were discovered, most of which were to be expected e.g. the higher the density, the higher the bending strength and the lower the moisture content, the higher the bending strength. There were however, some results which were not expected:

Orientation of annual growth rings

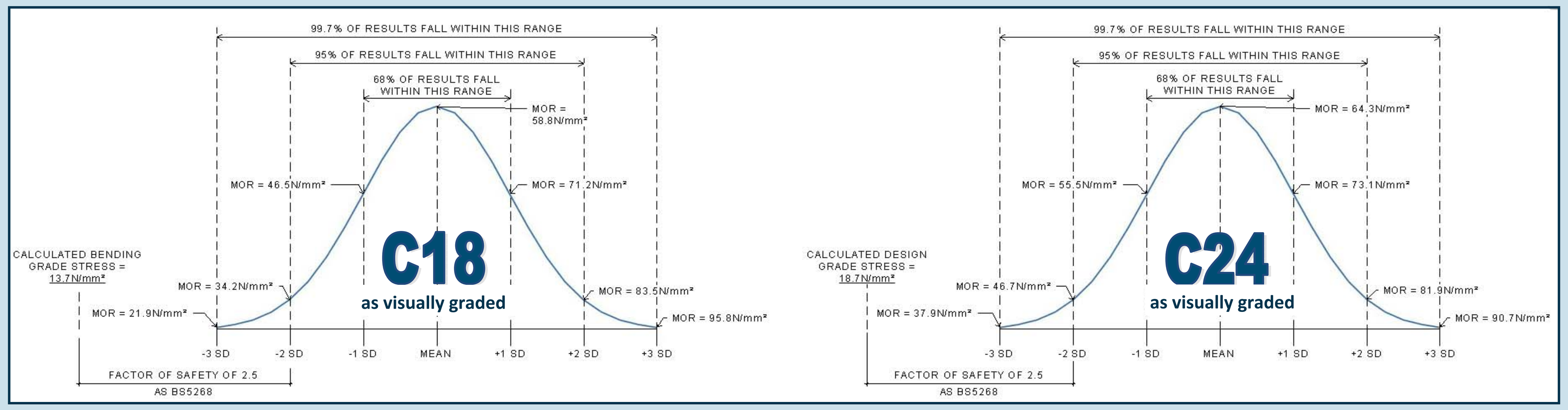
The tested modulus of rupture (bending strength) values were greater when the annual growth rings were orientated parallel to the load rather than non-parallel. The graph below shows how specimens of the same moisture content gave varying results depending on the orientation of growth rings.



A splintering tension failure

A brittle failure

Grade stress comparison

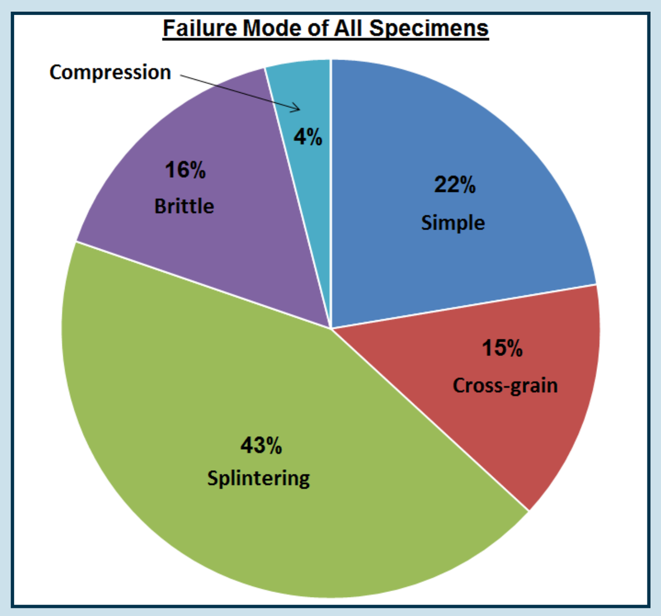


The same statistical analysis which was used on G.M.Lavers results to produce the grade stresses in BS5268 was used on the data obtained to compare whether the values apply to old timber. It was found that the timber sample produced much higher values than would be expected for both C18 and C24 timber. In fact, the grade stresses produced were closer to what would be expected for C40 timber.

	Experimentally determined bending grade stress (N/mm^2)	BS5268 bending grade stress (N/mm^2)
C18	13.7	5.8
C24	18.7	7.5

Failure Modes

The most common mode of failure was 'splintering tension', 43% of all of the specimens failed in this manner which, according to S.J.Record's research, implies that the specimens were relatively tough. On the other hand, 16% of the specimens failed in a 'brittle' manner implying that some of the specimens were not tough. When the results were grouped according to strength classification and orientation of annual growth rings, it was apparent that certain modes of failure were occurring more often than others, for example 'splintering tension' was the most common mode of failure for all groups except specimens with annual growth rings orientated non-parallel to the load where 'simple tension' was the most common failure.



5. How could the results affect engineers?

In summary, tested values of modulus of rupture (bending strength) were compared with values which would be obtained by an engineer if they were to visually grade the timber using BS4978 and apply grade values from BS5268. Also, the results were grouped according to whether the annual growth rings were orientated parallel or non-parallel to the load. The failure modes were also noted. The results which were found may cause an engineer to think about the following points:

- **The testing of the specimens led to significantly higher grade bending stresses than given in BS5268. This suggests that the grade bending stresses in BS5268 are too conservative.**
- **The testing of the specimens with annual growth rings orientated parallel to the load provided greater modulus of rupture (bending strength) values than those orientated non-parallel to the load. Is this a factor which could be considered in the appraisal of existing structures? The direction of load in relation to the slope of the grain is already taken in to account.**
- **16% of the specimens failed in a brittle manner and gave little warning before breaking. Engineers generally assume that timber elements would give plenty of warning before failure occurred (i.e. excessive deflection). This assumption was not proven by the testing carried out.**