Client Report :

Comparison of results for the current method of determining Modulus of Elasticity and the proposed "Global-E" method on Sitka spruce.

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Executive Summary

This project was a collaborative partnership between the Forestry Commission, the UK timber industry, the United Kingdom Timber Grading Committee (UKTGC) and BRE that resulted from a proposed change to the method of determining stiffness of timber. TC124 WG2 proposed a change to the current method of determining the modulus of elasticity (MoE) as set out in the testing standard for structural timber (EN408[1]). The proposed method was to determine the MoE by measuring the deflection used to calculate the MoE over the whole span. It was suspected that this “Global-E” method may give a different and possibly lower value for MoE by comparison to the current shear free method, measured over the centre third of the span. If this was the case there was significant implications for the home grown-timber industry.

This report sets out the comparative testing that was carried out on Sitka spruce to determine the test values for a selected population of timber when tested to determine the MoE for E-Cen (current method), E-true (former BS method) and the proposed Global-E method. The initial part of the testing to compare E-Cen values with Global-E was carried out to meet a deadline for voting on the proposal in January 2000. The E-true analysis was carried out after the results of the initial work were made public.

The work has shown that if E-Cen is taken as the independent variable then the calculated values for Global-E are higher for stiffness values between 6000 and 8000 N/mm^2 but significantly lower for stiffness values between 9000 and 13000 N/mm^2. This has implications for UK grown timber as it already has difficulty meeting the stiffness requirement of the higher strength classes and any further apparent reduction in stiffness will impact on the yield for these strength classes. If on the other hand the idea suggested by TC124-WG2 is adopted that Global–E is measured and converted to shear free (E-Cen) values for comparison with the values for stiffness in EN 338[2] (which remains as shear free values), the situation is different. Calculated values for E-Cen derived from the measured values for Global-E indicates that there is broad comparability between values. The calculated E-Cen values are generally slightly lower than the measured global–E values. Translated into strength classes the difference between the two sets of values is within the permitted $500N/mm^2$ rounding-up factor when determining acceptance to strength class criteria and so should have little impact upon on the current UK timber grading industry.

Contents

Introduction

A proposal from TC124 WG2 to change the manner of measuring the Modulus of Elasticity (MoE) had been made. The change entails measuring the MoE over the whole test span of the specimen rather than the central third, as is the current method. If accepted this would be the second change to the method of determining MoE within only a few years. The first change came about as the current European standards become normative and the UK adopted them. This change was from the then current BS 5820[3] test method known as E-true, a method used to allow close comparison with the bending arrangement in strength grading machines, to what has become known as the E-Cen method as described in EN408. This change resulted in lower MoE values being recorded for UK grown material.

The experience of the first change was that the yields for the higher strength classes were reduced, as the measured stiffness was lower than by the previous method. This resulted in caution over the new proposal, as it seemed likely that another reduction in measured stiffness may result and this could impinge upon the UK timber trade by again reducing yields. The driving imperative of the work was to have an indication of the likely implications of the change before voting on the proposal in January 2000. The second stage of the work was to derive conversion factors for the BRE database in case the proposal was adopted, as much of the information in the BRE data base remains as E-true MoE values and may need converting to Global-E values.

A consortium of the Forestry Commission, UKFPA and UKTGC formed with BRE to address the problem by testing populations of two species of timber and determining values for all three method of MoE for comparison purposes. The work reported here was carried out on Sitka spruce.

Description of the project

3 Comparison of E-Cen with Global -E methods for determining stiffness.

It was agreed that the timber industry under the auspices of the UKFPA would make the initial selection of timber, this was to save time as the deadline for achieving an indication of the likely out come was tight for the January meeting of TC124 WG2. Four sizes of timber were to be used, 47 x 100mm, 47 x 150mm, 47 x 175mm and 47 x 225mm. For each size 30 specimens were to be selected to reflect the range of growth characteristics common to the species. Due to the low number of pieces for each size the selection process had to be rigorous in identifying the range of characteristics that were necessary to make them meaningful and representative samples.

Testing was carried out on each of the 4 samples to determine E-true to BS5820, E-Cen to EN408 and Global-E to the draft test proposal for EN408. The tests were carried out consecutively on each sample such that all three tests were carried out before a measurable change in the moisture content occurred, thereby negating the need to make moisture content adjustments. For both E-Cen and E-true the deflection was measured at the neutral axis of the specimen but for Global-E the deflection measurement was taken off of the tension edge of the specimen, which was at variance to the stated method in the revised draft standard which indicated neutral axis. However, later changes indicated that the tension edge would be the preferred option.

Findings

The original intention was to convert E-Cen values that had already been established into Global-E values, as Global-E would be the standard reference measure of stiffness. However, TC124 WG2 decided to introduce Global MoE as the method of MoE determination EN408 while keeping the standard reference of stiffness as the shear free E-Cen for comparison to EN338. This was done before the TC124-1.1 document was circulated for public comment. Therefore, there was a need for conversion factors to be derived that would permit the translation.

The relationship between E-Cen and Global–E is displayed by the regression line in Figure 1 along with the R^2 value of 0.4673 equal to a correlation coefficient R of 0.684. The regression equation that describes the relationship is:

$$\boldsymbol{y = 0.4899x + 4167.2} \quad \text{(Equation 1)}$$

where:- *x* is the independent variable (E-Cen)

and *y* is the dependent variable (Global-E)

For Global-E values to be converted into E-Cen values then the resultant regression equation is different but the correlation co-efficient remains the same, Figure 2 shows the regression line for the relationship.

$$\boldsymbol{y = 0.9538x + 251.24} \quad \text{(Equation 2)}$$

where:- *x* is the independent variable (Global-E)

and *y* is the dependent variable (E-Cen)

For equation 1 the results were that the calculated Global-E values at the lower end of the stiffness spectrum were higher than the measured E-Cen values while at the upper end of the stiffness spectrum, E-Cen values were appreciably higher than the calculated Global-E values. This means that for C16 and C18 there was a slight increase in stiffness (around 10% for C16) but for the higher strength classes there was a significant and progressive loss of stiffness.

Equation 2 provides greater parity between Global-E and E-Cen values. However, the calculated E-Cen values were on the whole slightly lower than the measured Global-E values.

A comparison of the results for the regression equations 1 and 2 is shown in table1.

Table 1. Comparison of results for the regression equations 1 and 2.

Regression equation $y = 0.4899x + 4167.2$ x = E-Cen independent variable, y = Global-E dependent variable								
E-Cen Value	5000* *(5800)***	6000 *(6960)*	7000 *(8120)*	8000 *(9280)*	9000 *(10440)*	10000 *(11600)*	11000 *(12760)*	12000 *(13920)*
Global-E value	6617 *(7676)*	7107 *(8244)*	7596 *(8811)*	8086 *(9380)*	8576 *(9948)*	9066 *(10517)*	9556 *(11085)*	10046 *(11653)*
Regression equation $y = 0.9538x + 251.24$ y = Global-E independent variable, y = E-Cen dependent variable								
Global-E Value	5000* *(5800)***	6000 *(6960)*	7000 *(8120)*	8000 *(9280)*	9000 *(10440)*	10000 *(11600)*	11000 *(12760)*	12000 *(13920)*
E-Cen Values	5020 *(5823)*	5974 *(6930)*	6928 *(8036)*	7882 *(9143)*	8835 *(10249)*	9789 *(11355)*	10743 *(12462)*	11697 *(13568)*

*= Value at test moisture content (20%),

** = Value adjusted to 12% moisture content.

Like the comparison of E-Cen with Global-E it was originally conceived that E-true values would need to be converted into Global-E values but this now seems unlikely. Because if E-Cen remains the standard measure of stiffness then the conversion between Global-E and E-True will not be needed. However, the conversion factors have been derived, as above, in case the situation changes.

The regression line for Global-E against E-True is shown in Figure 3 and the regression line for E-True against Global-E is shown in Figure 4. The correlation co-efficient for the derived relationship between E-True and Global-E is R = 0.5518 (R^2 = 0.3045). This is lower than for the relationship between E-Cen and Global-E (R = 0.684 for R^2 = 0.4673). The regression equations that describe the relationships between E-True and Global-E are as follows:

$$\boldsymbol{y = 0.4793x + 4146.8} \text{ (Equation 3)}$$

Where:- x is the independent variable (E-True)

and y is the dependent variable (Global-E)

$$\boldsymbol{y = 0.6352x + 2891.6} \text{ (Equation 4)}$$

Where:- x is the independent variable (Global-E) and *y* is the dependent variable (E-True)

Table 2 shows the comparison of the results using regression equations 3 and 4 derived from the relationship between E-true and Global–E.

Table 2. Comparison of results for regression equations 3 and 4.

Regression equation *y* = 0.4793*x* + 4146.8 *x* = E-True the independent variable, *y* = Global-E the dependent variable							
E-True Value	6000* *(6960)***	7000 *(8120)*	8000 *(9280)*	9000 *(10440)*	10000 *(11600)*	11000 *(12760)*	12000 *(13920)*
Global-E Value	7023 *(8147)*	7502 *(8702)*	7981 *(8258)*	8460 *(9814)*	8940 *(10370)*	9419 *(10926)*	9898 *(11482)*
Regression equation *y* = 0.6352*x* + 2891.6 *X* = Global-E the independent variable, *y* = E–True the dependent variable							
Global-E Value	6000* *(6960)***	7000 *(8120)*	8000 *(9280)*	9000 *(10440)*	10000 *(11600)*	11000 *(12760)*	12000 *(13920)*
E-True Value	6703 *(7775)*	7338 *(8512)*	7983 *(9261)*	8608 *(9985)*	9244 *(10723)*	9879 *(11460)*	10514 *(12196)*

* = Values at test moisture content (20%),

** = Values adjusted to 12% moisture content.

Although not strictly part of this project a comparison of E-Cen and Global-E data accumulated as part of the Dynagrade project is set out in Annex 2. This was a much larger sample population than used in this study.

Conclusion and recommendations

1. Regression equations have been derived that allow for the calculation of Global-E values from E-Cen values (equation 1) and for E-Cen values from Global-E values (equation 2).

2. Regression equations have been derived that allow for the calculation of Global-E values from E-True values (equation 3) and for E-True values from Global-E values (equation 4).

3. Conversion of E-Cen values into Global-E values will result in benefits for lower stiffness Sitka Spruce grown in the UK in that it will lift the values for stiffness well above the threshold values for strength classes C16 and 18. However, this would have a detrimental on the higher stiffness material in that it will reduce the yields for the higher strength classes, where UK grown material already has difficulty meeting the stiffness requirements for the strength classes.

4. Conversion of Global-E values into E-Cen values show slightly lower stiffness values than those derived from measured Global–E. However, there is greater comparability when data are converted into strength classes and the values rounded to the nearest $500N/mm^2$.

5. Similar trends can be seen to the above when considering the relationship between Global-E and E-True. Having derived the relationships between E-true / Global-E and Global-E / E-true the values in the BRE data bank can be adjusted when required.

6. If the proposal to change the method of measuring the modulus of elasticity to Global-E is adopted by TC124-1.1, then conversion factors are available at BRE to convert existing data to the new required format. This assumes associated changes would be made to EN338 to express the stiffness in terms of Global-E. If this happens it would benefit the UK timber industry, as the majority of its product shows predominantly low stiffness, which would increase in apparent stiffness. However, timber at the upper stiffness end of the spectrum range would be penalised which may make UK timber less competitive for firms trying to enter new markets not traditionally supplied by home produced timber.

7. If the method of measurement in EN408 is changed to Global-E, for ease of measurement, but the stiffness values in EN338 remain in terms of shear free MoE, as determined by E-Cen then, the measured Global-E values could be converted into E-Cen values for comparison with EN338. This would maintain some comparability with the values as currently used. However, this proposal introduces yet another conversion factor into an industry already burdened with modification factors and will result in the end user specifying timber with values for stiffness not being directly measured as they are expressed in EN338 or BS5268; Part 2.

References

1). British Standards Institute 1995, Timber structures – Structural timber and glue laminated timber – Determination of some physical and mechanical properties. BS EN 408:1995.

2). British Standards Institute1995, Structural timber – Strength classes. BS EN 338: 1995.

3). British Standards Institute1979, Determination of certain physical and mechanical properties of timber in structural sizes. BS5820: 1979.

4). CEN 1998, Timber structures – Structural timber and glue laminated timber – Determination of some physical and mechanical properties. Draft revision document EN408 CEN / TC124 / WG2 N292 –March 1998.

Annexes 1 and 2.

ANNEX 1

This annex contains: -

Annex 2

This annex contains: -

Comparison of E-Cen and Global-E when measured as part of the Dynagrade project**.**

Figure A1; Global-E v E-Cen

Figure A2; E-Cen v Global-E

ANNEX 2

COMPARISON OF E-CEN AND GLOBAL-E WHEN MEASURED AS PART OF THE DYNAGRADE PROJECT.

Introduction

This annex is included for information and sets out the results from the measurement of MoE during the Dynagrade project. Global-E measurements were taken in parallel with E-Cen measurements in response to a request made and funded by Sven Ohlssen of Dynalyse AB. 415 specimens comprising 3 sizes (38mm x 100mm, 47mm x 100mm and 47mm x 175mm) were used for the comparison. The tests were carried out in sequentially and so the moisture content remained constant.

Results

From the analysis of results two regression equations were obtained, the first with E-Cen as the independent variable and the second with Global-E as the independent variable.

Figure A1 shows the results of Global-E against E-Cen and the resultant regression equation was:

$$\boldsymbol{y = 0.6036x + 3386.6} \quad \text{(Equation A1)}$$

where:- *x* is the dependent variable (E-Cen)

and *y* is the independent variable (Global-E)

Figure A2 shows the results of E-Cen against Global-E and the resultant regression equation was:

$$\boldsymbol{y = 1.0483x - 583.09} \quad \text{(Equation A2)}$$

where:- *x* is the dependent variable (Global-E)

and *y* is the independent variable (E-Cen)

For both cases the R^2 value was 0.6327 which relates to a correlation co-efficient of 0.7954.

Table A1. Comparison of results for the regression equations of Global-E against E-Cen and for E-Cen regressed against Global-E.

Regression equation *y* = 0.6036x + 3386.6 *x* = E-Cen independent variable, *y* = Global-E dependent variable.										
E-Cen value	4000* *(4480)***	5000 *(5600)*	6000 *(6720)*	7000 *(7840)*	8000 *(8960)*	9000 *(10080)*	10000 *(11200)*	11000 *(12320)*	12000 *(13440)*	13000 *(14560)*
Global-E value	5810 *(6507)*	6404 *(7172)*	7008 *(7849)*	7612 *(8525)*	8375 *(9380)*	8819 *(9877)*	9423 *(10554)*	10026 *(11229)*	10630 *(11906)*	11233 *(12581)*
Regression equation *y* =1.0483*x* – 583.09 *X* = E-Gross independent variable, *y* = E-Cen dependent variable.										
Global-E value	4000* *(4480)***	5000 *(5600)*	6000 *(6720)*	7000 *(7840)*	8000 *(8960)*	9000 *(10080)*	10000 *(11200)*	11000 *(12320)*	12000 *(13440)*	13000 *(14560)*
E-Cen value	3610 *(4043)*	4658 *(5217)*	5707 *(6392)*	6755 *(7566)*	7803 *(8739)*	8852 *(9914)*	9900 *(11088)*	10948 *(12262)*	11996 *(13435)*	N/A

4000* = Value at test moisture content (18%)

*(4480)*** = *Value* adjusted to 12% moisture content.

Conclusion

It can be seen from a comparison of results between those in Table 1 of the main report and those of Table A1 of the annex that the calculated values for both Global-E and E-Cen are similar. This is encouraging as to some extent it validates the results of the main study as the two sets of testing were carried independently, separated by time, of differing sample population size and the test material was drawn from different geographical locations.

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14 Comparison of E-Cen with Global -E methods for determining stiffness.