Understanding the composite characteristics of stressed-skin panels

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Summary

The composite properties of stressed-skin panel (SSP) systems are characterised by the interaction – composite action – and the portion of the sheathing acting with the joists – the tributary width. A discussion on the tributary width forms the focus of this paper. An analysis, which has been conducted considering the pattern of the strain distribution in the sheathing(s), is presented. It uses laboratory data of a major research project conducted at the University of Technology, Sydney, between 2002 and 2007 (Gerber 2007). This analysis indicates that under strict conditions, in particular structurally glued interlayers, a large portion of the sheathing contributes to the structural behaviour of SSP structures. A better use of the mechanical properties of the panels is also achieved. This paper also presents an analysis on the effects of discontinuities in the sheathing. It has been identified that such event causes a significant reduction of the sheathing contribution.

1. Introduction

In stressed-skin panel (SSP) structures, the sheathings are attached to the joists with the help of a structural adhesive. Thus, it is anticipated that portions of the sheathing(s) act compositely with the joists. As a result, longer span and/or shallower joist floors can be achieved (Onysko 1970), thus providing economic and architecturally favourable floor constructions.

The contribution of the sheathing to the structural performance of the floor is characterised by the composite action – interaction between the members – and the level of the sheathing contribution – tributary width, also called shear lag. They are respectively assessed with the strain distribution through the depth of the SSP section – vertical axis – and with the strain distribution in the sheathing – orthogonal direction to the deck span (Fig. 1). Fig. 1 also shows that these strain distributions should concord. Thus, the contribution of the sheathing is maximised by a high/full degree of composite action.

This paper focuses on the magnitude of the sheathing contribution and presents an empirical investigation of this aspect.

2. Literature review and background

Estimating the tributary width accurately is a fundamental aspect of a safe design of SSP structures. The tributary width can be difficult to approximate. It is not uniform along (Amana & Booth 1967; Vanderbilt et al. 1974) and across (Raadschelders & Blass 1995) the span because of stress transfer and shear deformation respectively. It is anticipated that peaks of stress occur where the panel is attached to the joists and throughs of stress are located in the portion of panel between the joists.

Quantifying the tributary width depends on the material properties of and the stress distribution in the panels. Because of the non-linear distribution, estimating the tributary width may prove complex (Amana & Booth 1967). In addition, it relies on material data, which are not always available, even in specialised literature.

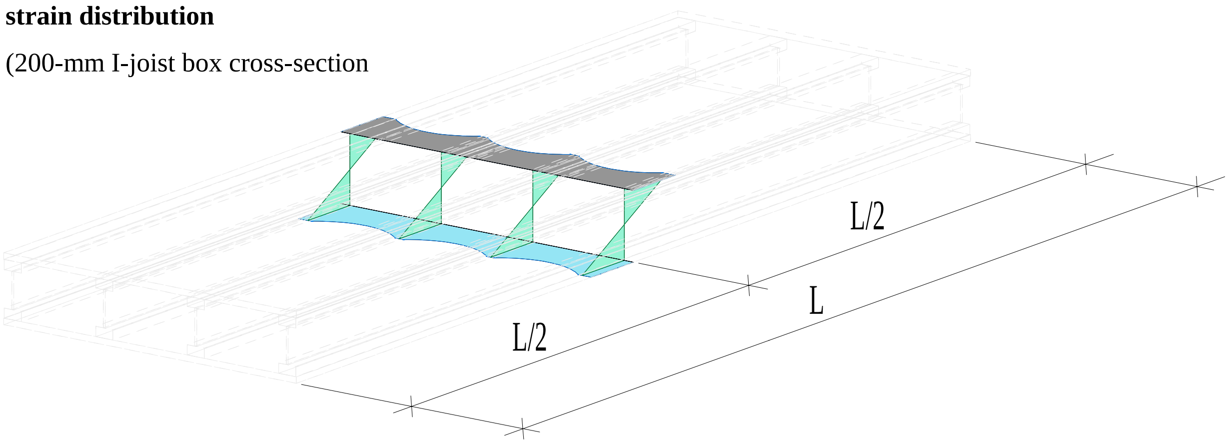

Fig. 1: Stress distribution in an SSP structure.

In the 1960s, Möhler, Abdel-Sayed and Ehlbeck (1963) carried out works on the tributary width of plywood sheathing and derived a geometric function, which accounts for the elastic orthotropic properties of the sheathing and the geometric dimensions of the floor. The buckling propensity of the compression flange is also considered together with the shear deformation in the panel.

For design convenience, however, an "idealised" tributary width is produced by equating the stress under the geometric curve of the non-linear distribution and a fictive uniform rectangular distribution (Fig. 2). Therefore, the panels take equal amounts of stress and the real and idealised T- or I-beams have similar ultimate and service performances (Amana & Booth 1967).

Different codes around the world have adopted this idealisation and provide directives for approximating the tributary width. A comprehensive analysis of the procedures found in these codes and other handbooks is presented elsewhere (Gerber 2007).

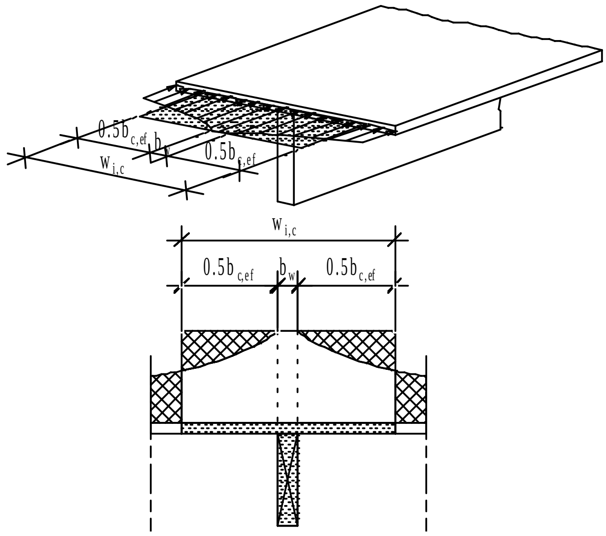

Fig. 2: Tributary width of the sheathing.

3. Approach for the empirical assessment of the tributary width

The empirical assessment aims to identify the contribution of the sheathing using an empirical approach – measurements of series of strain gauges (Fig. 3) – and to understand the effects of discontinuities[1)] or gaps in the sheathing – "damaged" state – complete the scope of this discussion.

This qualitative analysis corresponds to an assessment of the pattern of the orthogonal strain profile/distribution in the sheathing(s). Conformingly to the assumption that flexural action – four-point bending (Fig. 4) – generates normal stresses in the sheathing (Ozelton & Baird 2002), the full contribution of the sheathing is characterised by a uniformed distribution of the strain. Very small deviations from such distribution may, however, be caused by the occurrence of shear deformations (Raadschelders & Blass 1995). Strain intensity with some minimal variations can therefore be accepted as uniform and is hereafter qualified as "distinct" pattern.

[1)] The sheathing is discontinued by inflicting a cut in the maximum bending moment zone – 150mm from the mid-span.

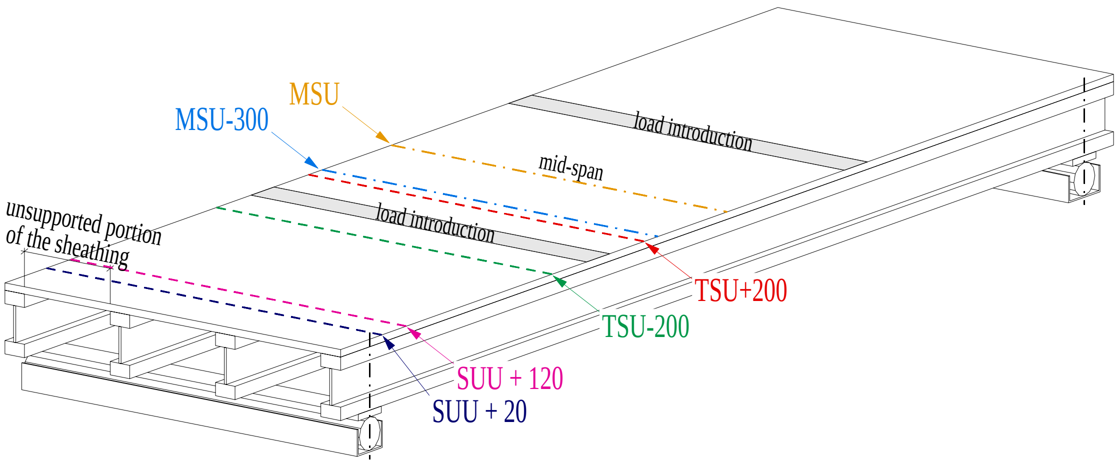

Fig. 3: Arrangement of the strain gauges series on the specimen's sheathing(s).

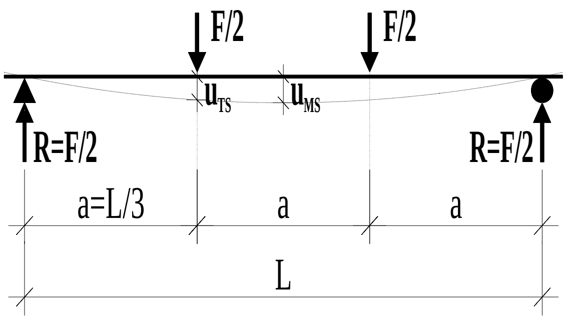

Fig. 4: Four-point bending test principle.

In the sheathing areas about the supports and discontinuities, the pattern of the strain profiles is anticipated to be disturbed, indicating some decrease of the structural contribution of the sheathing. Foschi (1969) and Ozelton and Baird (2002) suggest that at these locations the sheathing contribution is characterised by the occurrence of normal stress peaks and troughs in the sheathing located respectively in the portions of the panel directly superimposed to the joists and in the unsupported portions between the joists. The magnitude of the variations between the peaks and troughs can be viewed as indicators of the alteration degree of the sheathing contribution. This section of the analysis thus focuses on identifying this pattern – hereafter described as the "contra-distinct" pattern – in the specimens' sheathing.

Furthermore, discontinuing the sheathing(s) is anticipated to modify the strain distribution over the depth of the specimen cross-section, thus indicating that the composite action deteriorates. Such phenomenon has been identified elsewhere (Criswell 1981; Dawson & Goodman 1976; Gerber 2007; Moody & McCutcheon 1984).

4. Assessment of the tributary width

This analysis starts with a discussion of the test data of the specimens in healthy state (continuous sheathing) and corresponds to a qualitative comparison of the measured strain profiles and the distinct distribution pattern (see Section 3). It continues with an examination of the effects of sheathing discontinuities, ie., empirical data versus contra-distinct pattern (see Section 3).

4.1 Analysis of the tributary width – healthy-state specimen

In the healthy state (continuous sheathing(s)), it is anticipated that the measurements of the strain gauges installed on the sheathing tally with the distinct pattern. Hereafter, this analysis is conducted considering the test data of two representative specimens C08-01 and C08-03 (Fig. 5). Furthermore, C08-01 and C08-03 data are complementary.

In the upper sheathing of C08-01, TSU+200 and TSU–200 curves may suggest some disagreement of the strain distribution with the distinct pattern, in particular for TSU–200 data. Considering C08-03 specimen, the measurements of the upper sheathing (MSU) exhibit a strain pattern that arguably diverges to the distinct pattern as well.

Meanwhile, in the lower sheathing, C08-01 test data, TSL+200 and TSL–200, exhibit strain profiles that agree well with the distinct pattern (variation within about 10%). Furthermore in C08-03, the distinct pattern of strain distribution is well observable, ei., the variation is moderate and the peaks of strain occur on the joists.

However, the strain distribution in both the upper and lower sheathings also indicates that a large intensity of strain occurs in their unsupported portions (between the joists). This suggests that both panels experiences significant axial stresses. Thus, they act compositely with the joists.

The control gauges, CK (TSU–200) and CK (TSL–200), exhibit equivalent strain readings/ magnitudes to that of their corresponding data series. This verifies that the deck behaves symmetrically and confirms that the whole sheathings take a large intensity of axial stress.

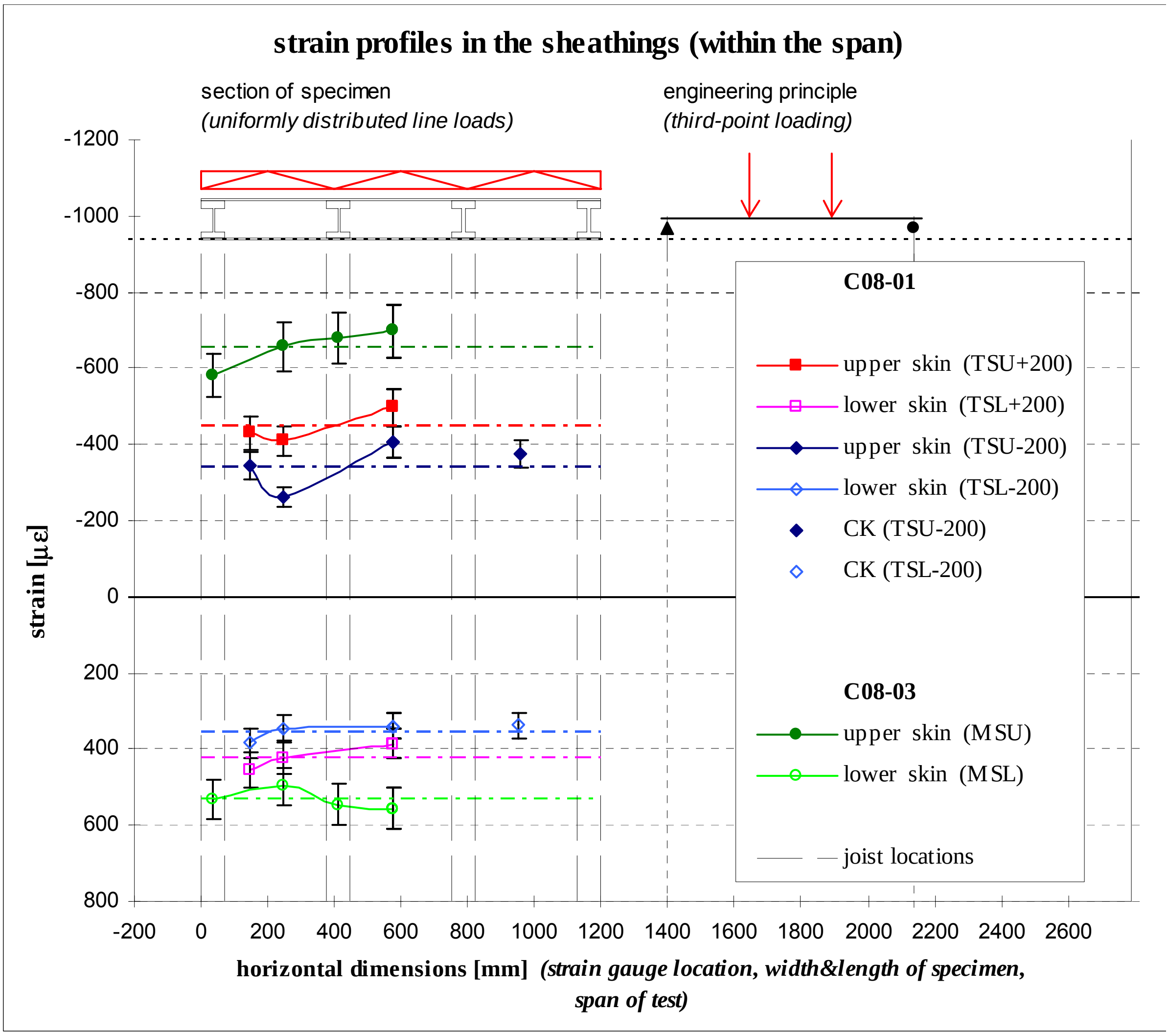

Fig. 5: Strain orthogonal strain in the sheathings – continuous sheathings.

4.2 Analysis of the tributary width – damaged-state specimen

This qualitative analysis focuses on the recognition of the “contra-distinct” pattern, ei., the strain intensity in the portions of the sheathing on the joists and between the joists exhibits significant differences. It is conducted with the test data of a representative specimen, C09-01 (Fig. 6).

The strain profiles (MSU and MSL) agree very well with the criteria of the contra-distinct pattern, peaks of strain on the joists and troughs of strain between the joists (quasi-zero strain). This indicates that the portions of the sheathing acting compositely with joists are reduced at the locations of MSU and MSL series.

Examining MSU–300 and MSL–300 – unfortunately the analysis of the strain pattern is penalised by the absence of measurements on the joists, it may be argued that the available readings point toward a similar pattern than MSU and MSL. Firstly, all four gauge series are arranged symmetrically about the cut (±150 mm) and, secondly, they exhibit strains of identical intensity in the unsupported portions of the sheathings. It is therefore legitimate to state that MSU–300, MSL–300, MSU and MSL exhibit similar strain patterns, thus, that MSU–300 and MSL–300 agree with the contra-distinct pattern.

Elsewhere, Gerber (2007) has identified that near a support, where the stress in the sheathing is transferred to the joists, the contra-distinct strain pattern is also recognisable. This may indicates that a similar phenomenon occurs near a gap in the sheathing, ie., the stress in the sheathing transits through the joists.

NOTE: In Fig. 6, the dashed curves with markers depict the strain profiles of the healthy-state specimen – data indexed to the load magnitude of the specimen in the damaged state.

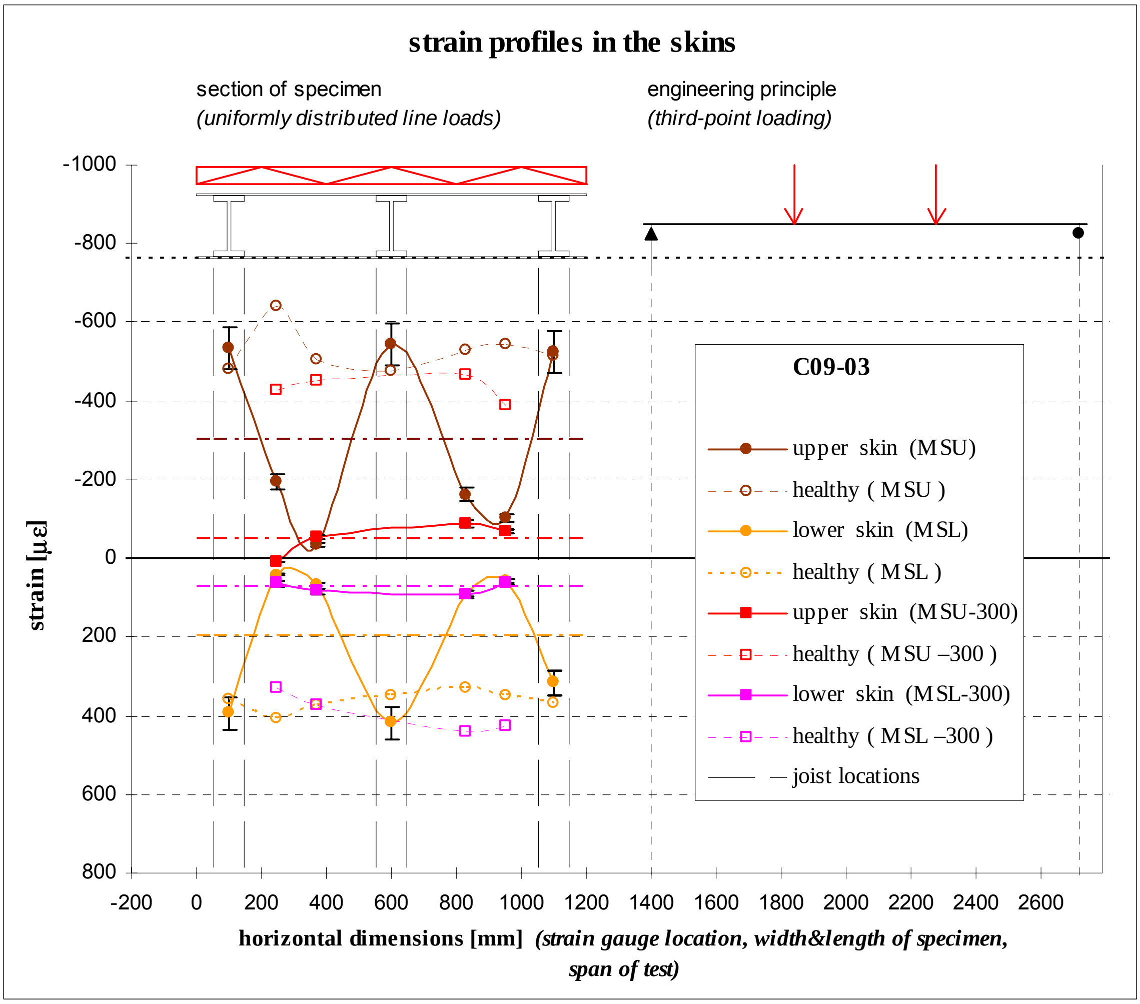

Fig. 6: Strain orthogonal strain in the sheathings – discontinuous sheathings.

5. Concluding summary

The analysis of the tributary width demonstrates that, in SSP structures with continuous sheathings, large portions – quasi the whole – of the sheathing act compositely with the joists. The distinct pattern – uniform strain distribution in the sheathing – has been identified in the laboratory specimens. It is therefore concluded that, in conditions such or equivalent as those of the laboratory investigation, a full contribution of the sheathing – as composite flange to the joists – can be considered.

Discontinuities in the sheathing have been identified to deteriorate the structural contribution of the sheathing. The contra-distinct pattern, characterised by peaks of strain on the joists and troughs of strain between the joists, occurred as such in the laboratory specimens with discontinued sheathing. Thus, it is advisable to consider a reduced contribution of the sheathing in these conditions.

Furthermore, this analysis indicates the EC5 (European Committee for Standardisation 1995) design directives for SSP structures are correct for the conditions of continuous sheathing(s). This may impose structural splicing of the sheathing. On the other hand, EC5 may not be suitable for SSP systems with discontinued sheathing. In such state, SSP systems are structurally weakened because of the deteriorated composite action (Gerber 2007) and reduced sheathing contribution.

6. Acknowledgement

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7. References

[1] Amana, E. J. & Booth, L. G. 1967, 'Theoretical and Experimental Studies on Nailed and Glued Plywood Stressed-Skin Components: Part 1. Theoretical Study', *Journal of the Institute of Wood Science*, vol. 4, no. 1, pp. 43–69.

[2] Criswell, M. E. 1981, 'New Floor Design Procedures', in Proceedings of 'The Forest Products Research Society Conference on Wall and Floor Systems: Design and Performance of Light-Frame Systems', Forest Products Research Society, Denver (CO), USA.

[3] Dawson, P. R. & Goodman, J. R. 1976, 'Variability Simulations of Joist Floor Systems', *Wood Science*, vol. 8, no. 4, pp. 242–251.

[4] European Committee for Standardisation 1995, Design of Timber Structures — General Rules and Rules for Buildings, vol. Eurocode 5 (ENV 1995-1-1), European Committee for Standardisation CEN, Brussels, Belgium.

[5] Foschi, R. O. 1969, Stress Distribution in Plywood Stressed-Skin Panels with Longitudinal Stiffeners, Research Report, Department of Fisheries and Forestry, Canadian Forestry Service, Forest Products Laboratory, Vancouver (B.C.), Canada.

[6] Gerber, C. 2007, 'Wood Stressed-Skin Panels: An Investigation into their Behaviour, Load Distribution and Composite Properties', Ph.D. Thesis, Faculty of Engineering, University of Technology, Sydney (NSW), Australia.

[7] Möhler, K., Abdel-Sayed, G. & Ehlbeck, J. 1963, 'Zur Berechnung Doppelschaliger, Geleimter Tafelelemente', *Holz als Roh- und Werkstoff*, vol. 21, no. 8, pp. 328–333.

[8] Moody, R. C. & McCutcheon, W. J. 1984, 'Sheathing Properties and Component Performance on Light-Frame Structures', in Proceedings of 'Structural Wood Composite: Meeting Today's Needs and Tomorrow's Challenges', Forest Products Research Society (Publisher), Minneapolis (MN), USA, pp. 93–99.

[9] Onysko, D. M. 1970, Performance of Wood-Joist Floor Systems: A Literature Survey, Report No. OP-X-24, Eastern Forest Products Laboratory, Ottawa (ON), Canada.

[10] Ozelton, E. C. & Baird, J. A. 2002, Timber Designers' Manual, 3rd edn, Blackwell Publishing, London, UK.

[11] Raadschelders, J. G. M. & Blass, H. J. 1995, 'Stressed Skin Panels', in H.J. Blass, P. Aune, B.S. Choo, R. Görlacher, D.R. Griffiths, B.O. Hilson, P. Racher & G. Steck (eds), Timber Engineering – STEP 1, Centrum Hout, Almere, The Netherlands.

[12] Vanderbilt, M. D., Goodman, J. R., Criswell, M. E. & Bodig, J. 1974, A Rational Analysis and Design Procedure for Wood Joists Floors, National Research Foundation, Grant No. GK-30853, Colorado State University, Department of Civil Engineering, Fort Collins (CO), USA.

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There has been a growing movement to utilize biomass, in the face of global warming, a serious shortage and depletion of fossil resources, and the consequent rise in prices. A typical biomass resource is wood. It is a resource converted from carbon dioxide in the atmosphere through photosynthesis of solar energy. This circulating resource returns to carbon dioxide through combustion or biodegradation. Wood species and its uses are remarkably diverse. The most important aspect of wood—renewable or sustainable resources using solar energy—is that human beings commit themselves to their production. The use of wood for timber engineering has direct influence on human life, affecting people involved and producing wider ripple effects on the community and various fields. In other words, its role is driving force and efficiency is not the only measure. We need to take account of forests, which are the place for production, and of the ecological system, in which living creatures co-exist. Deeply concerned with issues of climate and environment, we must be always aware of the need for cooperation in terms of “space” (in same generation) and “time.” (beyond generations).

The 10th WCTE Conference 2008 in Miyazaki, Japan received many abstracts and proceedings for presentations with topics of interest spanning the spectrum of the timber engineering field.

We do hope these reports are effective and instructive for mutual understanding between these sectors and will also connect into “the next ones”.

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