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ON-SITE MECHANICAL TEST OF TIMBER SCAFFOLD BOARD

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OVERVIEW

Solid timbers are widely utilised as scaffold boards and working platforms in constructional and maintenance works (Figure 1). Selecting the suitable species groups and minimum grades are the keys for reliable application of timber as scaffold board. Choosing the right timber species and grade could save money, enable reusing, expedite the operations, minimise accident and most importantly avoiding fatality. However, not everyone has the knowledge and experience in handling of timber-based materials. Basic understanding and training concerning the science of timber are critically required even by professional engineers (Mohd-Jamil & Mohamad Omar 2015). Thus, a straightforward on-site mechanical testing is recommended on random samples to verify the bending properties of timber scaffold board prior to installation.

Using only the existing mechanical data to define the loading capacity of a timber scaffold board is not practically ideal. The mechanical characteristics of timber vary with species, age, size and supplies. The basic and grade stresses of a timber group were derived from a single representative species, and yet the actual supplies consist of numerous species. For example, there are more than 40 different species of keruing in the country, but instead, the reference values for working stresses of keruing timber were computed from the mechanical test results of a single species, i.e. *Dipterocarpus baudii* (MS 544 2001). Besides, most data were derived from small clear timber specimen tests rather than actual size of scaffold board in flatwise mode. Hence, from these considerations, it appears that on-site mechanical test is essential to establish reasonably more accurate strength characteristics of timber scaffold boards. Although the approach may not be an exact science, it is nonetheless necessary and inexpensive to apply.

This article provides a detailed procedure for assessing the flexural performance of timber scaffold board on-site, where a universal testing machine is not available. The contents describe methods and calculations to determine the bending capacity, modulus of rupture, modulus of elasticity and density.

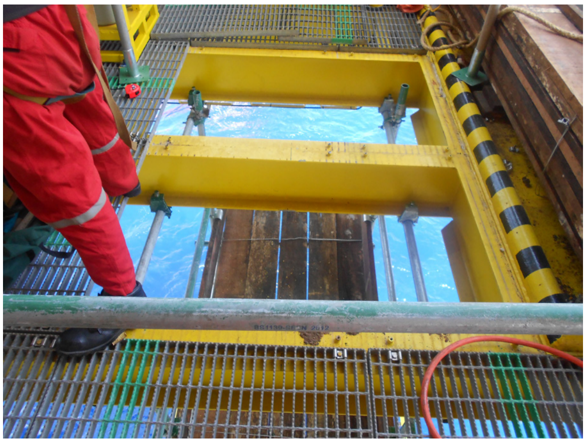


Figure 1 A platform of timber scaffold boards on offshore oil rig (courtesy of Shapadu)

SAMPLING

i. The number of samples is recommended to be 5% of the total boards of each species in every supply batch (Mohd-Jamil et al. 2016). For example, in a supply consisted of 500 kempas and 500 kapur boards, 25 boards of each species shall be tested.

ii. Test samples shall be selected from boards of the lowest grade. The detailed grading specifications shall be referred to Mohd-Jamil (2015). In the absence of a qualified grader, the grading assessment can be conducted non-standard, visually based on timber properties, natural and processing defects as described in Table 1.

iii. The moisture content, MC (%) of the sample boards shall be determined using a timber moisture meter.

iv. Thickness (t), width (w) and length (l) of every sample board shall be measured using a measuring tape prior to the destructive test. Every board shall be weighed to determine the density, ρ (kg/m^3) using the equation:

$$\rho = \frac{m}{t \times w \times l} \quad \text{Equation 1}$$

where m is the mass (kg) of the sample board, t is the thickness (m) of the sample board, w is the width (m) of the sample board, and l is the length (m) of the sample board.

Table 1 Sampling criteria for on-site mechanical test of scaffold board of a timber group

	Specification	Superior grade	Lower grade
1.	Timber properties	Higher density	Lower density
		Dried condition (moisture content of 19% or below)	Higher moisture content
		Sap-free	Contain more sapwood
2.	Natural defects	Knot-free	Having more and larger knots
		Without decay	Stained and decayed
3.	Processing defects	Dimensionally uniform	Excessive bowing, spring, twisting, cupping
		Without or less fissures	Excessive checks and splits

TEST METHOD

Testing arrangement

i. Test shall be conducted in flatwise mode of four-point loading arrangement as illustrated in Figure 2.

ii. The bending span, L1 shall be constructed using scaffolding frames or common scaffolding tubes and couplers. The purpose is to arrange two flexural supports (i.e. B1 and B2) at a gap of L1. L1 shall be adjusted to the maximum possible span with overhang, r not more than four times the thickness of the sample board.

iii. The loading span, L2 shall be designed to the narrowest possible to match a three-point static bending test arrangement. Loading supports (i.e. P1 and P2) shall be made of uniform rectangular metal weights of predetermined mass. The length of the metal weights shall exceed the width of the test sample.

iv. A loading platform of predetermined mass of approximately the same width, double the thickness and length of not more than 2/3 of the sample board shall be placed above and symmetrical to the rectangular metal weights. The loading platform shall be made from high stiffness and manageable material such as laminated veneer lumber (LVL).

Loading force

i. Dead weights of predetermined mass are placed gradually until the board fails. The amount of added weight, W (kg) shall be recorded at every loading.

ii. The magnitude of deflection shall be measured at the bottom-centre point of the test sample using a ruler. The ruler shall be firmly fixed on the floor axis to allow readability of the deflection during loading.

iii. Every sample board shall be tested until failure. The bending failure of the sample is indicated either by the split or fracture of the board or collapse of the dead weights. The maximum load is calculated as the total weight near failure.

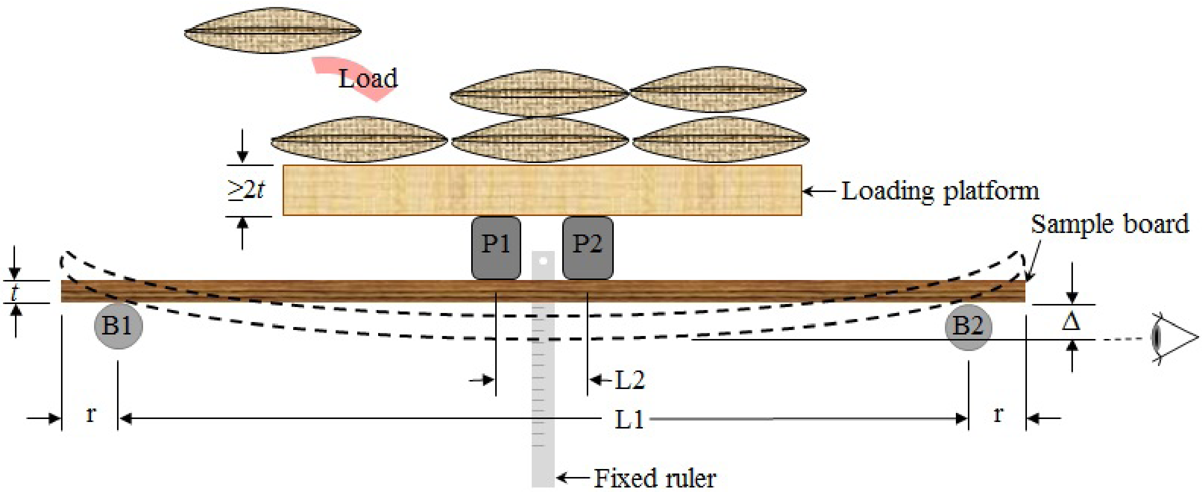


Figure 2 Arrangement of on-site mechanical test of timber scaffold board

DERIVATION OF MECHANICAL PROPERTIES

Bending capacity

The bending capacity of a sample board is equal to the maximum load. The maximum load, F_{max} (N) shall be calculated using the equation:

$$F_{max} = W_t g \qquad \text{Equation 2}$$

where W_t is the total weight before failure (kg), and g is the gravitational acceleration (approximately 9.81 m s^{-2}).

Modulus of rupture

The bending strength or flexural strength, also known as modulus of rupture, MOR (N mm^{-2}) of a sample board shall be calculated using the equation:

$$\text{MOR} = \frac{3F_{max}(L1 - L2)}{2wt^2} \qquad \text{Equation 3}$$

where F_{max} is the maximum load (N), L1 is the support span (mm), L2 is the loading span (mm), *w* is the width (mm) of the sample board, and *t* is the thickness (mm) of the sample board. The modulus of rupture of a timber species (of one supply batch) shall be represented by the average value of MOR of all tested samples.

Modulus of elasticity

Load versus deformation graph of each tested sample shall be plotted using data obtained from the loading and deflection measurements. The slope of the graph, S (N mm^{-1}) of each sample board shall be measured approximately within the gradient of 0.1 F_{max} and 0.4 F_{max} using the equation:

$$S = \frac{0.4F_{max} - 0.1F_{max}}{\Delta_{0.4} - \Delta_{0.1}} \qquad \text{Equation 4}$$

where F_{max} is the maximum load (N), $\Delta_{0.4}$ is the deflection (mm) at $0.4F_{max}$, and $\Delta_{0.1}$ is the deflection (mm) at $0.1F_{max}$.

The bending modulus of elasticity, MOE (N mm^{-2}) of each sample board shall be calculated using the equation:

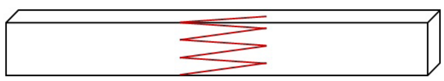
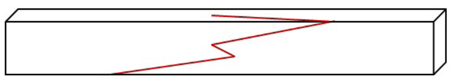
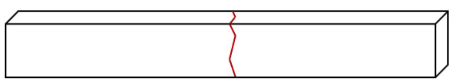
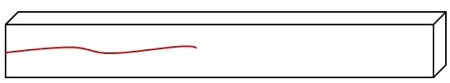
$$\text{MOE} = \frac{S}{4wt^3}\left(4\left(\frac{L1 - L2}{2}\right)^3 - 3\left(\frac{L1 - L2}{2}\right)L1^2\right) \qquad \text{Equation 5}$$

where S is the slope of the graph (N mm^{-1}), L1 is the support span (mm), L2 is the loading span (mm), *w* is the width (mm) of the sample board, and *t* is the thickness (mm) of the sample board. The modulus of elasticity of a timber species (of one supply batch) shall be represented by the average value of MOE of all tested samples.

INTERPRETATION OF FRACTURE MODE

Each sample board shows a mode of fracture once tested to failure. The fracture mode gives an indication of some characteristics of the timber scaffold board. Some common modes of fracture and their interpretation are presented in Table 2.

Table 2 Facies of fracture in timber scaffold board test (Mohd-Jamil & Roszalli 2015)

Facies of failure	Illustration (bottom view)	General interpretation
Centre splintering		- Straight-grained board - Knot-free - Decay-free
Cross-grained		- Cross-grained board - Slightly lower strength than the expected value
Brash tension		- Most probably decayed board - Substantially lower strength than the expected value - Prone to sudden fracture
Failure at knot		- Weak point due to presence of knot - Lower strength than the expected value depending on the position of the knot - Prone to sudden fracture
Horizontal split		- Inconsistent stiffness over the width - Unstable at higher loading

SUMMARY

The on-site mechanical test is recommended on random samples of timber scaffold board for the verification of mechanical properties prior to installation. A step by step procedure is provided to assist engineers and safety officers in minimising the risk of injury and fatality in construction and maintenance works. For comparison analyses, the mechanical properties obtained from the on-site tests can be verified with the existing data of Malaysian timbers e.g. in Lee et al. (1993).

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APPENDIX 1

Abbreviations & Symbols

B1	Flexural support 1
B2	Flexural support 2
F_{max}	Maximum load
g	Gravitational acceleration
l	Length of a sample board
L1	Bending span
L2	Loading span
m	Mass of a sample board
MC	Moisture content
MOE	Modulus of elasticity
MOR	Modulus of rupture
P1	Loading support 1
P2	Loading support 2
r	Sample board overhang
S	Slope of load vs deflection
t	Thickness of a sample board
w	Width of a sample board
W	Weight
W_t	Total weight
Δ	Bending deflection
ρ	Density of sample board

Choosing the right timber species and grade for the scaffold board application could save money, enable reusing, expedite the operations, minimise accident and most importantly avoiding fatality. However, not everyone has the knowledge and experience in handling of timber-based materials. Basic understanding and training concerning the science of timber are critically required even by professional engineers. Thus, an on-site test is recommended on random samples of timber scaffold board for the verification of mechanical properties prior to installation. This article provides a detailed procedure for assessing the performance of timber scaffold board on-site where a universal testing machine is not available.

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