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Occupational Risk Assessment: Review of Wooden Scaffold Board Application in Malaysian Oil and Gas Industry

(Kajian Risiko Pekerjaan: Penilaian terhadap Aplikasi Papan Perancah Kayu dalam Industri Minyak dan Gas di Malaysia)

MOHD JAMIL ABDUL WAHAB*, NOOR AZRIEDA ABD RASHID,
SALMIAH UJANG & LIM SENG CHOON

ABSTRACT

Timber scaffold boards have been widely utilised in the offshore construction industry. However, technical specifications and inspection procedure for the application of scaffold boards from a wood material were inadequate. In the development of the standard requirements, evaluation of actual engineering practices could indicate the level of workplace safety. A study was conducted to identify risk and safety measures concerning the use of timber scaffold boards in construction. This article discusses on the occupational risks and ergonomics issues of the scaffolding application based on the physical and mechanical conditions of tropical timber scaffold boards extracted from offshore oil and gas rigs. The boards were exposed to a seasonal climate of East Coast monsoon of South China Sea between November and February. The scaffolding application extended up to 20 m directly above the ocean surface and some boards were completely immersed below the ocean surface particularly during elevated tidal waves. Some of the boards were installed as the on-deck platforms. Forty scaffold boards fabricated from tropical timber species were evaluated. Physical characteristics of the boards were described by natural and man-made factors. A three-point bending test was conducted to determine the maximum load capacity of each board and the mode of fracture was evaluated. Timber identification test was conducted to identify the groups of the timber being used. The microscopic observation confirmed the presence of hyphae which indicated the biological deterioration has happened in some of the boards. Occupational risks were summarised based on the results of the physical and mechanical assessments.

Keywords: Marine construction; safety; timber properties

ABSTRAK

Papan perancah kayu telah digunakan secara meluas di dalam industri pembinaan luar pantai. Walau bagaimanapun, spesifikasi teknikal dan prosedur pemeriksaan untuk aplikasi papan perancah daripada bahan berasaskan kayu adalah tidak lengkap. Dalam usaha membangunkan piawaian tersebut, penilaian terhadap amalan sebenar kejuruteraan boleh memberikan gambaran tentang tahap keselamatan di tempat kerja. Satu kajian telah dijalankan untuk mengenal pasti bahaya dan langkah-langkah keselamatan berkenaan penggunaan papan perancah kayu di dalam pembinaan. Artikel ini membincangkan risiko kerja dan isu ergonomik aplikasi perancah berdasarkan keadaan fizikal dan mekanik sampel papan kayu tropika yang diambil dari pelantar minyak dan gas luar pantai. Sampel papan tersebut terdedah kepada pertukaran cuaca dan musim tengkujuh di Pantai Timur antara bulan November hingga Februari. Aplikasi perancah menjangkau ketinggian 20 m di atas permukaan laut dan sebahagian papan ditenggelami air terutama ketika air pasang. Sebahagian papan telah digunakan sebagai platform atas pelantar. Empat puluh sampel papan daripada pelbagai spesies kayu tropika telah dikaji. Ciri fizikal papan dikategorikan sebagai faktor semula jadi dan buatan. Ujian lenturan 'three-point' telah dijalankan untuk menentukan kapasiti beban maksimum setiap sampel dan jenis kegagalan yang berlaku dianalisis. Ujian identifikasi telah dijalankan untuk menentukan jenis kumpulan kayu yang digunakan. Pemerhatian mikroskopik mengesahkan kehadiran hyphae yang menunjukkan bahawa pereputan biologi telah berlaku pada sebahagian papan. Risiko kerja telah dirumuskan berdasarkan hasil ujian fizikal dan mekanik tersebut.

Kata kunci: Keselamatan; pembinaan luar pantai; sifat kayu

INTRODUCTION

In the practices of petroleum and petrochemical industries, the measures of safety are given a high priority. Driven by the supports from integrated mega multinational corporations such as Petroliam Nasional Berhad (PETRONAS), Shell, ExxonMobil and China National Petroleum Corporation (CNPC), oil and gas engineering has advances to the most modern technological frontier. High investment has been made to ensure the entire upstream and downstream activities comply and adhere to the health, safety and environment (HSE) regulatory framework (Anon. 2012). According to the Petroleum Management Unit of PETRONAS, to date, there are over 300 oil and gas offshore stations actively in operation along the Malaysian coastline (Anon. 2010).

Nevertheless, the national protocol on selection, use and maintenance of solid timber for scaffold board application is regrettably inadequate. Important details on the manufacturing tolerances, moisture content, grades and method for mechanical properties determination were not properly regulated (Anon 1986). MS 1714 (2003) is the standard method to distinguish the grades of structural timber based on visual assessment. Unfortunately, the method was not designed to establish the strength limitations of each grade. Furthermore, the method has never formally tested and validated for timber scaffold board application. Worst, even the awareness on the appraisal for structural timber grading among oil and gas community is rather doubtful, set aside the implementation obligation.

Pope et al. (2005) studied the effect of sloping grain to the modulus of rupture and modulus of elasticity of timber scaffold boards. They demonstrated that standardised visual grading process is significant in determining sloping grain on timber scaffold boards and suggested for amendments on the existing procedure. Even though grading of timber solely based on visual appraisal is not an exact science, the method is proven effective and inexpensive to perform. Hubler (2011) reported that visual grading is explicit to establish an at most 5% below grade scaffold boards. However, percentage of 'off-grade' scaffold board may be present among the graded batches. The effectiveness of visual inspection is subjective to the qualification, experience and competency of the assessor. As a result, fatal incidents on construction sites still occurred until today. In a study, from a total of 621 fatal incidents at building construction sites, 160 cases were caused by falls of workers related with non-complying scaffolds (Chia et al. 2005). Based on the statistic in Malaysian construction industry, 819 occupational accidents related to scaffolding system were reported in 2000-2009 (Heap & Thuan 2014). The effective assessment of timber scaffold boards' quality for building and maintenance works is not only for safety, but it offers monetary advantage as well. Apart from the cost for procurement of new timber boards, the expenses for removal, reinstallation, logistic and storage is substantial due to the site location issue. Currently, in the offshore construction sector, timber scaffold board quality is being evaluated through an ambiguous appraisal (Mohd Jamil & Mohamad Omar 2015). Overvalued on the boards quality may lead to casualties. On the other hand, underrated boards will supposedly end up with unnecessary replacement. The evaluation and inspection of timber scaffold boards which solely based on opinion are very subjective and uneconomical. Decisions of engineering or technical issues by incompetent workers will probably result with unwanted costs or even human losses.

For decades, oil and gas industry is one of the major contributors to the Malaysian economy. The country is now aiming as the premier hub for oil and gas services in the region (Anon. 2011), thus developments of timber technology play an important role in the offshore construction sector. At present, an effort is being carried out to develop the national standard specifications for timber scaffold board application. Since there are very limited technical records found regarding Malaysian timbers as scaffold board, foreign standards and specifications such as BS 2482 (2009) and AS 1577 (1993) will be the basis for references.

In chorus, factual evaluation of current practices will greatly assist in the development of the standard guideline. This article reports on the physical and mechanical conditions of timber boards extracted from oil and gas work site, as an indication on how they are utilised. The details are designed to address the occupational risks and assist the technical decisions concerning wooden scaffold board application.

MATERIALS AND METHODS

Analysis were conducted on 40 scaffold boards made of solid tropical hardwoods. These boards were extracted from offshore oil and gas rig built in South China Sea. Review on the characteristics of the boards was performed based on physical evaluation, mechanical properties test, failure evaluation and wood identification. Some boards were tested for the presence of fungi.

PHYSICAL EVALUATION

The nominal cross-cut dimension of the boards was 40 × 225 mm. The length varies between 2500 and 3000 mm. Physical study was conducted by measurement of the actual thickness, width and length at the middle section of every board. Physical conditions of the boards were categorised into several features based on visual inspection.

MECHANICAL PROPERTIES ASSESSMENT

Three-point bending test was performed using Shimadzu universal testing machine. The board was placed on two circular supports at 1800 mm apart. Monotonic force of 6.6 mm/minute was applied through a semi-circular loading head until the board fails. Failure was described by fracture formation and decrease of force reading. The test arrangement is shown in Figure 1. Maximum force of each board was measured and recorded using a load cell and Trapezium software. Moisture content (MC) and density were determined from 25 mm cross-cut section of each board using oven-dried method.

TIMBER IDENTIFICATION TEST

Identification test was conducted by an anatomist to determine the timber group of each board. Visual assessment was carried out by examining the macroscopic

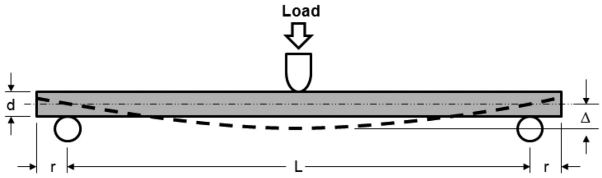

FIGURE 1. Bending test arrangement for scaffold board with nominal dimension of d = depth of specimen (40 mm), L = bending span (1800 mm), r = overhang ([length of board – L]/2 mm) and Δ = bending deflection

features using a magnifier. The anatomical characteristics of 10× magnifications were observed on the cross section cut. Spot characteristics were also used to determine the identity of the timber.

FUNGI INVESTIGATION

Boards with rotten parts were distinguished during physical evaluation. A standard slide preparation, as well as microscope study, was carried out on these selected boards. Slides were prepared from thin wood film of 0.05 micron using microtome. Microscopic investigation using Leica DME was conducted to verify the presence of decaying agent. A total of 9 slides were evaluated.

RESULTS AND DISCUSSION

PHYSICAL EVALUATION

Qualitative analysis of physical details for each timber board, namely board 01 to 40 was conducted (Table 1). The results of the physical observation were categorised under natural and man-made causes. Majority of the boards was observed with distorted dimension. Distorted dimension includes bowing (20 boards), twisting (6), spring (2) and kinked (3). Corrosion of end band was found on every board. Fourteen boards completely lost their end band on both ends. Shake formation was found on 3 boards. Most of the boards (95%) were found with end split. End check and surface check were observed on all boards. A total of 6 boards were found having rotten section. Knot was found on 9 boards and wane was observed on 2 boards. Man-made causes were described as gouging (15), notch (7), saw kerf (3), surface contamination (22) and burnt mark (3).

Every surface of the boards was rough-sawn. This was reasonable since rougher surface improves walking grip and traction. The thickness of the boards varied between 31 and 40 mm. Based on the British standard, the thickness and acceptable tolerance of timber scaffold board shall be of 38±2 mm. This shall be measured at 20% MC (BS 2482 2009). Whereas the Australian standard specified that the thickness and tolerance of the plank shall be of 38+3 mm and not lesser. This is for measurement at MC not exceeding 15% (AS 1577 1993). The width of the boards varies between 190 and 242 mm. The targeted width based on BS 2482 is 225±5 mm when measured at 20% MC. Whereas AS 1577 states a minimum width of 220+5 mm.

Compliance with standard dimension and tolerances reflects on the stability and uniformity of the working platform. Ensuring that the scaffold boards are having an equal thickness is strictly necessary to minimise the risk of tripping. Even if the boards were at the same thicknesses during installation, periodical inspection should be conducted since sagging due to prolonged loading could also affect the evenness. Similarly, working platform consists of scaffold boards of non-uniform widths create gaps in between each board.

Trip and slip at the workplace resulted in thousands of injuries every year (Anon 2012). It causes musculoskeletal harms, cuts, bruises, bone fractures and dislocations. Trip occurs when a worker suddenly catches his or her foot on an object or surface. A more serious injuries caused by tripping can also occur such as fall from height, fall on stairs and fall into hole or water. One common practice of fixing boards to the platform is by strapping of metal wire. Loose or improper tie could be an obstruction and causes tripping. Similarly, obstruction of a solid object such as projecting nail could also cause tripping.

Timber boards with distorted dimension will also affect the uniformity of the platforms. Bowed and twisted boards affect the flatness of the platform surface. Spring and kinked introduce gaps between adjacent boards. Distortion of board during service could also loosen the fixing. In such extreme changes of oceanic climate, control of the absorption and desorption of moisture against solid timber is impractical. Thus, some degrees of dimensional distortion of the timber boards are anticipated. However, the use of timber boards of selected cutting patterns may reduce the amount and rate of distortion.

End bands of the scaffold boards were made of metal plates with a nominal dimension of 0.8 mm thick and 20.0 mm in width. These end bands were nailed on the sides and cross sections of the timber boards. Based on AS 1577, fixing of end bands made of metal, plastic or wood is compulsory to restrain end splitting. Figure 2 shows the effect of exposure to oceanic atmosphere on a metal end band. Metallic substances severely deteriorate in corrosive marine environment, particularly when the material was entirely submerged below the sea during high tide. It was observed that both the end bands and the nails were extensively corroded. Many parts of the end bands were destroyed and end bands of some boards were completely loss. The deterioration of the metal plates formed spiky and harmful edges. Act 139 of Malaysian Laws (Anon. 1986)

TABLE 1. Physical evaluation of timber scaffold boards

	Natural											Man-made					Dimension (mm)		
Board Number	Corroded end band	Loss of end band	Bowing	Twisting	Spring	Kinked	Knot	Shake	End split	Rot	Wane	Gouging	Notch	Saw kerf	Contamination	Burnt mark	Thickness	Width	Length
01	√		√						√								33.38	194.17	2702
02		√	√						√			√	√				36.31	192.83	2705
03		√			√				√		√	√			√		36.31	194.67	2535
04	√			√			√						√	√	√	√	34.14	220.50	2563
05	√								√			√			√		35.39	203.67	3045
06	√				√				√			√	√		√		34.67	217.67	3106
07	√		√						√			√					33.81	194.00	3076
08	√							√	√	√							35.33	222.67	2564
09	√			√					√			√	√	√	√		34.84	219.67	3020
10	√						√	√	√			√			√	√	37.20	202.50	3030
11		√	√				√		√			√			√		32.05	225.00	2557
12		√	√						√								37.36	216.33	2478
13	√		√						√								34.24	223.83	2501
14	√			√					√	√		√			√		36.41	202.83	3094
15		√	√				√		√	√					√		32.21	242.00	3046
16	√		√				√		√						√		38.16	219.33	3083
17	√			√					√				√	√			36.39	218.50	3080
18	√			√					√			√					30.72	224.33	2609
19	√		√				√		√	√			√		√		34.61	191.83	3038
20	√			√					√								32.67	239.33	2457
21		√				√			√						√		39.56	216.00	3007
22	√							√	√						√		34.21	190.33	3045
23	√								√			√			√		36.48	217.33	3010
24	√		√						√						√		34.43	212.67	3049
25	√		√						√								34.92	200.00	3021
26		√					√		√			√			√		37.46	215.67	2546
27		√							√						√		34.35	195.17	3062
28		√							√						√		34.26	197.00	2510
29		√	√						√						√		35.29	198.00	3020
30		√	√						√				√		√		37.46	196.50	3040
31		√				√			√						√		34.15	193.33	3578
32	√		√				√		√	√		√				√	34.97	196.83	3724
33		√	√						√	√					√		34.37	197.00	3175
34	√		√						√		√						38.69	195.00	3678
35	√		√						√			√					39.04	200.33	3616
36	√		√						√	√							34.41	197.67	3699
37	√		√														33.55	200.50	3555
38		√				√	√		√								33.50	237.33	3054
39	√		√						√			√					34.51	208.50	3049
40	√								√								37.48	200.17	3105
Total	26	14	20	6	2	3	9	3	38	6	2	15	7	3	22	3			

FIGURE 2. Illustration of an end band before and after exposure to oceanic atmosphere

stated that metal parts in scaffolding application shall be of suitable quality and free from corrosion. Besides, concern about the sharp edges on end bands is stated in BS 2482 as to avoid injury to workers. Thus far, this subject has never been an argument of safety, but it is definitely important for future improvement of timber scaffold board application.

Knot is the most common strength-reducing defect of timber boards. In fact, the main factor for low strength is not only the knot itself, but also the sloping grain surrounding it (Mohd Jamil & Mohd Zamin 2014). End splits were observed on most of the boards. End split was measured by the distance from board's edge towards the end of crack extension. The length of the cracks measured from 33 to 100 mm. Wane is characterised by inclusion of bark or insufficient wood proportion at a corner or along an edge of a timber board. Generally, section next to the wane is the sapwood thus a precaution for durability is necessary. Cup shakes on timber boards are detachment of layers on the tangential surfaces. In theory, a cup shake decreases the functional thickness of a board thus load is tolerated only by the remaining dimension. Unfortunately, in most cases, shake is only visible after the board started drying out. Nevertheless, the presence of knot, end split, wane and shake are allowable for scaffold board and other structural timber applications. However, the permissible limits are based on different grades of visual grading assessment.

A total of seven boards had notches. The number of notch on each board varied with three notches (1 board), two notches (3 boards) and one notch (3 boards). The notches were between 35 and 100 mm of boards' width. Saw kerf was found on 3 boards due to improper notching. The length of the kerfing varied between 30 to 66 mm.

Contamination and burn mark on board's surface were presumably caused by construction activities. Contaminated boards were observed having paint drips, wax drips, oily substances and other chemical contaminants. Some paint marks by roller were also observed. Burn marks on scaffold boards are probably caused by contact with adjacent metal welding work.

Prohibition of the scaffold boards with contaminated surface is to avoid the risk of slippery platform (Anon. 1986). However, appropriate actions to remove contamination and restore traction are practical. Another reason is to avoid the overlooked of timber defects. Timber defects such as rot and shake will be unnoticeable under paint and greasy substances.

A total of 15 scaffold boards were found with gouged section. 11 gouges were observed at the edge-end, 3 at the edge-middle and 1 at both edge-end and edge-middle. Gouges are probably caused by an impact hit of working tools or by a dropped impact of the board itself. It was reported that timber breakage caused by externally applied forces does not deteriorate the strength of the remaining parts. However, gouging reduces the effective dimension of the cross section.

MECHANICAL PROPERTIES AND FRACTURE EVALUATION

Table 2 shows the bending test results of each board. The average maximum load was 6.64 kN. The lowest and highest maximum loads were 0.57 and 13.82 kN, respectively. The density of the boards ranged between 473 and 1100 kg/m^3. Moisture contents (MC) were approximately the same, within 13.7 to 17.6%. However, these are not the absolute on site MC, which should be much higher. Thus, it is rational to assume that the maximum load for each board during on site is lower than the obtained value.

Overall, there were five modes of fracture observed during destructive test namely center splintering, cross-grained, brash tension, failure at knot and failure at notch. The facies of failure is described in Figure 3. Correlation between density, maximum load and failure mode of each board is shown in Figure 4. High density boards demonstrated higher maximum strength. Most boards of higher strength failed by center splintering. Apparently, majority of the lower strength boards failed in brash tension mode.

As fracture always begin at a defect point, timber boards which failed in splintering mode are most likely having straight grain and free of knot. Nevertheless, crossing grain and knots can be distinguished with a proper visual grading procedure. Brash tension failure is normally associated with decay, characterised by abrupt breakage across the grain without splinters (Highley & Scheffer 1989). Thus, species and grades selection plus periodical inspection on the timber boards are vital to prevent decay.

Notches are man-made and resulted with unnecessary kerf when the sawing is inaccurate. From a total of 7

TABLE 2. Mechanical properties evaluation of timber scaffold boards

Board number	Density (kg/m^3)	Moisture content (%)	Maximum load (kN)	Failure Mode
01	869.5	15.4	8.85	Centre splintering
02	744.4	14.0	5.03	Failure at notch
03	824.3	15.0	7.36	Cross-grained
04	1011.0	13.8	5.04	Failure at notch
05	741.6	14.3	7.48	Centre splintering
06	856.3	14.2	6.05	Centre splintering
07	692.4	15.3	3.20	Cross-grained
08	645.0	14.5	2.58	Brash tension
09	986.4	15.3	5.01	Cross-grained
10	473.2	15.9	3.73	Failure at knot
11	956.3	15.0	5.97	Brash tension
12	794.2	16.1	7.51	Centre splintering
13	925.5	14.6	11.88	Centre splintering
14	580.1	15.4	6.28	Centre splintering
15	788.5	14.3	7.22	Cross-grained
16	686.7	16.5	5.92	Failure at knot
17	701.7	16.6	6.56	Failure at notch
18	803.5	16.2	2.66	Brash tension
19	743.6	15.7	4.31	Failure at knot
20	860.5	15.4	4.325	Brash tension
21	868.5	16.5	10.17	Centre splintering
22	878.8	14.1	7.98	Centre splintering
23	850.3	14.5	12.33	Centre splintering
24	851.9	14.9	7.27	Centre splintering
25	791.5	15.2	5.36	Cross-grained
26	852.5	15.1	8.13	Failure at knot
27	659.0	16.3	7.13	Centre splintering
28	975.7	16.5	7.19	Centre splintering
29	552.2	15.6	5.69	Centre splintering
30	874.4	14.4	9.88	Failure at notch
31	995.6	16.4	6.74	Centre splintering
32	711.2	15.7	5.73	Failure at knot
33	890.3	15.2	0.57	Brash tension
34	892.7	17.1	8.14	Centre splintering
35	838.4	17.6	9.48	Centre splintering
36	782.4	16.6	2.43	Brash tension
37	822.1	16.3	8.13	Centre splintering
38	728.3	15.1	4.11	Centre splintering
39	773.8	13.8	8.48	Centre splintering
40	1100.2	14.8	13.82	Centre splintering

boards with notches, 4 boards failed at the edge cut during flexure test. The notching of timber board develops stress concentrations around the notch, as well as a reduction of the area resisting the bending and shear forces. Burawska et al. (2011) reported that the maximum stress in bending of notched solid timber depends on the size of the opening, the larger the opening, the higher the stress.

Thus, notch and saw kerf considerably reduce the bending strength of timber scaffold boards. Based on the flexure formula, the calculation of maximum bending stress:

$$\sigma = K.\mathrm{Mc/I},$$

where M is the resultant internal moment (Nmm); c is the distance (mm) from the neutral axis to outermost fiber; I is the area moment of inertia (mm^4); and K is the stress concentration factor. As a result of notching, the maximum critical loading capacity for timber scaffold board (width w, thickness d, span L) is reduced to the ratio of K:

$$\mathrm{P_{max}} = \frac{2\sigma \mathrm{wd}^2}{3\mathrm{L}} \times \left(\frac{1}{K}\right) = \mathrm{P_{expected}}/K.$$

WOOD IDENTIFICATION

Groups of 40 timber scaffold boards were identified according to their trade names. A total of 17 different types of timber were detected (Table 3). Specific gravity (SG), modulus of rupture (MOR) and modulus of elasticity (MOE) were determined by bending test of small clear specimens. The average values are presented according

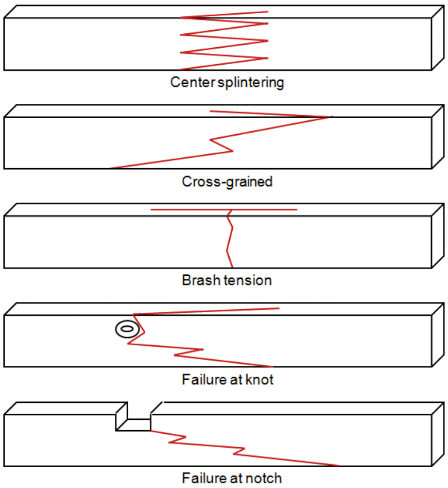

FIGURE 3. Facies of timber scaffold board failure (bottom view)

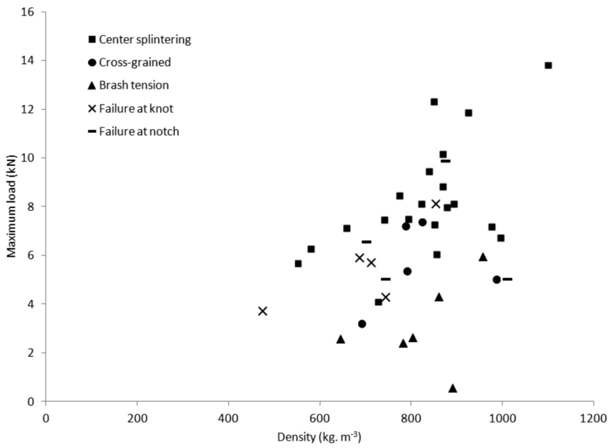

FIGURE 4. Maximum load versus density of the scaffold boards

TABLE 3. Average specific gravity, modulus of rupture and modulus of elasticity

Timber Group	Quantity of boards	Specific gravity		Modulus of rupture (N.mm^{-2})		Modulus of elasticity (N.mm^{-2})	
		Results	Established record	Results	Established record	Results	Established record
Bangkal	1	0.75	n.a.	118	n.a.	13985	n.a.
Bintangor	4	0.57	0.45-0.53	99	74	12524	14300
Derum	1	0.71	0.64-0.69	53	94	6761	15200
Kandis	1	0.84	n.a.	119	n.a.	14973	n.a.
Kelat	7	0.74	0.66-0.73	107	116	13032	17600
Kempas	11	0.74	0.71-0.74	132	122	17078	18600
Keranji	1	0.77	0.75-0.97	124	134	15924	20100
Keruing	1	0.68	0.57-0.81	97	76-133	11270	12900-22300
Kulim	1	0.82	0.66-0.71	135	107	15998	14900
Mata ulat	1	0.83	0.75	128	n.a.	16148	n.a.
Mempening	1	0.77	0.72-0.80	101	115-120	11817	18100-19400
Merbatu	1	0.84	0.74-0.77	134	119	17534	19700
Mertas	1	0.71	0.76-0.81	115	122	13821	18100
Minyak berok	2	0.85	0.65-0.69	115	101	14129	14800
Perupok	1	0.43	0.50-0.51	60	76-79	9048	12200-12600
Resak	1	0.96	0.62-0.86	159	n.a.	17995	n.a.
Samak	1	0.58	0.51-0.62	83	87-88	9802	12000-12300

to respective timber group. In addition, the average values of established records from Lee et al. (1993) are also presented for comparison. In general, SG, MOR and MOE were comparable to established records. Variation in the mechanical properties of timber is common, even from the same species. In this assessment, however, MOR and MOE of the timber derum was exceptionally low despite having high SG. On the other hand, kulim timber showed very high SG, MOR and MOE values than established records.

Most of the timber groups are regularly used for structural purposes. Timbers such as kelat, kempas, keranji, keruing, mata ulat and resak are suitable for construction of beams and bridges. In addition, kulim timber possesses a certain degree of resistance to attack by marine borers. Likewise, timbers of merbatu and mertas are often utilised for salt water piling and marine construction works. However, technical data on bangkal and kandis timbers are insufficient and they rarely available in the market. Taxonomic revision of kelat and keruing timbers produced numerous species hence the timbers have significant variation in their properties. The timbers of bintangor and perupok are categorised as light hardwood and seldom used for heavy constructional applications (Wong 1982).

FUNGI INVESTIGATION

Microscopic study was conducted on rotten samples to verify the presence of a decay agent. Slides were prepared to examine the cellular profile of the timber. Microscopic view of 40× magnification of the slides showed the

FIGURE 5. Microscopic view of hyphae on a sample slide

presence of hyphae (Figure 5). The growing phase of fungi is characterised by hyphae in the form of microscopic threads that developed from germinating spores. In addition, hyphae indicated the extent of microbiological deterioration of the timber boards.

Biological deterioration of timber is commonly caused by decay fungi and wood-boring insects such as termites, carpenter ants and beetles. Among these factors, decay fungi cause the greatest amount of damage to timber components of offshore and shoreline structures. Deterioration of timber by fungi is related to surrounding humidity and MC of the timber board. Similar to most organisms, decay fungi require oxygen plus favourable temperature and moisture. The temperature range for optimum growth of decay fungi is normally from 21 to 30°C. Timber MC of 40-80% is considered as favourable condition for fungal development on timber material (Highley & Scheffer 1989). Thus, in theory, if timber is properly dried and then protected against wetting, it will not decay. Here in Malaysia, the equilibrium MC for timbers in air-dry state is within the range of 15 to 19% (Wong 1982). Offshore, the on-site equilibrium MC is supposedly higher.

The rate of wood deterioration by decay fungi depends on the chemical and mechanical properties of timber and the species of the fungus. Thus, the service life of structural timbers highly depends on the selection of species, installation and maintenance procedures that suited to physical and climatic features of the construction site. Treatment of timber using appropriate preservatives increases its service life. Common options for preservatives are; oil-type preservatives such as creosote or petroleum solutions of pentachlorophenol and waterborne preservatives such as copper chrome arsenate and ammoniacal copper arsenate (Highley & Scheffer 1989). However, there is a concern for toxicity when the application of chemically treated timbers is in direct contact with human.

OCCUPATIONAL RISKS

Unlike applications such as beams and trusses, scaffold board does not only tolerate loads, but also contributes to the

TABLE 4. Risks of timber scaffold board application

Risk	Potential causes	Preventive measures
Cut and injury	Corrosion of end band Splinter of gouged board Projecting nail or screw Fallen objects from platform with gap Fallen objects from platform with notched board	Use non-corroded end band (e.g. polyester material) Visual grading – gouged board Visual inspection – contamination Visual grading – width of the board Avoid notching
Tripping	Boards of unequal thickness Bow and twisted board Sagging due to concentrated force or prolonged loading Projecting nail or screw Waney edge	Visual grading – thickness of the board Drying the board to 20% moisture content or below Avoid concentrated and prolonged placement of heavy load Visual inspection – contamination Visual grading – wane
Slipping	Oil or wax contaminant Loose wane Loose setting of board	In-service inspection – contamination Strip-off the bark completely In-service inspection – fixing
Fall from height	Tipping of board Structural failure of board Rotten board	Visual grading – length of the board In-service inspection – fixing Selection of suitable timber species Visual grading – knot Avoid notching and kerfing Selection of suitable timber species Periodically inspection – rot Minimise painting on the board's surfaces
Toxic	Board exposed to chemical	Avoid using boards with chemical treatment
Burn	Fire from burning residue	Avoid contact with welding work and other flames

safety and efficiency at the workplace. Thus, the application of timber scaffold board entails structural, durability and ergonomic considerations simultaneously. Based on the analyses of the timber boards, some potential occupational risks related with the use of scaffold board application are summarised in Table 4.

Based on the present discussion, it was found that some practices concerning timber boards violated the basic guidelines for scaffolding application. Even though they were not deliberate acts of disregarding safety, but some of the findings were clearly evidences of a policing failure.

Visual grading is a potential process to eliminate timbers with defects, thus reducing low strength boards. Although the MS 1714 (2003) visual grading method is practically available for the quality assessment of tropical timber, but it was never adequately proven effectual for scaffold board application. Thus the permissible limits of critical fissures such as knots, sapwood and cross-grained are uncertain. Besides, the effectiveness of MS 1714 method for flatwise-suspended application is not completely evaluated.

National Timber Industry Policy aims for global recognition on national timbers through certification scheme (Anon. 2009). It is time to provide greater importance to the development of regulation as well as the implementation of certification scheme for scaffold boards of Malaysian timbers.

CONCLUSION

Natural factors describing the physical characteristics of the boards were bowing, twisting, spring, kinked, corrosion of end band, shake formation, end split, surface check, rotten section, knot and wane. Man-made causes were described as gouge, notch, saw kerf, surface contamination and burnt mark. Three-point bending test gave the average maximum load of 6.64 kN. The lowest and highest maximum loads were 0.57 and 13.82 kN, respectively. The density ranged between 473 and 1100 kg/m^3. Five types of fracture observed during destructive test namely center splintering, cross-grained, brash tension, failure at knot and failure at notch. Microscopic study on selected samples confirmed the presence of hyphae. Based on the results of these tests, several workplace risks related to timber scaffold board application were determined – cut and injury, tripping, slipping, fall from height, toxic and burn.

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Forest Research Institute Malaysia
52109 Kepong
Selangor Darul Ehsan
Malaysia

*Corresponding author; email: mohdjamil@frim.gov.my

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