CALCULATING APPARENT RELIABILITY OF WOOD SCAFFOLD PLANKS

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ABSTRACT

Current safety requirements of the American National Standards Institute (ANSI A10.8) for wood scaffold planks are rooted in a history of generally good performance. The requirements are prescriptive in nature, making the standard easy to use. However, in its current form the standard prescribes only maximum allowable spans and limits its scope to three plank sizes and three load conditions. It does not specify what constitutes acceptable performance in solid-sawn scaffold planks. Thus, the requirements cannot be applied with uniform reliability to different plank systems. At the request of the ANSI A10.8 Subcommittee, an ad hoc advisory group from the wood industry was formed to address this problem.

This paper relates published requirements for wood scaffold planks in codes and standards to the allowable bending stresses published by lumber grading agencies based on a set of assumptions recommended by the ad hoc group. A methodology is proposed, based on requiring equivalent structural reliability, for designing alternative wood-based scaffold planks.

It is anticipated that this paper will be useful to producers and users of wood scaffold plank in its illustration of the sensitivity of both performance and reliability estimates to assumed material variability and distribution type. It is hoped that this report will generate discussion, both on the ANSI requirements themselves and on the best methodology to translate those requirements into measures of safety.

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INTRODUCTION

Scaffolds are temporary structures. They are intended to provide access to a building during its construction and maintenance for workers and materials. Because the configurations and loadings on scaffolds vary from site to site and because individual scaffolds are rarely in place long enough to develop a performance history, it is difficult to define performance requirements. By contrast, codes and standards for permanent structures have continually refined load and strength requirements.

This paper proposes a method by which strength requirements for one component of the scaffold system, the planks, can be defined in terms of standards used for permanent structures. The specific objectives of the paper are: (1) To define the intent of the current deterministic American National Standards Institute Standard (ANSI) strength requirement, (2) to relate published allowable stresses for wood planks to the ANSI requirement, (3) to calculate the apparent reliability index for commonly used solid-sawn wood planks, and (4) to propose a procedure for design of alternative wood-based planks based on the concept of equivalent reliability.

The National Bureau of Standards (NBS) has defined research needs for the development of improved scaffold standards. Hunt [1] has compiled many of the findings of the NBS study. His report is useful in this examination of wood scaffold planks because it reviews the requirements of many codes and standards, and it questions the lack of any published connection between scaffold standards and conventional wood design procedures. After attempting to compare stresses under loads specified by ANSI A10.8 [2] with an estimate of plank strengths, Hunt concluded that “the general provision of ANSI (and the Occupational Safety and Health Administration (OSHA) [3]), which specifies a 4 to 1 strength factor, reflects incognizance of the existing technical bases by which wood design values are determined.” Hunt based this statement on calculations for one span and loading in which changes in assumed load duration and plank moisture content can vary the safety factor on the fifth percentile from 2.7 to 6.9.

An ad hoc advisory group to the ANSI subcommittee revising the A10.8 standard was formed to address some of the questions raised by Hunt’s report, and to generalize the standard to cover wood scaffold plank other than traditional visually graded solid-sawn plank. This report examines current usage, based on input from the ad hoc advisory group and as specified in codes and standards, as a basis for determining assumed relationships between loads specified by ANSI A10.8 and strength requirements for wood scaffold planks. These relationships can be used to express design requirements for scaffold planks in terms of conventional allowable design stresses.

CURRENT PLANK REQUIREMENTS

Accepted plank usage

Examination of codes and standards shows that nominal 2- by 10- and 2- by 12-inch (actual 1½- by 9¾-in. (38- by 235-mm) and 1½- by 11¼-in. (38- by 285-mm)) scaffold planks are the most widely used sizes. Limited industry production data [4] support this observation. It appears that nominal 2- by 10-inch planks on an 8-foot (2.4-m) span are commonly used and widely accepted. This size is also used on 10-foot (3.0-m) spans, but such usage is only allowed by about half of the codes and standard cited by Hunt [1]. This break between universal acceptability on an 8-foot span and disagreement on a 10-foot span would appear to indicate a potential “boundary region” of safety in the opinions of specification writers.
ANSI specifies the design load due to the weight of a worker carrying hand tools to be 250 pounds (115 kg). This requirement would be excessively conservative if only static loads are considered, as only about 2% of adult males in the United States weigh at least 250 pounds [5]. However, if one multiplies the estimated average static weight (170 pounds, 75 kg) of a worker by a dynamic amplification factor to account for the effects of walking (averaging about 1.5 according to Sentler [6]), the resulting effective load becomes 255 pounds force (1135 N). Thus, this paper will assume that the ANSI 250-pound concentrated load requirement is a good estimate of the effective weight of one worker on a plank when the dynamic effects of walking are considered.

The following example of a nominal 2-by-10-inch plank under the ANSI “one worker” loading serves to illustrate the relationship between span and maximum induced stress. Under this load the induced maximum stress for a 1½-by-9¼-inch (38-by-235-mm) plank on a simple span ranges from 1,730 pounds per square inch (psi) (11,930 kN/m²) on an 8-foot (2.4-m) span to 2,160 psi (14,890 kN/m²) on a 10-foot (3.0-m) span.

So, in progressing from 1,730 to 2,160 psi (11,930 to 14,890 kN/m²), virtually all specifications implicitly accept the former stress, but half of them do not permit the increase to the latter.

ANSI Strength requirements

There is no single requirement that causes as much confusion and controversy in ANSI A10.8 as section 3.4, which states:

“Scaffolds and their components except as noted herein shall be capable of supporting without failure at least four times the maximum intended load. . .”

The first thing about this section that strikes the technical reader is that its wording violates the laws of statistical probability in explicitly requiring a zero failure rate. Undoubtedly, this was not intended. Consequently, if one is permitted to interpret the intent of this wording, the only problem is defining, in contemporary terms, the relationship between the load and resistance distributions implied by ANSI. If ANSI-specified loads can be assumed to be the average of the load distribution, a rough estimate of where this average (multiplied by 4) intersects the strength distribution can be found by a process of elimination.

Using the previously defined 2 by 10 on an 8-foot span with a maximum induced stress of 1,730 psi (11,930 kN/m²), the “target level” of comparison is 1,730 psi × 4 or over 6,900 psi (47,600 kN/m²). This stress can be compared to three different strength measures: the published allowable stress, the population near-minimum, and the population mean.

Starting with a conservative assumption, one can compare four times the ANSI-specified load to published allowable design stresses such as those found in the National Design Specification (NDS) for Wood Construction [7]. This would be a reasonable interpretation of the term “safety factor.” This assumption would require the NDS value to be over 6,900 psi (47,600 kN/m²) to satisfy the factor of 4 requirement. Although published allowable stresses for some grades of visually graded lumber exceed 2,000 psi (13,790 kN/m²), they rarely, if ever, exceed 3,000 psi (20,680 kN/m²). Thus, this assumption is not even close to being realistic.

The assumed relationship between load and resistance would be less stringent if one assumes that the aforementioned 6,900 psi (47,600 kN/m²) relates to a near-minimum (fifth percentile) short-term test strength. Even this assumption would require planks to have an average strength of over 13,000 psi for a population with an assumed coefficient of variation of 30%. Planks on a 10-foot span would need an average strength of over 17,000 psi to satisfy the same criterion. As in the
previous assumption, such values are not realistic.

A third, somewhat liberal, assumption would be that the stress induced by the ANSI load and the mean short-term strength are separated by a factor of 4. With estimated average strengths of visually graded solid-sawn wood scaffold planks in the range of 6,000 to 9,000 psi (41,370 to 62,050 kN/m²), this assumption is very good. Thus, current usage appears to be fairly close to producing an “average safety factor” of 4. In equation form, this can be expressed as:

\[ \sigma_{wL} \leq \frac{R_m}{4} \]  

in which \( \sigma_{wL} \) = maximum induced stress at ANSI working load and \( R_m \) = mean plank strength. This is the definition of the ANSI safety factor that will be used to relate ANSI requirements to traditional design stresses for lumber.

**Allowable stresses for wood**

As described more completely in the NDS, allowable stress values for use in design are based primarily on American Society for Testing and Materials (ASTM) standards augmented by additional experimental information. The relationship between allowable stress and the population is roughly this: The allowable stress is an estimate of a near-minimum point, commonly the fifth percentile, of the strength distribution in a short-term test divided by a factor to adjust for the anticipated duration of the design load, and a safety, or accidental overload, factor. ASTM D 2555 [8] provides information on strength of clear wood specimens and ASTM D 245 [9] explains how to adjust clear wood values to estimate design stresses for visually graded structural lumber.

In the ASTM procedure a population of wood specimens is tested, yielding a mean \( R_m \) and coefficient of variation \( V_R \) of strength. The fifth percentile of the population \( R_{0.05} \) is then calculated; commonly used normal statistics yield:

\[ R_{0.05} = R_m(1 - 1.645 V_R) \]  

and lognormal statistics yield:

\[ R_{0.05} = R_m e^{-(0.5 Y^2 + 1.645 Y)} \]  

where

\[ Y^2 = \ln(1 + V_R^2) \]

**TABLE 1**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Factor</th>
<th>Recommended by</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content</td>
<td>1.00</td>
<td>CSA</td>
<td>Normal scaffold use **</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>NDS</td>
<td>If dry use</td>
</tr>
<tr>
<td></td>
<td>0.80</td>
<td>NDS</td>
<td>If wet use</td>
</tr>
<tr>
<td>Duration of load</td>
<td>1.25</td>
<td>CSA</td>
<td>Assumes 7-day duration</td>
</tr>
<tr>
<td>Load sharing</td>
<td>1.10</td>
<td>CSA</td>
<td>3-plank minimum **</td>
</tr>
<tr>
<td></td>
<td>1.15</td>
<td>NDS</td>
<td>3-member minimum</td>
</tr>
<tr>
<td>Fire retardant treated</td>
<td>0.90</td>
<td>NDS</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.82</td>
<td>APA</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.75</td>
<td>AITC</td>
<td></td>
</tr>
</tbody>
</table>

* CSA S269.2-M1980 [10].

** Factor explicitly given for scaffold plank use.
The fifth percentile is divided by a factor to account for load duration effects (approximately 1.62 to correct to 10-year or “normal” duration) and by an additional explicit safety factor (1.3), so:

$$f_b = \frac{R_{0.05}}{2.1}$$

in which $f_b$ = published allowable bending stress.

In addition to the factors already considered, published grading rules and corresponding allowable stresses must account for load-sharing, strength ratio and size effects, and adjustment for moisture content. Final choice of appropriate stress modification factors to account for these effects is the responsibility of the engineer or designer. However, published standards and other literature (Table 1) offer useful guidelines in this area.

Table 1 shows that the Canadian Standards Association (CSA) [10] scaffold standard specifies factors for duration of load (1.25 for 7-day duration) and for load-sharing systems (1.10, 3-plank minimum). It also provides guidance for definition of inservice moisture condition. Although some NDS factors are also shown in the table, NDS does not specifically address scaffold applications. The CSA scaffold standard is of particular interest specifically because it addresses wood scaffold plank in terms familiar to both scaffold users and wood designers. Its basic reference to design of wood scaffold members [11] is the primary design reference for wood structures in Canada. In contrast to the North American approach, the Standards Association of Australia [12,13] specifications for wood scaffold planks are formatted to look like grading rules rather than design specifications. The British Standards Institution [14] specification for timber scaffold boards is formatted much like the Australian standards.

One factor in Table 1, concerning the effects on strength and on toughness of fire-retardant treatments (FRT), is an area currently under active research investigation. The NDS specifies a 10% reduction in allowable bending stress for fire-retardant-treated wood. However, research shows [15] that impact strength is more severely affected by FRT chemicals than is bending strength. Some industry associations in the United States [16,17] are already using larger reductions of up to 25% as normal design practice. As scaffold planks are potentially subjected to many impact or dynamic loads, a similar reduction may be appropriate.

Equations (1) through (4) can be used to find “scaffold use factors” for various assumed load durations and distribution parameters. Table 2 contains factors that must be applied to published allowable stresses if the ANSI-specified safety factor is to be preserved. For example, assuming a 30% coeffi-

### Table 2

Factors to relate allowable stresses to ANSI scaffold use *

<table>
<thead>
<tr>
<th>$V_a$</th>
<th>Normal</th>
<th>Lognormal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>5-Minute</td>
<td>7-Day</td>
</tr>
<tr>
<td></td>
<td>basis</td>
<td>basis</td>
</tr>
<tr>
<td>0.20</td>
<td>0.78</td>
<td>0.60</td>
</tr>
<tr>
<td>0.25</td>
<td>0.89</td>
<td>0.69</td>
</tr>
<tr>
<td>0.30</td>
<td>1.04</td>
<td>0.80</td>
</tr>
<tr>
<td>0.35</td>
<td>1.24</td>
<td>0.96</td>
</tr>
</tbody>
</table>

* $\sigma_{\text{scaffold}} = \text{factor} \times f_b$. 
cient of variation in strength and using the traditional assumption of a normal distribution coupled with the CSA recommended 7-day duration factor yields:

\[(\text{stress})_{\text{ANSI}} \leq 0.80 \cdot f_b\]

in which 0.80 is the appropriate entry from Table 2.

For simplicity, the plank dead load stress \((s_{DL})\) was intentionally left out of the derivation above. It can be included if \((\text{stress})_{\text{ANSI}}\) is defined as:

\[(\text{stress})_{\text{ANSI}} = \sigma_{WL} + \sigma_{DL}/4\]

(5)

The dead load stress in Eq. (5) is divided by 4 because it is excluded in the ANSI standard from the required safety factor of 4.

Based on this derivation, and on the judgment of the ad hoc advisory committee to the ANSI A10.8 subcommittee, the factor relating allowable stresses to stresses for scaffold plank will be 0.80 in the revised A10.8 standard.

**RELIABILITY OF SCAFFOLD PLANKS.**

**Computed reliability of solid-sawn**

Methods for computing reliability of structural systems abound in the literature [18,19,20]. Most recent applications of reliability-based analyses to codes and standards have settled on “first-order second-moment” methods to calculate a reliability index, \(\beta\) [21].

As the only objective in calculating reliability indices in this paper is to establish a basis for comparison, the calculations are kept simple and brief. Assumptions such as distribution type and relative positions of mean load and resistance must be reasonable but, in the absence of adequate data, they certainly cannot be rigorous.

In the basic calculations, load and resistance are assumed to have the same type of distribution. The calculations were performed both on assumed normal and lognormal distributions, but lognormals were believed to better represent loads and resistances. Both of these distributions can be completely characterized solely by a mean and standard deviation (or coefficient of variation).

Although most distributions in the literature for strength of wood members qualitatively resemble the lognormal (right-skewed), recent test data indicate that some high grades of lumber may actually be left-skewed. Further study in this area is recommended.

For purposes of this example, ANSI section 3.4 will be interpreted to intend that planks designed according to ANSI A10.8 have a mean strength equal to four times the mean induced stress. This is the definition of the “average safety factor” of 4 discussed earlier.

In one notable departure from the exact wording of section 3.4 in ANSI A10.8, the author has chosen to substitute “ANSI working load” for “maximum intended load.” The substitution is for two reasons; first, the term “maximum intended load” is not defined either in ANSI or anywhere else in the literature for scaffolds, and second, the author believes that the ANSI working loads represent a load more likely at or above the mean of the load distribution than below. Thus, the substitution is probably conservative.

If normal distributions are assumed the reliability index can be expressed as:

\[
\beta = \frac{R_m - Q_m}{\sqrt{\sigma_R^2 + \sigma_Q^2}}
\]

(6)

in which \(R_m = \text{mean strength}, Q_m = \text{mean load effect}, \sigma_R = \text{standard deviation, coefficient of variation in strength}, \text{and} \sigma_Q = \text{standard deviation, coefficient of variation in load effect.}\)

If lognormal distributions are assumed:

\[
\beta = \frac{\ln(R_m/Q_m) + (Z^2 - Y^2)/2}{\sqrt{Y^2 + Z^2}}
\]

(7)
TABLE 3
Calculated reliability indices (β) for strength variability (V_r) range expected for solid-sawn

<table>
<thead>
<tr>
<th>V_r</th>
<th>Distribution type</th>
<th>Lognormal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Lognormal</td>
</tr>
<tr>
<td></td>
<td>V_r = 0.2</td>
<td>V_r = 0.2</td>
</tr>
<tr>
<td>0.20</td>
<td>3.64</td>
<td>3.85</td>
</tr>
<tr>
<td>0.25</td>
<td>3.51</td>
<td>3.65</td>
</tr>
<tr>
<td>0.30</td>
<td>3.35</td>
<td>3.43</td>
</tr>
<tr>
<td>0.35</td>
<td>2.94</td>
<td>2.94</td>
</tr>
</tbody>
</table>

in which \( Y^2 = \ln(1 + V_r^2) \) and \( Z^2 = \ln(1 + V_r^2) \).

Based on the “average safety factor” of 4 as interpreted by this author from ANSI A10.8, by definition:

\[ R_m/Q_m = 4 \]  

(8)

Table 3 shows the calculated reliability indices for normal and lognormal distributions over a range of load and strength variability.

The calculated reliability index, \( \beta \), does not reflect actual failure probabilities for scaffold plank systems. The index represents the reliability of a population of single-plank scaffold platforms under a hypothetical population of loads. In reality, planks are often part of multiple systems, which tends to increase reliability. In addition, a major intangible that dramatically decreases the probability of overload is the “human factor”. The loads on scaffold planks are not truly random or induced by uncontrollable phenomena. Workers place the loads and walk onto the platforms. Few workers would walk onto a plank already deflecting excessively. Thus, the \( \beta \)’s calculated here are only used for calibration of the relative reliability of various plank systems.

As shown in Table 3, the calculated reliability index for visually graded solid-sawn plank based on these assumptions ranges from 2.1 to 4.9. The table also shows that the calculated reliability is significantly different for assumed normal versus lognormal distributions, but is not overly sensitive to small changes in assumed coefficient of variation for solid-sawn plank.

Here, the ad hoc advisory group to the ANSI A10.8 subcommittee has decided that a single \( \beta \) should be recommended for calibration. This group recommends that lognormal distributions be assumed for these calculations and that both distributions have an assumed variability of 30%. Thus, the assumed reliability index for visually graded solid-sawn scaffold plank is 3.34.

Equivalent reliability

As wood-based scaffold planks other than visually graded solid-sawn planks enter the marketplace, a rational basis for calculating their design requirements would be to require

<table>
<thead>
<tr>
<th>V_r</th>
<th>Average safety factor</th>
<th>V_r</th>
<th>Average safety factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>2.59</td>
<td>0.20</td>
<td>3.19</td>
</tr>
<tr>
<td>0.075</td>
<td>2.64</td>
<td>0.225</td>
<td>3.36</td>
</tr>
<tr>
<td>0.10</td>
<td>2.71</td>
<td>0.25</td>
<td>3.55</td>
</tr>
<tr>
<td>0.125</td>
<td>2.80</td>
<td>0.275</td>
<td>3.76</td>
</tr>
<tr>
<td>0.15</td>
<td>2.91</td>
<td>0.30</td>
<td>4.00</td>
</tr>
<tr>
<td>0.175</td>
<td>3.04</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Assumes lognormal distribution, \( \beta = 3.34 \), and \( V_r = 0.3 \).
equivalent reliability. In this way materials that exhibit lower strength variability could be designed with a lower average safety factor without decreasing their overall reliability.

Equation (7) can be solved to find the relative safety factor, \( x \) (defined as \( R_m/Q_m \)), needed to obtain equivalent reliability (equal \( \beta \)) for alternative wood-based planks:

\[
x = \exp \left[ \beta \left( Y^2 + Z^2 - (Z^2 - Y^2)/2 \right) \right]
\] (9)

Substituting \( \beta = 3.34 \), this equation yields the average safety factor required for plank populations with coefficients of variation, \( V_r \), to have the same reliability index as solid-sawn (Table 4).

**APPLICATION TO SCAFFOLD PLANK DESIGN**

Because the application of this procedure may be somewhat confusing, this section of the paper provides examples of calculations for both visually graded solid-sawn planks and for alternative wood-based planks.

*Visually graded solid-sawn planks.* The published allowable stress must be corrected for moisture condition, depth effects, and scaffold use. Normal scaffold application is assumed to be dry use [10]. Depth corrections are minor, but are mentioned here because grading agencies commonly use a 3-inch (76-mm) depth basis in establishment of allowable stresses. The scaffold use factor (0.80) already includes a 1.25 load duration increase.

Thus, if a hypothetical 1½- by 9¼-inch (38- by 235-mm) scaffold plank had a published wet-use stress of 1.800 psi (12,410 kN/m²), this number could be multiplied by 1.25 if it qualified for dry-use stresses, by \((3/1.5)^{1.09}[9]\) to account for depth effects, and finally by 0.80 to convert to scaffold use:

\[
1.800 \times 1.25 \times (3/1.5)^{1.09} \times 0.80
\]

\[
= 1.940 \text{ psi (13.380 kN/m²)}
\]

The resulting “factored” allowable stress is then compared to stresses induced by ANSI loads. For a one worker loading on an 8-foot (2.4-m) span:

\[
(\text{stress})_{\text{ANSI}} = \sigma_{\text{wL}} + \sigma_{\text{dL}} / 4
\]

\[
= 1,730 + 90 / 4
\]

\[
= 1,752 < 1,940, \text{ acceptable.}
\]

*Alternative wood-based planks.* Derivation of allowable design stresses for planks other than visually graded solid-sawn are based on the premise that the mean and coefficient of variation of the plank population are known. It is beyond the scope of this paper to recommend either a minimum number of tests or a specific test configuration. However, because the choice of relative safety factor from Table 4 is highly dependent on the coefficient of variation, this parameter must be determined in a statistically valid manner.

The allowable stress for scaffold use is determined by dividing the population mean by the appropriate factor from Table 4 and correcting to 7-day duration:

Scaffold allowable stress

\[
= \left( \frac{\text{mean of short-term test}}{\text{factor}} \right) \times \left( \frac{1.25}{1.62} \right)
\]

in which “factor” = relative safety factor from Table 4.

For a hypothetical population of planks with a short-term mean MOR of 7,000 psi (48,260 kN/m²) and a coefficient of variation of 15%, the factor (from Table 4) is 2.91 and the scaffold allowable stress is:

\[
(7,000/2.91) \times (1.25/1.62)
\]

\[
= 1,860 \text{ psi (12,820 kN/m²)}
\]

When derived in this manner, the scaffold allowable stress is similarly compared to stresses induced by ANSI loads. For the same one-worker loading on an 8-foot (2.4-m) span:

\[
(\text{stress})_{\text{ANSI}} = \sigma_{\text{wL}} + \sigma_{\text{dL}} / \left( \text{factor} \right)
\]

\[
= 1,730 + 90 / 2.91
\]

\[
= 1,760 < 1,860, \text{ acceptable.}
\]
DISCUSSION OF ACTUAL RELIABILITY

As in all analytical exercises, the calculations in this paper consider only a limited number of physical parameters and contain certain assumptions (Appendix A). Thus some discrepancy between calculated or “apparent” reliability and actual “in-use” reliability can be expected.

Two factors come to mind that would increase actual reliability in the field—worker experience and wood’s “special” material behavior. Worker experience is the biggest intangible influence on actual field reliability. Strength distributions of lumber are based on testing all pieces in a given sample, but if the same sample appeared on a job site, workers would select planks for various uses, and discard some, based on how they “feel.” This “feel,” based on experience with many planks, may include consideration of such factors as density, ductility, and possibly even some dynamic properties of the plank. Some material properties inherent to wood are its ability to withstand impact loads substantially greater than its long-term strength and its characteristic “crackling noise” as failure approaches. Both properties could provide additional measures of safety in typical field use.

Conversely some scaffold planks are proof-loaded in the field prior to use, often to multiples of design load, in an attempt to eliminate weaker boards. In fact, this practice was actually recommended by the National Safety Council in 1937 [22]. As discussed by Freas [23] with respect to similar practices on ladders, such testing, if improperly done, can damage the plank to the point of eliminating its ductile failure mode. Thus, such onsite proof testing can actually decrease reliability.

For the reasons mentioned above, it is anticipated that the actual reliability of wood scaffold planks would be higher than the calculated reliability in this paper if worker experience and ductile material behavior are accounted for. However, this additional safety could be eliminated if a plank exhibits a brittle failure mode. Thus, neither the definition of safety factor (average = 4) nor the calculated reliability ($\beta = 3.34$) given in this paper should be extrapolated to nonwood planks, or even to wood-based planks that do not exhibit the aforementioned characteristics of wood behavior under load.

SUMMARY AND RECOMMENDATIONS

This paper has reviewed the safety requirements for scaffold planks in ANSI A10.8 and has related those requirements to published allowable stresses based on ASTM D 245.

A methodology is proposed by which wood-based scaffold planks that are different from traditional visually graded solid-sawn planks can be evaluated on an equivalent reliability basis.

All calculations and discussions herein are based on many assumptions, most of which are explicitly or implicitly part of current ANSI or ASTM standards. The calculations show that solid-sawn scaffold planks can be designed using published allowable stresses with an added safety factor to satisfy ANSI requirements.

The exercises performed in this paper are valid indicators of actual safety of wood scaffold planks only if loadings on planks are truly represented by ANSI load requirements and if the strength of full-size scaffold planks can be deduced through ASTM procedures. To verify both load and resistance the following research is recommended:

1. Onsite load surveys to determine the true distribution of plank loads.
2. Surveys of plank usage—recording plank sizes, grades, species, moisture content, and spans.
3. Detailed study of plank failures.
4. Experimental determination of the strength distribution of full-size planks.
5. Study of jobsites to determine whether
planks are re-sorted or otherwise selectively used.

Completion of research in all five areas is necessary before actual onsite reliability of scaffold planks can be determined.

ACKNOWLEDGEMENTS

Without the recommendations of the ad hoc advisory group to the ANSI A10.8 subcommittee, this report would be little more than an academic exercise. The contributions of John Sebelius, Ray Todd, Brad Dempsey, Paul Myhaver, and especially Sherman Nelson, the chairman, are gratefully acknowledged.

Also acknowledged are Fred Petersen, chairman of the A10.8 subcommittee, under whose guidance the standard is being revised and Bill Galligan, for his extensive review of the initial draft of this paper.

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23 A.D. Freas. Don't test that ladder!. International Fire Fighter. 32 (10) (1949) 15–16.

APPENDIX A: ASSUMPTIONS

Assumptions implied in ANSI A10.8

(1) Working loads are realistic and reflect the approximate "average" load for a given
use. (Based on Hunt’s limited load survey the area loadings appear to be underestimated; based on the weight distribution of workers, the concentrated loadings are extremely conservative if only static loads are considered, but more realistic if dynamic effects are included.)

(2) The spans specified for wood plank are currently used, and are generally satisfactory.

(3) The specified safety factor of 4 can be interpreted as an “average safety factor”—that is, the average strength equals four times the average induced stress.

**Additional assumptions**

(1) The published allowable stress for lumber represents the fifth percentile of the strength distribution divided by a factor that includes a “safety factor” and a “load duration factor”. (For bending, $SF \times LDF = 2.1$.)

(2) The load duration effect, as defined in the NDS [5], is reasonably accurate for high grades of lumber such as scaffold plank.

(3) Based on the CSA Standard [10], the appropriate duration factor for scaffold use is “normal” duration $\times 1.25$, representing an assumed design load duration of 7 days.

(4) Reliability equations can be used to establish the apparent reliability of current systems.

(5) Normal or lognormal distributions can adequately characterize load and strength distributions.

(6) The coefficient of variation of the load distribution can be adequately characterized at about 30% for each load condition. This value is cited in reference [20] and is estimated to be slightly conservative, especially for the concentrated load cases.