A Comparative Assessment of the Scantling Rules for Indonesian Wooden Fishing Boats: ISO 12215-5:2008 and BKI Wooden Boat Regulation (2006)

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ABSTRACT

In this study, ISO 12215-5 load-resistance methods were applied using measured properties of Indonesian hardwoods to optimize scantlings for traditional wooden fishing boats, with the results benchmarked against BKI (2006) rules. Six commonly used tropical species were analyzed, and scantlings were computed on a dataset of 74 designs and 27 operational vessels, incorporating density and durability considerations. Compared with BKI's geometry-based formulas, ISO's stress-based approach produced leaner yet compliant scantlings and a repeatable species-sensitive workflow. The practical impact includes density-corrected improved compliance for keels and shelves, and a clarified procedure for integrating the durability class into the safety margins for tropical service. The findings support aligning the national practice with ISO's load-resistance framework while calibrating margins to indigenous timber behavior.

Keywords-scantling optimization; ISO 12215-5; BKI 2006; wooden fishing boats; tropical hardwoods; density correction

I. INTRODUCTION

The use of traditional wooden fishing vessels remains widespread in Indonesian coastal and small-scale fisheries [1]. However, the structural rules governing their construction, particularly those set by the Indonesian Classification Bureau (BKI, 2006) [2], rely predominantly on empirical and geometric formulations that do not explicitly incorporate the mechanical behavior of the materials or real-world operational loads. In contrast, ISO 12215-5:2008 adopts a load-resistance methodology that integrates stress-based calculations and safety factors derived from the mechanical properties of boatbuilding materials (ISO, 2008; SSC-446, 2007) [3, 4]. This study, therefore, foregrounds a direct comparison and ISO-guided optimization of scantlings to clarify the implications for Indonesian practice.

This discrepancy is significant in the Indonesian context, where indigenous hardwoods, such as Swietenia macrophylla, Shorea spp., and Paraserianthes falcataria, are commonly used. These species exhibit varying densities, decay resistance, and strength properties, which influence their suitability for marine applications. Prior research has shown that tropical hardwoods, although locally available, may not always meet safety thresholds if evaluated under international criteria [5, 6]. Additionally, the wood degradation due to moisture and biological exposure—such as rot and borer attacks—further reduces the effective strength of components over time [7, 8]. Studies in humid/tropical service further emphasize the need to account for density and durability class when applying the ISO-based design to wooden craft.

Recognizing the limitations of the BKI approach, this study proposes an engineering-based optimization of the scantling requirements by integrating ISO 12215-5 formulas with bending strength test data of six indigenous wood species. The research addresses the following questions: (RQ1) Do ISO-based scantlings differ materially from BKI (2006) across hull components? (RQ2) Do density and durability adjustments improve compliance in tropical service? (RQ3) How should mixed-species construction be reflected in rule application? The study tests the following hypotheses: (H1) ISO yields thinner yet compliant scantlings versus BKI; (H2) density/durability corrections increase compliance; (H3) component-wise species assignment affects the required dimensions. The study addresses both the structural integrity and practical feasibility of maintaining traditional boatbuilding with improved engineering accuracy and material efficiency.

II. METHODS

This study integrates comparative rule-based and experimental approaches to optimize the structural scantling of traditional Indonesian wooden fishing vessels using indigenous hardwoods. To determine the safety factor applied in the BKI Wooden Boats Regulation (2006), a comparison was conducted with ISO 12215-5:2008. While BKI defines scantling purely based on a geometric function of the vessel's main dimensions (length *L*, breadth *B*, and depth *H*), ISO adopts a load-resistance method that accounts for mechanical strength and stress calculations. The study applies statistical uncertainty methods for analysis. The ISO stress design for planking is defined by:

$$t = s \times \sqrt{\frac{p_d}{k_2 \cdot \sigma_d}} \tag{1}$$

where t is the required plank thickness (mm), s is the panel spacing (mm), P_d is the design pressure (N/mm^2), σ_d is the design stress (N/mm^2), and $k_2 = 0.5$ is the material correction factor for orthotropic wood.

By rearranging the units and applying the value of k_2, the formula can be transformed into a load capacity model as:

$$p_d = 2 \times \sigma \left(\frac{t}{s}\right)^2 \tag{2}$$

ISO defines the plank thickness as given in (2), where $\sigma_d = 0.5 \times \sigma_{uf}$. Rearranging for BKI scantling numbers gives an implicit BKI safety factor of 3.0, three times ISO's value. This transformation indicates that the ISO plank thickness requirement is derived from the standard plate response equation for materials under load, as discussed in SSC-446. It confirms that ISO relies primarily on the design stress and structural response rather than the empirical dimensional rules. A similar approach is adopted in the ISO frame design, which considers the maximum bending moment on beams clamped at both ends. For such frames, ISO assumes a design stress that is 0.4 of the ultimate flexural value, or a safety factor of 2.5. (ISO 12215-5:2008; SSC-446, 2007)

A model dataset of 74 fishing-boat designs was created using typical hull ratios from traditional Indonesian boatyards (UD. Jati Pagar Nusa), covering L/B = 3.48-4.12 and B/H = 2.14-2.4. The selected boatyard represents traditional shipyards with similar dimensional ratios and long-standing construction practices, producing wooden vessels distributed across multiple provinces. The plank thickness and frame section modulus were calculated using both ISO and BKI methods. The selection criteria included the representativeness across common length classes and the ratio bounds observed in the field, with outliers excluded. The ratio of the results provided a baseline to estimate the implicit safety factor in BKI, approximately 3 times that of ISO.

Secondary data from [9] were used to compare the derived design stress limits to the actual bending strength (four-point test) of six Indonesian hardwood species. The ultimate flexural strength σ_{uf} values were compared to BKI and ISO stress assumptions. The species selection was justified by prevalence in Indonesian yards, supply-chain availability, and coverage of density/durability classes. The study used the 5th percentile of greater than or equal to 90 samples per species for conservativeness and quantified uncertainty.

Measurements from 27 operational wooden boats across seven provinces were collected, including principal dimensions and in-situ density. Because vessels mix species by function rather than using a single timber, the study assigned materials by components (keel/keelson, stem/sternpost, frames, planking versus deckhouse/bulkheads). Also, in places where the species were unknown, bracket analyses were conducted using heavy/medium versus light timbers. The structural compliance was assessed using original BKI rules and corrected utilizing a density ratio factor following ISO's approach for adjusting scantling to actual material properties. The structural compliance was evaluated using BKI rules and adjusted with ISO-based density correction. The correction used $k_\rho = \sqrt{\rho_{ref}/\rho_{act}}$ for thickness and $k_\rho = \rho_{ref}/\rho_{act}$ for section modulus. Compliance was considered achieved when the actual values exceeded the corrected requirements for both the plank thickness and frame modulus.

III. RESULTS AND DISCUSSIONS

ISO 12215-5 uses a load-resistance approach based on material strength, particularly the modulus of rupture and wood density, yielding a design stress (σ_d) of $0.5\sigma_{uf}$ (ISO, 2008; SSC-446, 2007) [10, 11]. In contrast, BKI applies empirical formulas based on hull dimensions (BKI, 2006), lacking stress-based calibration. Figure 1 shows that BKI generally requires thicker planks than ISO across the $L(B/3+H)$ range, indicating higher implicit safety margins but lower material efficiency [12]. Figure 2 compares transverse frame modulus requirements. ISO yields consistent values tailored to actual stresses, while BKI's values are over-dimensioned, with limited sensitivity to material properties [13, 14]. This gap highlights the advantage of ISO in integrating structural mechanics and optimizing timber use [15]. The mechanical tests on Paraserianthes falcataria, Shorea spp., Swietenia macrophylla, and others show large variations in bending strength (CoV up to 38%) [6]. As listed in Table I, ISO safety factors align closely with the lab tests, while BKI implies safety factors greater than 3, which may misrepresent the actual load resistance [5]. ISO's stress-based design better represents timber performance across species variability, supporting the modernization of national standards with verified mechanical data [16].

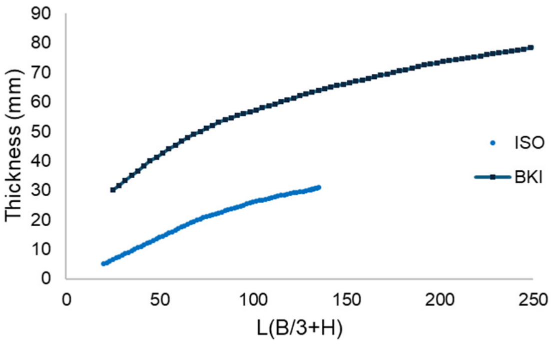

Fig. 1. Comparison of plank thickness requirements based on BKI and ISO standards as a function of *L*(*B*/3+*H*).

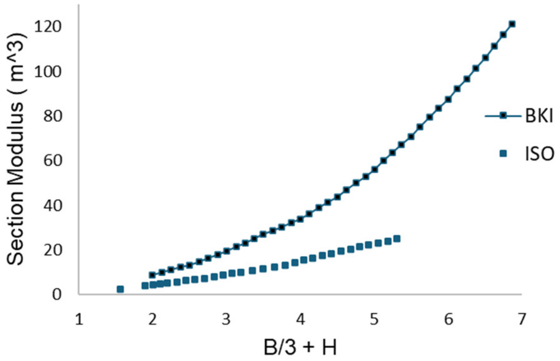

Fig. 2. Comparison of transverse frame section modulus requirements based on BKI and ISO standards as a function of (*B*/3 + *H*).

TABLE I. COMPARISON OF BENDING STRENGTH: BKI AND ISO STANDARDS VERSUS ACTUAL TEST RESULTS FOR VARIOUS WOOD SPECIES

Wood species (scientific name)	**Bending stress (MPa)**	**ISO σ_{uf} (MPa)**	**BKI σ_{uf} (MPa)**	**σ_{uf} BKI/actual ratio (%)**
Paraserianthes falcataria	22.7	26.3	7.03	31
Anthocephalus cadamba	27.2	23.29	6.22	22.9
Shorea spp.	51.2	31.78	8.49	16.6
Palaquium spp.	33.1	33.98	9.08	27.4
Swietenia macrophylla	28.4	32.88	8.78	30.9

The long-term exposure reduces the wood strength. Table II indicates that Class III woods (e.g., Koompassia malaccensis) may lose up to 60% compressive strength by 15 years, whereas Styrax benzoin shows smaller losses. This pattern matches prior reports linking the microbial decay to reduced capacity [17, 18].

Long-term exposure reduces the wood strength significantly. As depicted in Table II, Class III woods like Koompassia malaccensis lose up to 60% compressive strength after 15 years, while Styrax benzoin performs better. This trend, as evidenced in Figure 2, echoes findings from [17, 19], linking the microbial decay to structural failure.

BKI does not explicitly account for decay, whereas ISO includes moisture/biological resistance provisions [20]. Thus, ISO offers a more realistic basis for tropical service, especially under marine degradation. Thus, ISO provides a more realistic basis for tropical vessel safety, particularly under marine degradation scenarios [7]. The inspection of 27 wooden vessels across Indonesia revealed that structural elements like hull planks generally met BKI dimensions. However, keels and shelves often fell short. Table III shows that the compliance improved after applying density correction, reflecting higher actual wood densities than assumed, as presented in Figure 3. After the density correction (ρ_{std}/ρ_{act}), the compliance of keels rose from 60 % to 95 % (± 1 mm plank, ± 2 cm^3 frame uncertainties), confirming the optimization.

TABLE II. COMPRESSIVE STRENGTH OF WOOD OVER TIME IN DIFFERENT DURABILITY CLASSES

Wood species	**Part**	**Durable class**	**Strong class**	**Compressive strength (kg/cm^2)**		
				1 year	**10 years**	**15 years**
Koompassia malaccensis Maing	Keel	III-IV	I-II	716.9	406.5	263.9
Styrax benzoin	Stem	I	I-II	606.4	480.1	467.6

TABLE III. ASSESSMENT OF STRUCTURAL COMPLIANCE OF WOODEN SHIP COMPONENTS BEFORE AND AFTER ADJUSTMENT FOR WOOD DENSITY

Ship component	**As measured**		**Adjustment due to density**	
	Accepted	**Rejected**	**Accepted**	**Rejected**
Shell Plank	0.85	0.15	1.00	0.00
Deck Plank	0.90	0.10	1.00	0.00
Frames	1.00	0.00	1.00	0.00
Floor	1.00	0.00	1.00	0.00
Shelves	0.25	0.75	0.90	0.10
Keel	0.60	0.40	0.95	0.05

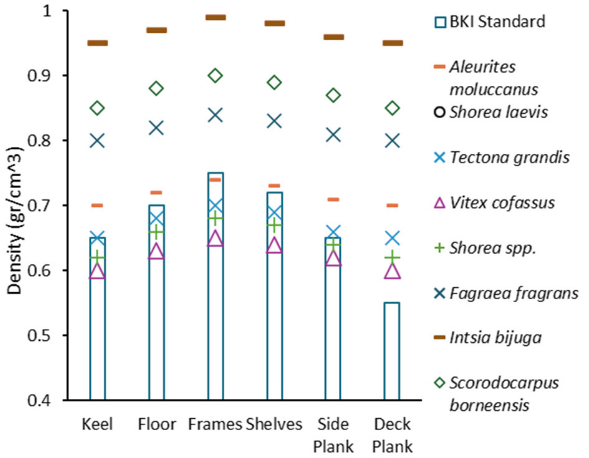

Fig. 3. Comparison of measured wood density in wooden boat components against the BKI standard.

This finding supports the feasibility of integrating density-based adjustments in local standards, in line with ISO's adaptable approach [6, 21]. Aligning regulations with the observed material behavior can improve safety and material efficiency, especially for keels and shelves.

IV. DISCUSSIONS

ISO 12215-5's load–resistance framework explains the observed differences with BKI and clarifies why ISO yields leaner yet compliant scantlings. As summarized in Figures 1 and 2, the median ISO/BKI thickness and section-modulus ratios favor ISO. Moreover, Figure 3 demonstrates that applying measured densities shifts several components from non-compliant to compliant [6, 16]. Interpreting these results with the 5th-percentile material basis, as presented in Table I, indicates that BKI embeds higher implicit safety margins, which can increase the structural mass and fuel use without proportional safety gains. Thus, the advantage is not merely thinner scantlings, but a stress-based sizing that ties capacity to the measured timber properties [22, 23].

Tropical service accelerates material degradation; therefore, the durability class must be explicitly considered in the design. Table II exhibits an up to 60% compressive-strength loss by 15 years for lower-durability woods, justifying decay-adjusted margins [21, 24]. When density and durability are accounted for, the component-level compliance improves, as portrayed in Table III, especially for keels and shelves, supporting that ISO-integrated optimization is both material-efficient and safety-robust in humid, biofouling-prone waters.

The following are the practical pathways for standards:

- Density corrections and durability-class factors should be embedded in scantling checks.
- Periodic nondestructive evaluation, such as ultrasonic/MOEd, is required to track in-service property loss [25].
- Performance-based acceptance criteria tied to ISO design stresses with stated reliability targets should be adopted.

This approach maintains the structural integrity while reducing unnecessary timber use and improving the payload/fuel efficiency.

V. CONCLUSION

Integrating ISO 12215-5's stress-based design with indigenous timber data improves structural accuracy and material efficiency relative to geometry-based BKI rules. With density and durability adjustments, compliance increases—most notably for keels and shelves—and the design capacity better reflects the in-service behavior.

Based on the obtained findings, the current study offers the following recommendations for regulators:

- Adoption of ISO-aligned scantling checks with mandatory density and durability inputs.
- Periodic inspection/NDT for aging timber is required.
- Publishing component-wise guidance for mixed-species construction.

The study makes the following recommendations for the industry:

- Assigning high-durability/high-strength woods to primary members and lighter species to superstructures to manage weight and cost.
- Limitations (species records, sampling, decay assumptions) suggest caution in generalization, but the framework is transferable and supports progressive updates of national rules.
- Future work should establish life-cycle reliability targets, expand field property databases, and test hybrid timber–composite details.

DATA AVAILABILITY

The dataset, along with processing scripts, is available from the corresponding author upon reasonable request.

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