International Journal of Civil
Engineering (IJCE)
ISSN (P): 2278-9987; ISSN (E): 2278-9995
Vol. 9, Issue 3, Apr–May 2020; 1-8

International Academy of Science, Engineering and Technology
Connecting Researchers; Nurturing Innovations

SIMPLE METHODOLOGY OF MEASUREMENT UNCERTAINTY FOR MECHANICAL TEST PARAMETERS OF PLYWOOD ON STATIC BENDING STRENGTH

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ABSTRACT

The main objective of this study was to develop a simplified methodology for assuring the quality of wood based panel products through measurement of mechanical properties of static bending strength viz. modulus of rupture of plywood along or across the grain direction. The methodology includes the measurement of uncertainty related to these parameters that plays a vital role in quality assurance plan. Measurement of uncertainty may be quantified using calculation estimation of single components of uncertainty. For estimation of uncertainty of mechanical test parameters in some cases, it is hardly possible to include all possible components of uncertainty. This paper presents a methodology of calculation of measurement uncertainty based on test data of samples received for testing, data obtained from internal quality control and data on inter-laboratory comparison, thus reaching maximum probability of comprising all components of uncertainty. The knowledge of uncertainty in measurement is of great importance for all users of laboratory services, laboratory itself and all interested parties that benefit from the results of research where reliability of rest results are of outmost importance.

KEYWORDS: *Estimation of Uncertainty, MoR, Plywood, Standard Deviation*

Article History

Received: 30 Mar 2020 | Revised: 31 Mar 2020 | Accepted: 10 Apr 2020

INTRODUCTION

Quality of measurements has assumed great significance in view of the fact that measurements provide a basis for all control actions. Incidentally, the word measurement should be understood to mean both a process and the output of that process. It is widely recognized that the true value of a measurement and (or a duly specified quantity to be measured) is indeterminate, except when known in terms of theory. From the concerned measurement process, we can obtain an estimate of approximation to the true value. Even when appropriate corrections for known or suspected components of error have been applied, there still remains an uncertainty, that is, a doubt about how well the result of measurement represents the true value of the quantity being measured. From the recent studies, many researchers have pointed to the fact that person completed physics laboratory course are often able to demonstrate mastery of the mechanical techniques (calculation of mean, standard deviation etc.) but they lack in appreciation in measurement of uncertainties. Moreover, it is also a very good practice to evaluate and report the uncertainty associated with the test results. Sometimes, a customer may wishe to require a statement of uncertainty to know the limits within which the results reported assume to lie.

A laboratory should base its measurement uncertainty evaluation on existing knowledge and experimental data as concluded by Zogovic [5]. Thus obtained measurement uncertainty is necessary for the user, together with results so that proper decision could be made for example when comparing results with acceptable values, tolerance limits or permissive (legal) values, the laboratory, to be aware of quality of its own measurements (whether there is a difference among different laboratory results, or the results obtained at the same laboratory under different conditions), and thus improve it to necessary level.

A methodology developed by Silva [9] for determining the results of measurements concerning tensile mechanical properties and their respective uncertainties have a possible systemic application associated with advanced concepts which can be implemented in industrial, research centre.

A probilistic and metrological approach based on probability theory for the analysis and interpretation of data has been done by Buffler [2], where they stated that understanding of the interpretation of data by evaluating scientific evidence is an essential life skill in the present information age.

The logical inconsistencies in the traditional approach to data treatment together with the form of instruction by Buffler [2] that ignores testing prior views about measurement further cultivate the researcher misconceptions about measurement in scientific context. Further, they gave a emphasis that coherence of the approach will foreground the central role of experiment in physics and the interplay between scientific inferences based on data and theory.

Awachat [8] had developed a methodology for determining results of measurement concerning hardness properties and respective uncertainties having possible systemic application which is associated with advanced metrology concepts giving reliability to the results of the hardness properties as well as possibility of implementation in material testing laboratory.

The estimation of uncertainty in mechanical testing by Tarafder [1] focused on the concepts associated with the procedure for estimation of uncertainty and the application for the determination of uncertainty in tensile testing. They concluded that degree of rigor needed in an estimation uncertainty measurement for the client, the existence of narrow limit on which decisions on conformance to a specification is based.

The study carried out by Machado [4] gives an inter-institutional working plan to evaluate the testing machine performance and the uncertainty associated with fatigue tests of orthopedic implants including identification and quantification of uncertainty source which will be useful to metrology from dynamic force calibration.

This Code of Practice prepared by Pezzuto [3] on measurement and testing programme under reference SMT4-CT97-2165 has simplified the way in which uncertainties are evaluated. It had produced a series of documents in a common format that is easily understood and accessible to customers, test laboratories and accreditation authorities and in one of the seventeen produced by the UNCERT consortium for the estimation of uncertainties associated with mechanical tests on metallic materials.

METHODOLOGY

The international standard ISO/IEC 17025 is one of the basic document which can be accepted as the guide for the accreditation of the technical competence of the laboratories that performs testing activities. From Cl No 7.6 of the standard regarding process requirements, it is understood that,

- The testing laboratories should have procedure and they should apply procedures for calculation of the measurement uncertainties. In some of the cases, the calculation may include statistical measurement uncertainty.

In those cases, the testing laboratory try to identify all the uncertainty components involved in the testing work and has to do a reasonable estimate. During calculation of the measurement uncertainty, all the uncertainty components that are important for a certain situation they should be considered being used appropriate analysis methods.

- In cases where rigorous evaluation of the MU may be precluded, due to the nature of the test method, estimation is made based on an understanding of the theoretical principles or practical experience of the performance of the methods.
- Technical records for each laboratory activity includes, results, report, sufficient information to enable repetition under conditions as close as possible to the original, identification of factors affecting the result and Measurement of Uncertainty.

The presentation of the final test results of mechanical test parameters to be made in a limited way just a value for the final result is informed, without the respective uncertainty of associated measurement. The uncertainty of test results after testing is made necessary in several situations as for instance during analysis of the conformity or in the interpretation of test for measurement results. An estimate for measurement of uncertainty on least based consideration should contain all the components of the influence quantity that compose the calculation of the uncertainty of the testing that allows to establish a middle of evaluating the capacity of the equipment used which is adapted for the validation of the results obtained. The consideration of a given component of the uncertainty factors also indicates aspects of the testing to which we should give more attention or even to achieve perfect procedure. For testing laboratories, we have to undergo the calculation of the uncertainty of the test parameters step by step as follows:

- To make a list all the factors that can influence the measured values.
- To undertake a preliminary estimate of the values of the components of the uncertainty.
- To esteem the values that are attributable to each component of test parameters significant of the uncertainty and to express in the form of a standard deviation.
- To consider the components and to decide which are dependent and if there is a dominant component.
- To take into consideration of the sensitivity coefficients.
- To add the dependent components which are the correlated input quantity.
- To add the variances of the independent components with to component resulting from the previous item, in the case of the non existence of a dominant component to extract the square root from that sum, generating the combined uncertainty.
- To multiply the value of the previous item for an constant factor k as per % of confidence level mentioned in the calibration procedure of the equipment.
- To calculate the final result. The mathematical model is according to the tensile properties is measured below:
    1. To take ‘n’ reading and or observation for a given input quantity, say a1, a2, a3, a4, ……… an
    2. To Calculate the mean of the reading or observations as given below: $\hat{a} = a1 + a2 + a3 + a4 \ldots\ldots + an / n$

3. To calculate standard deviation about the mean as σ = √ { 1 / (n-1) iΣn (a1 - ân)2}

4. To calculate standard deviation of the mean

5. To calculate Coefficient of variance CV = (σ x 100) / â

6. To calculate Type A uncertainty (Ua) = CV / √n

7. To calculate degrees of freedom associated with the measurement (v) = n-1

8. To calculate Type B uncertainty for test parameter Modulus of Rupture (MoR):

   Modulus of Rupture (MoR), N/mm2 $= \frac{3\ P'L}{2\ bh^2}$

Uncertainty due to variable parameters due to length, width and thickness are to be calculated as

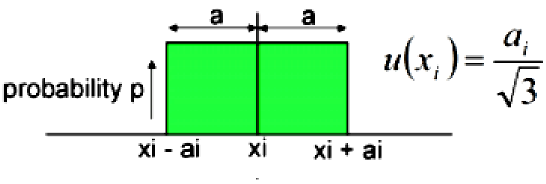
- Length (L) $= Uc_1$
- Width (b) $= Uc_2$
- Thickness (h) $= Uc_3$

Uncertainty due to instruments and equipments used during testing as per relevant test methods

- 10 Ton capacity Universal Tension Machine having load cell 10 KN= Ua_1
- Measuring Scale of 1000 mm length = Ua_2
- Vernier Calliper upto 150mm length = Ua_3

Uncertainty as per calibration certificate of the equipments calibrated through NABL approved calibration laboratories = ± a with p% confidence level to be calculated. The uncertainty calculated to be converted to a standard uncertainty by dividing it by the coverage factor (K) at defined confidence level, Us = a / k

The sensitivity coefficient has been assumed as 1 and also since the value of measure and is equally likely to lie anywhere within the limits, the distribution of uncertainty is assumed as Rectangular distribution.



Uncertainty contribution, $Ub_1 = Us / 1$

9. Combined uncertainty, % = $\sqrt{U_a^2 + Uc_1^2 + Uc_2^2 + Uc_3^2 + Ub_1^2} = Uc(y)$

10. Extended uncertainty assuming normal probability distribution at 95% confidence level = Ud(y) % = 2 x Uc(y) %

11. Overall uncertainty

    Y = â ± Ud(y) %

    = {â ± (Ud(y) / 100) x â} N/mm^2 with k = 2 at 95% confidence level

RESULTS

The material used for the study and calculation was general purpose plywood, Moisture Resistance Rrade as per Indian Standards IS 303 -1989 (RA 2003) and its test method as per IS: 1734-1983. The thickness of the plywood was 12mm.

Test Specimens

Five pieces of test specimen were taken from plywood board which was rectangular in shape. The depth of the specimen was equal to the thickness of board and the width was plies is parallel to the span, the length of the sample was 48 times the depth plus 5 cm. The sample was preconditioned to a constant mass at a relative humidity of 65 ± 5 percent and at a temperature of 27 ± 2°C. The width and depth of each specimen was measured to an accuracy of not less than ± 0.3 percent.

Testing of Sample in Universal Testing Machine

10 Ton capacity Universal Testing Machine having load cell 1 Ton was the equipment used for the testing. The load was applied through an appropriate loading block for centre loading with a continuous motion of the movable head throughout the test till a failure is indicated. The rate of application of load was such that the unit rate of fibre strain is equal to 0.001 5cm/cm of outer fibre length per minute within a permissible variation of ± 25 percent. The rate of motion of moving head was

$$N = \frac{zL^2}{6d}$$

Where,

N = rate of motion of moving head in cm/min,

z = unit rate of fibre strain in cm/cm of outer

fibre length per minute = 0.0015

L = span length in cm, and

d = depth of beam in cm.

Table 1: Summary of Standard Uncertainty Components for Length of Test Specimen

UNCERTAINITY CALCULATIONS

Type of test =	Length	Level of confidence in % =	95
Sample code =	A	coverage factor k =	2
Species	Plywood MR		

Type A uncertainity (U_{a2}) — Table 1

values \ unit	mm
1	626
2	626
3	625
n =	3
Mean =	625.667
SD =	0.577
CV =	0.092 %
u x/√n =	0.333
Type A uncertanity U_{a2} =	0.053 %

Table 2 — Calculated uncertainity as per caliberation certificate

	U %	Range
Steel Scale	0.00036	1000 mm

Type B uncertainity (ub) (select instruments actually used during testing procidure from Table 2) — Table 3

Uncertainity due to instruments used:-

Type of uncertainity	Source	Estimation of quantity (CV)	Probability distribution	Devisor	Std. uncertanity	Sencitivity coefficient	Uncertainity contribution	Deg of freedom
Ub1	Steel Scale	0.00036	Normal	2	0.00018	1	0.00018	y=3

Combined uncertainity=	$\sqrt{Ua^2 + Ub1^2 + Ub2^2 + ...}$	0.05327681	%			
Extended uncertainity		0.10655362	%			mm
Result	625.666667 ±	0.10655362	%	= 625.6666667	±	0.666670472

Table 2: Summary of Standard Uncertainty Components for Width of Test Specimen

UNCERTAINITY CALCULATIONS

Type of test =	Width	Level of confidence in % =	95
Sample code =	A	coverage factor k =	2
Species	Plywood MR		

Type A uncertainity (U_{a3}) — Table 1

values \ unit	mm
1	50
2	51
3	51

n = 3
Mean = 50.667
SD = 0.577
CV = 1.140 %
u x/√n = 0.333
Type A uncertanity U_{a3} = 0.658 %

Table 2 — Calculated uncertainity as per caliberation certificate

	U %	Range
Steel Scale	0.00036	1000 mm

Type B uncertainity (ub) (select instruments actually used during testing procedure from Table 2) — Table 3

Uncertainity due to instruments used:-

Type of uncertainity	Source	Estimation of quantity (CV)	Probability distribution	Devisor	Std. uncertanity	Sensitivity coefficient	Uncertainity contribution	Deg of freedom
Ub1	Steel Scale	0.00036	Normal	2	0.00018	1	0.00018	y=3

Combined uncertainity=	$\sqrt{Ua^2 + Ub1^2 + Ub2^2 + ...}$	0.65789476	%		
Extended uncertainity		1.31578952	%		mm
Result	50.6666667 ±	1.31578952	%	= 50.66666667 ±	0.666666692

Table 3: Summary of Standard Uncertainty Components for Thickness of Test Specimen

UNCERTAINITY CALCULATIONS

Type of test =	Thickness	Level of confidence in % =	95
Sample code =	A	coverage factor k =	2
Species	Plywood MR		

Type A uncertainity (U_{a4}) — Table 1

values \ unit	mm
1	12.46
2	12.54
3	12.60
4	12.37
5	12.65
6	12.59

n = 6
Mean = 12.535
SD = 0.103
CV = 0.824 %
u x/√n = 0.042
Type A uncertanity Ua4 = 0.336 %

Table 2 — Calculated uncertainity as per caliberation certificate

	U %	Range
Digimatic Caliper	0.0076	150 mm

Type B uncertainity (ub) (select instruments actually used during testing procedure from Table 2) — Table 3

Uncertainity due to instruments used:-

Type of uncertainity	Source	Estimation of quantity (CV)	Probability distribution	Devisor	Std. uncertanity	Sensitivity coefficient	Uncertainity contribution	Deg of freedom
Ub1	Digimatic Caliper	0.0076	Normal	2	0.0038	1	0.0038	y=6

Combined uncertainity=	$\sqrt{Ua^2 + Ub1^2 + Ub2^2 + ...}$	0.3364418	%		
Extended uncertainity		0.6728836	%		mm
Result	12.535 ±	0.6728836	%	= 12.535 ±	0.08434596

Table 4: Summary of Standard Uncertainty for Static Bending Strength of Plywood along the Grain Direction (Modulus of Rupture) of Test Specimen

UNCERTAINITY CALCULATIONS

Type of test =	MoR	Along the Grain	Level of confidence in % =	95
Sample code =	A		coverage factor k =	2
Species	Plywood MR			

Type A uncertainity (Ua1) Table 1

values \ unit	Mpa
1	83.13
2	80.52
3	88.98
4	80.67
5	84.21
n =	5
Mean =	83.502
SD =	3.448
CV =	4.129 %
u x/√n =	1.542
Type A uncertanity U_{a1} =	1.847 %

Table 2

Calculated uncertainity as per caliberation certificate

	U %	Range
UTM Kalpak 1T load cell(Comp)	0.82	10000N

Type B uncertainity (Ub) (select instruments actually used during testing procidure from Table 2) Table 3

Uncertainity due to instruments used:-

Type of uncertainity	Source	Estimation of quantity (CV)	Probability distribution	Devisor	Std. uncertanity	Sencitivity coefficient	Uncertainity contribution	Deg of freedom
Ub1	UTM Kalpak 1T	0.82	Normal	2	0.41	1	0.41	γ=5

Combined uncertainity=	$\sqrt{U_{a1}^2 + U_{a2}^2 + U_{a3}2 + U_{a4}2 + \ldots}$	2.36780016	%			
Extended uncertainity		4.73560031	%			Mpa
Result	83.502 ±	4.73560031	%	=	83.502 ±	3.954320973

CONCLUSIONS

The universal testing machine uncertainty factor is affecting to a quite extent and hence proper care to be taken for calibration and setting of the machine so that the uncertainty factors get reduced. The main influence factor in the determination of the uncertainty of measurement of the static bending strength (MoR) was the variation attributed to the measure and, that is the repeatability obtained in the measurements of the studied properties. Hence every measurement instruments no matter about its acting capacity should be exempted of provoking mistakes when it is in use, the static bending strength test plywood material. Even thought if the result of the measurement is not perfect, it is possible to obtain reliable information since the result of the measurement is associated with its respective uncertainty. In this, study was to analyse a method for determining the result of measurement concerning static bending properties and their respective uncertainties.

Hence, a testing laboratory should base its measurement uncertainty evaluation on existing knowledge and experimental data. Thus, the obtained measurement uncertainty is necessary for the end user, together with results so that proper decision could be made for example when comparing results with acceptable values, tolerance limits, the testing laboratory to be aware of quality of its own measurements done (whether there is a difference among different laboratory results, or the results obtained at the same laboratory under different conditions), and thus improve it to necessary level.

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