UNIVERSITI TEKNOLOGI MARA

TENSILE STRENGTH CLASS SYSTEM FOR MALAYSIAN HARDWOOD ACCORDING TO EUROPEAN STANDARDS EN 384 AND EN 408

NURUL IZZATUL LYDIA BINTI ZA'BA

Thesis submitted in fulfillment
of the requirements for the degree of
Doctor of Philosophy
(Civil Engineering)

Faculty of Civil Engineering

July 2019

ABSTRACT

Timber has been widely used as load-bearing building elements such as roof trusses, beams and columns subjected to tensile, shear, bending and compression loading. In order to design such structural system, the strength properties of a timber need to precisely determined. Currently, in Malaysia, the strength properties are based on MS 544 which were determined by grade stresses of small clear specimens. However, in Europe and partly in North America, the concept of grade stresses of small clear specimens has been abandoned and new approach involving determination of characteristic values in structural sized specimens has been introduced to produce more accurate data for structural timber design purpose. Glue laminated timber (GLT) is now the most versatile engineered structural timber products produced in many countries. In order to produced GLT, information on characteristic tensile strength is used. Therefore, there is need to establish the tensile strength data for Malaysian timber based on characteristic values as data in EN 338 are specially mention to be used for softwood timber only. Nine species namely Balau, Kempas, Kapur, Kelat, Resak, Keruing, Mengkulang, Light Red Meranti and Geronggang, varied from strength group (SG) 1 to SG 7 were chosen from region Kelantan, Pahang, Johor and Sarawak to perform tension test in both small and structural sized specimens. The test were done according to BS373:1957 for tension parallel and perpendicular to grain of small clear specimens and EN408 for tension parallel to grain of structural sized specimens with total of 3360 specimens tested. A very weak correlation of density versus tensile strength and moderate correlation for modulus of elasticity (MOE) versus density were observed for all species. Tensile grade stresses determined from both small clear and structural sized are found to be higher compared to the data in MS 544 as tensile strength in MS 544 are concurrently calculated by 60% of the bending strength values. The order of grade stresses for small clear specimens are Balau, Mengkulang, Light Red Meranti, Keruing, Kapur, Kelat, Resak, Kempas and Geronggang. However, different order were observed for structural sizes which is Kempas, Keruing, Kapur, Balau, Mengkulang, Kelat, Resak, Geronggang and Light Red Meranti. Thus, there is a weak correlation found in grade stresses between small clear and structural sized specimens. The characteristic values of tensile strength determined are also higher and did not fit in Table 2 EN338 so new strength class timber was establish. Kempas, Balau, Keruing, Kelat, Resak, Kapur, Mengkulang, Light Red Meranti and Geronggang are devoted to strength group T36M, T33M-HD, T30M, T29.5M-HD, T27M-HD, T26M, T21M, T14.5M and T11.5M respectively. Different trend of characteristic tensile strength, $f_{t,0,k}$ versus characteristic density, ρ_k, has been found where, ρ_k more than 700 kg/m^3, the $f_{t,0,k}$ of the species are found to decreasing. A new equation to determine characteristic MOE, $E_{t,0,k} = 0.54E_{t,0,mean}$ and mean density $\rho_{mean} = 1.01\rho_k + 151.7$ were establish. A validation study on the T-class with the properties of glulam was conducted and the result shows that based on this study, the current formula in design the bending strength of glulam from tropical hardwood was found not suitable. This is due to the properties of tensile strength for Keruing does not fit with the establish T-table in EN 338.

ACKNOWLEDGEMENT

Alhamdulillah, with the name of Allah S.W.T, the Most Compassionate and Most Merciful, all praise is due to Allah S.W.T, Lord of the Universe. Blessings and peace be upon His Final Prophet Muhammad S.A.W.

First of all, I would like to express my profound gratitude to my supervisors, Professor Dr. Zakiah Binti Ahmad, Dean of Faculty of Civil Engineering Universiti Teknologi Mara (UiTM) for her professional, enthusiastic guidance, continuously motivation, and efforts throughout my studies and the entire research work. In addition, I would also like to thank my co-supervisor, Professor Dr. Simon Aicher, Senior Acedemic Director of MPA University of Stuttgart for his consistently assistance, patient and guidance on my research and thesis. I could not have imagine having better advisors for my PhD study. Their dedication and commitment to my works will always appreciated and remembered.

My appreciation also goes to the technician team from Faculty of Civil Engineering Lab, Muhammad Tarmizi Ismail and Azri Syafiq Kamarozaman for the help in setting and fixing the testing machine. Without them, I could never have completed my experimental work. I would also like to acknowledge the Director General of Malaysian Timber Industry Board (MTIB) for funding this research.

Special thanks goes to my dearest friends, Dr. Lum Wei Chen, Anis Azmi, Adnie Baharin and all of friends name not mention here. Their support and help always give motivation and energy for me to finish the thesis. My appreciation also extended to my brothers and sisters for always believing in me.

Heartfelt acknowledgement are expressed to my beloved husband, Lieutenant Commander Ir. Wiratman Bin Arman. Without the guidance, support, encouragement and advises, I may never have overcome this long journey in my studies. To my children, Nur Qaleesya Sofea and Muhammad Qhalish Amsyar, thank you for the understanding and patience and for being great children. When I felt down, their love will always give me strength to face all the problem happened. My love for them is beyond infinity and words are not enough to say how grateful and lucky I am to have them in my life.

Finally, this thesis is dedicated to my very dear mother, Norhamizah Radzali and my beloved father Za'ba Saad. Thank you for the love, care, pain, sacrifice and to bring the best out of me since I was born. May both of you be blesses with health, happiness and love here and in the hereafter.

Thank You!

TABLE OF CONTENTS