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RESEARCH ARTICLE

THE MECHANICAL PERFORMANCE OF PARALLEL TDG BAMBOO LAMINATED COLUMNS (TDGLC)

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Abstract

A research study conducted in Thailand aimed at developing and adding value to agricultural products, specifically focusing on bamboo. The agricultural sector in Thailand plays a significant role in the economy and society, employing a large portion of the population and generating income equal to approximately 9% of the country's GDP. The government aims to enhance the competitiveness of Thai agricultural products and increase their value for the benefit of local communities. The research focuses on utilizing bamboo for construction projects, particularly in the form of Thai *Dendrocalamus Giganteus* bamboo (TDG) laminated columns (TDGLC). The study involves a production process to create man-made TDGLC and investigates the mechanical properties of these columns. The research examines the performance of parallel bamboo laminated columns under axial compression tests. Specimens of TDG bamboo, aged between 3 and 4 years, were cut into strips and clamped together to form columns of various lengths and cross-sections. The cross-section sizes ranged from 100 mm to 203 mm, with lengths of 1 meter, 2 meters, and 3 meters. The compression load and classification of long and short columns were analyzed based on the proportioning of length and cross-section. The research identified specific column types that exhibited either strength failure (short columns) or buckling failure (long columns). However, two column types, C603 and C402, showed mixed results, with both strength and buckling failures. Although their slenderness ratios exceeded 60, the primary mode of failure indicated that these specimens should be classified as short columns. It was observed that defects in the specimens influenced their load capacity, with higher slenderness ratios resulting in greater lateral deflection corresponding to the peak load. The equation used to calculate the load capacities aligned well with the test results. Overall, the study contributes to the understanding of TDGLC performance in construction applications and provides insights into the mechanical behavior of bamboo columns under axial compression.

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Introduction:-

In Thailand, the agricultural sector is the country's largest source of labor. It is an important source of income for many households in the population. However, when considering the return of income, it was found that the agricultural sector, which uses the majority of the country's labor, or more than 40 percent of all workers in the country, can't generate as much income as it should [3]. Farmers are a group with a lower average income than other occupations and a lack of income security. There are seasonal fluctuations. There are many bamboo species in Thailand that can be planted in every region of the country [4]. Since Thailand is a country where the majority of the population are agricultural people, it is very important to develop and add value to agricultural products. Increase the value of agricultural products through smart products. Thai people have been familiar with construction materials such as bamboo for a long time. Bamboo has been used in construction in Thailand since ancient times, such as in traditional Thai houses. But the problem encountered is that bamboo has a short lifespan. In addition, alternative construction materials such as steel, wood, and cement are being used in construction more and more, causing the construction of bamboo in Thailand to decrease.

Bamboo construction in Thailand involves the direct use of bamboo clumps. The problem encountered is that it is difficult to adapt for use in modern construction. Because bamboo has unique properties, such as being round and unequal in size, the bamboo clumps are thick at the bottom and the ends are slender. Therefore, the mechanical properties of bamboo are not equal in each part. Bamboo is an all-weather plant and grows rapidly in comparison to other construction plants [5-9]. The period of bamboo harvesting for use in construction is as short as 3 years, compared to 15–30 years for other types of timber. In addition, bamboo is a plant that can grow quickly and can grow in all regions of Thailand.

Promoting the cultivation of bamboo for processing will generate income for farmers. Promote planting bamboo for a better environment in the future to promote income generation without damaging the environment. The above-mentioned reasons make bamboo a potential substitute for wood. [10-14] to develop bamboo into an agricultural product that meets the needs of a variety of construction projects. Processing bamboo for use in the construction industry, such as TDGLC, in structural applications such as columns can increase the efficiency of using bamboo. Therefore, this research study developed a man-made TDGLC production process to study the mechanical properties of TDGLC. TDG is a bamboo that has been studied for mechanical properties by a group of researchers from Ramkhamhaeng University to develop and use it in construction in the form of bamboo clumps that are processed in various ways. The mechanical properties of TDG bamboo aged 3–4 years were tested, as were the physical properties [15-18]. The results showed that TDG bamboo is the largest bamboo in Thailand; when fully grown, it has a circumference of 80–90 cm, a diameter of 330–230 mm, and a wall thickness of 110–30 mm [19-21]. The mechanical properties are: compression test 29.74–43.79 MPa, tensile test 159.38–257.68 MPa, and bending test 2.21-3.47 MPa. The mechanical properties for the test were determined using the following wood standards: ASTM D 143-09 [22] and DPT 1221-51 [23-26]. TDGLC have been studied by [27] the tests can be summarized as follows: compressive strength with a standard size of 50 x 50 x 200 mm load 129.38–245.58 MPa. [28] Studied the bending strength of TDG laminated beams with a size standard of 50 x 50 x 760 mm. The test specimens are divided into two types: FR and NFR. The test results showed that the FR type beam can resist bending tests of 26491.77 MPa, and NFR 15637.46 MPa. Past research in Thailand, tests of the mechanical properties of a small scale of TDG bamboo laminated columns were conducted. Therefore, this study aims to examine the compression behavior of TDGLC structural member realistic cross-section. The specimens are divided into 3 groups by cross section; 100 mm, 152 mm, and 203 mm, which have different slenderness; 1, 2, and 3 meters. Based on the experimental and computational investigation, the formula for calculating stability factors will be proposed for TDGLC

Materials and Methods:-

TDG bamboo aged between 3-4 years was selected for this research. Bamboo specimens were collected by cutting from the base of the bamboo at a distance of 3.5 m. Bamboo was grown in a bamboo plantation in Nan Province at Tha Wang Pha District. Although the purpose of this research is to test the mechanical properties of bamboo columns in actual use, it is also to provide research on environmentally friendly materials. Therefore, it is very important to collect detailed production cycle data from past studies. [29-33] it is found that data storage is the main problem found in the research and analysis of the impact of material measurement on the environment. Therefore, we realize the importance of storing data systematically according to the detailed production cycle, as shown in Figure 1. Provide effective data storage for future carbon footprints and environmental impacts. The determination of the production cycle in this study is divided into the following three key cycles:

The first production cycle is the production process and treatment of the wood before use. These include transportation, drilling, immersion in water and solution processing, and bamboo drying, as shown in Figure



1.

Figure 1:- Preservation of bamboo.

The second production cycle is the production cycle for making bamboo strips. These include measuring, cutting, and planing the bamboo. The importance of this process is that the bamboo strips must be the same size and smooth, as shown in Figure 2.



Figure 2:- The process of the strips making.

The third production cycle of forming TDGLC consists of the following production processes: cutting the bamboo into strips, planing the strips with a wood planer machine, and gluing and compressing the strips to form the column, as shown in Figure 3 shown the whole production process. The forming process is shown in figure 3.3. Forming by hand gluing and using a clamp to compress bamboo splits into different cross-sectional sizes at a length of 3 meters



Figure 3:- Laminated Bamboo Processing Process.

According to the compressive tests, the compression strength for TDG laminated bamboo in Thailand was 49.27 MPa, with a modulus of elasticity of 7721.04 MPa and an ultimate compression strain of 0.02. The details are in Table 1. A standard bamboo of 20 mm in cross section at 250 mm in length was used for the determination of mechanical properties of 150 test specimens.

Table 1:- Mechanical performance of TDG laminated bamboo (standard size).

Property	Maximum	Minimum	Average
Compressive strength parallel to grain f_v (MPa)	69.65	20.82	49.27
Modulus of elasticity in compression E_c (MPa)	9518.59	5365.74	7721.04

Code and specimens:-

The TDG bamboo column is divided into three parts, with a cross-section of 4, 6, and 8 inches, and different lengths of 1, 2, and 3 meters. Figure 4. Shows (a) a cross section, (b) a column length of 3 meters, and (c) a column cut to a different length.



Figure 4:- The TDG column is a. cross-section, b. length, and c. cut to various lengths.

Considering the length and compression, 3 groups of specimens were constructed and detailed information is shown in Fig. 5 and Table 2. As for the naming rule for the groups, C4 + length is for the group cross-section 4 inches, while 01 is a length of 1 meter

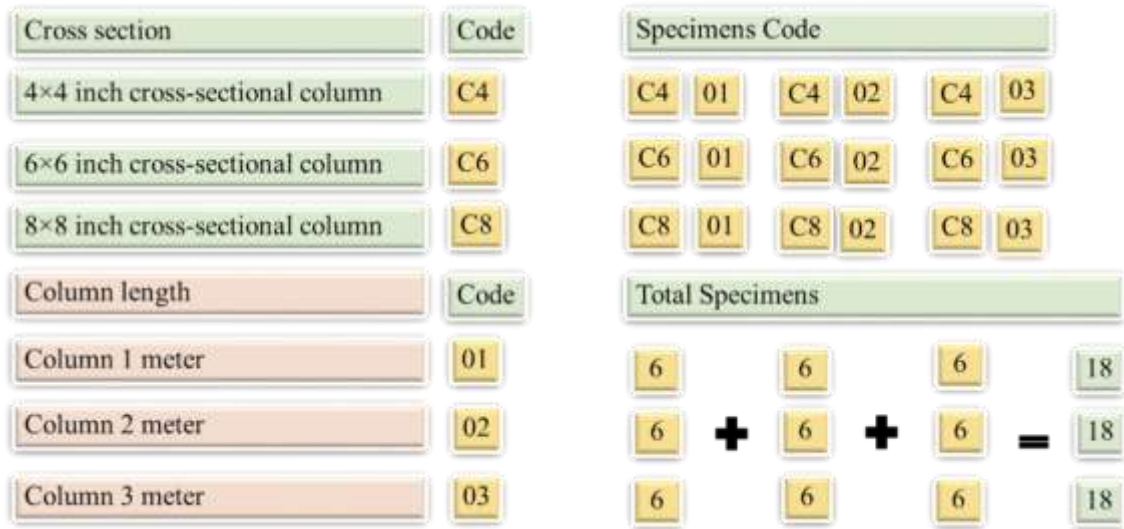


Figure 5:- Detail of the test specimens.

Table 2:- Specimens.

Type	Cross-section(inch)	Length(m)	Number of Specimen
C401	4	1	6
C402	4	2	6
C403	4	3	6
C601	6	1	6
C602	6	2	6
C603	6	3	6
C801	8	1	6
C802	8	2	6
C803	8	3	6

Experimental tests:-

The test setup is depicted in Fig. 6. One strain gauge, which was adhered to the middle side surface of the specimens as indicated in Fig. 6, was used to measure the displacement of the specimen along its axial direction. A compression testing device with a 2000–3000 kN capacity was used for the test. The Digital Display TTR-080G read the test. The entire loading time is regulated to be between 8 and 10 minutes. The control variable in this study was the increment of the load in each test, 100 kN at a rate of 1.0 kN per second until the specimen is damaged. And record the details of the failure and the shrinkage distance of the specimen.

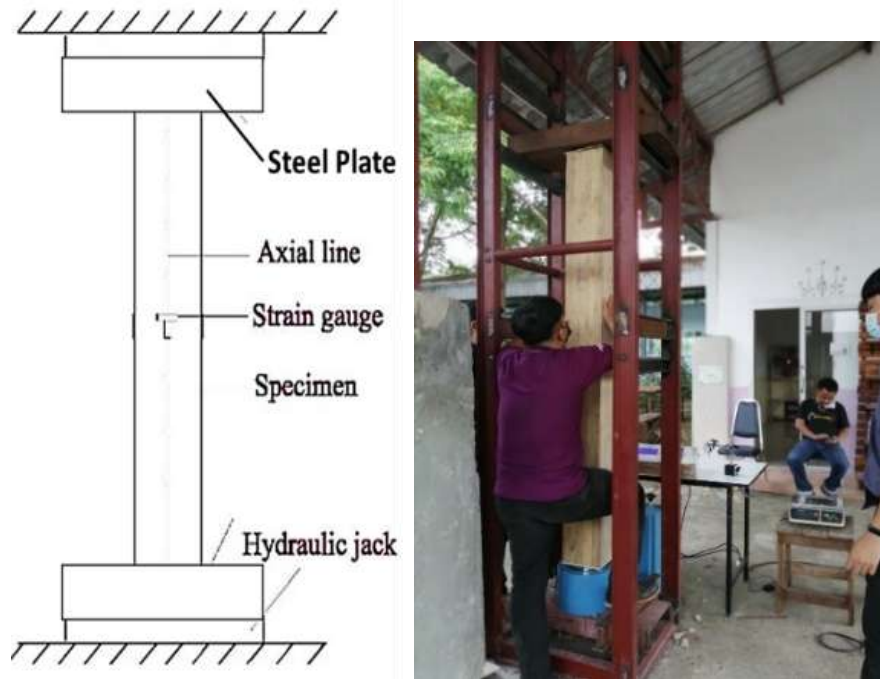


Figure 6:- Detail of the test specimens.

Test Results and Discussion:-

Failure mode and mechanism

The failure process for all specimens. The results detail as show in the table 3. The failure study of specimens in this test revealed that two types of failures were identified according to specimen type, as follows from the study of the slenderness ratio to identify short-and long-column properties. The short-and long-column samples were separated to study the practice.

Table 3:- The Failure of the column.

Type	Mode	The Failure detail
C401	Strength failure (MODE I)	Spitting along the glue line (glue fail)
C402	Strength failure (MODE I)	Spitting along the glue line (glue fail)
C403	Buckling Failure (MODE II)	Spitting along the glue line (glue fail)
C601	Strength failure (MODE I)	Spitting along the glue line
C602	Strength failure (MODE I)	Spitting along the glue line at the top
C603	Strength failure (MODE I and II)	Spitting along the glue line
C801	Strength failure (MODE I)	Spitting along the glue line at the top
C802	Strength failure (MODE I)	Spitting along the glue line at the top
C803	Strength failure (MODE I)	Spitting along the glue line at the top

According to The Engineering Institute of Thailand Under H.M. The King's Patronage (EIT) 1007-34, item 5303 (a), where h is the length of the column. The specification of the short pole is

$$\frac{h}{r} \leq 60$$

Where r is radius Gyration is calculation from the formula 1.

$$r = \sqrt{\frac{I}{A}} \text{ (1)}$$

Where I is moment of Inertia is calculation from the formula 2.

$$I = \frac{bt^3}{12} \text{ (2)}$$

Analysis of the failure MODE I: most specimen's failure were caused by glue. It can be seen that the specimens form longitudinal traces that fall apart in such a way that the wood inside is not damaged, but tear marks are found in the glue when studying the pieces. The specimens were cut in detail for study. It is found that the glue inside shows unequal bonding. Some rings are visible, some are glued, and some are not glued. That indicates the molding quality of the glue, as shown in Figure 7.



Figure 7:- Splitting Mode cause by glue failure.

TDGLC specimens used to study the adhesive failure, it was found that the specimens shown in Fig. 7 show that the adhesive strips have peeled off the wood and the adhesive disparities leave patches. Most of the sample fail in Splitting caused by 3 type of glue failure as following; Adhesive failure (ADH), cohesive failure (CO) and, Light - fibre -tear failure (LFT)

The TDGLC specimens, there are two types of failures: thesplitting failure, called strength failure (MODE I). This type of failure is mainly observed in short columns and the deflection failure, called that Buckling failure (MODE II), which occurs in long columns

Strength Failure

Failure Mode I; TDGLC specimens from groups C801-C803 split along the glue line at the top, as shown in Fig. 8. 1. The small pieces of the strip form a small arch, and after taking the pieces out of the test machine, the arch springs back to the original. For cross section 8-inch, the failure only occurs at the top column. TDGLC groups C601 and C602, most of them splitting along the glue line as shown in Fig 9. As shown in Fig8.3, TDGLC groups C401 and 402 have a thicker splitting distance along the glue line than TDGLC groups C801-C803 and C601-C602.



Fig. 8:- Strength Failure MODE I.



Fig. 9:- Strength Failure MODE I.

Buckling Failure

Failure mode II; TDGLC group C403, all of them splitting along the glue line with buckling failure as shown in Fig.10 and 10. 1. The strip piece under the steel block occurs in an arch, and the pieces not under the steel plate are still in a straight line. Some specimens of C603 spitting along the glue line and the strip beneath the steel plate were buckling, but the pieces not under the steel plate were still in the original no-arch line for this test. 6 columns of C603 are buckling. 2 columns with approximately 33% buckling



Fig. 10:- Buckling Failure MODE II.



Fig. 11:- Buckling Failure MODE II.

A study on the failure of bamboo TDGLC found that 8-inch cross-section had higher stresses than 6-inch and 4-inch cross-sections. The shorter columns had greater stress than the longer column but from the test results, it was found that the curves overlap, indicating that the TDGLC small cross-section with short length cross-section can replace the TDGLC large cross-section with long length. Comparison of failures of columns of different cross-sections by analyzing the effect of stress and slenderness ratio.

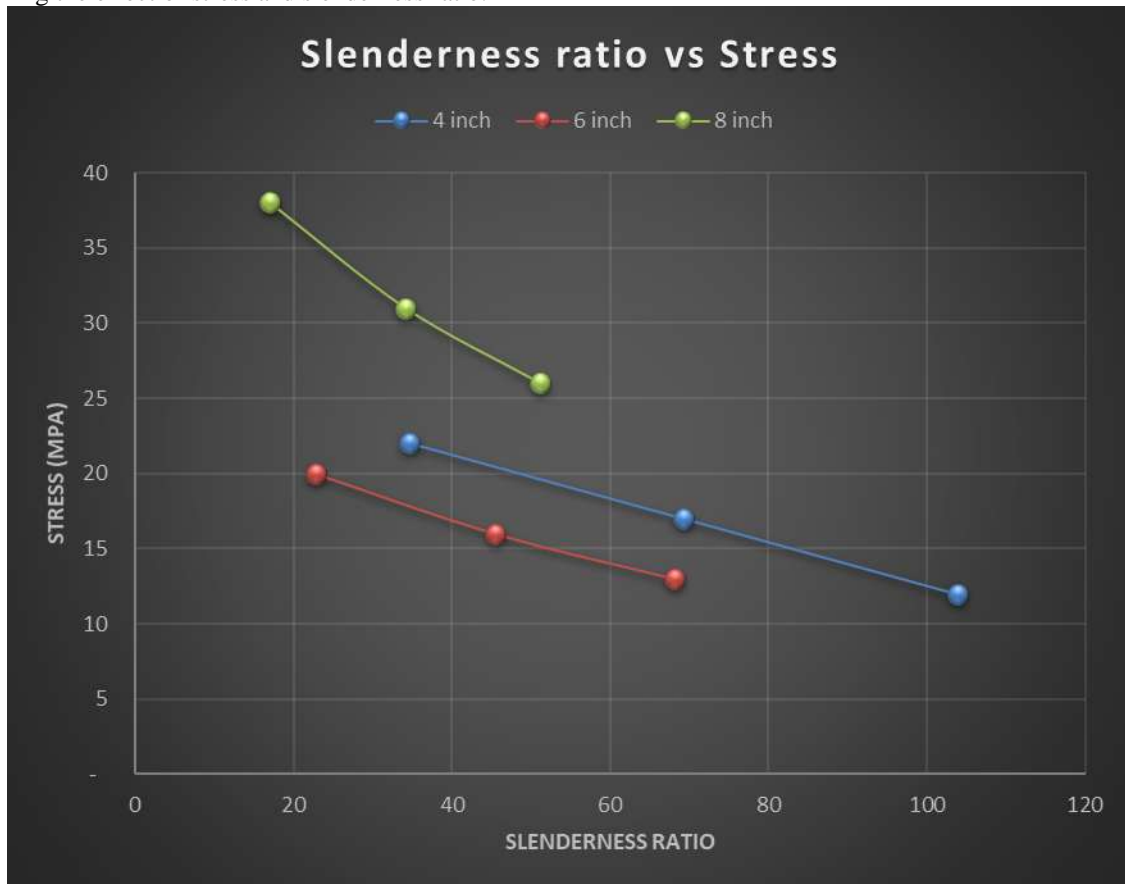


Fig. 12:- Slenderness ratio vs. stress.

A study on the failure of TDGLC found that 8-inch cross-section had higher stresses than 6-inch and 4-inch cross-sections. The TDGLC shorter columns had greater stress than the longer poles. The classification of TDGLC specimens by type of short column and long column from the test and analysis of the failure results showed that

From the TDGLC with a cross section of 4 inches at the length 2 meter (C402) as shown in Figure 12, the blue lines overlap the gray and orange graph lines. The test results showed that the TDGLC cross-section of 4 inches at a length of 2 (C402) was found to be able to bear the force close to the column with a cross-section of 6 inches at a length of 3meter(C403).From the graph, the colored dots can be seen orange and blue are very close in value.Even TDGLC 4 inches cross section at 1 meter length (C401) can withstand compressive loads similar to those of bamboo poles 6 inches long by 2 meters (C602) or 8 inches crossed at 1 meter length (C803).

Ultimate capacity and Strain

For TDGLC type C401-C403 Analysis of the ultimate capacity and strain from the test results as shown in Fig. 13. The TDGLC test results were divided into three groups; the high capacity loads were C801, C802, and C803, Loads with a medium capacity were C601, C602, and C603, and the last group were loads with lower capacity were C401, C402, and C403. High strain occurred in specimens subjected to a high load.

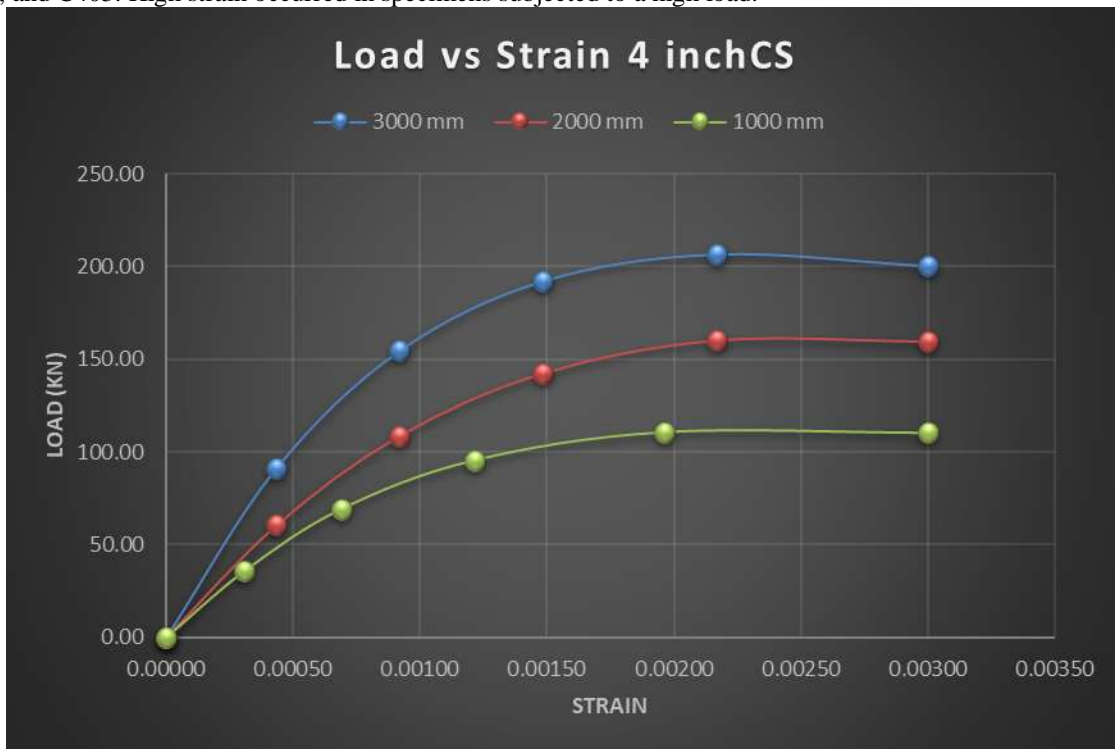


Fig. 13:- Load vs. strain with a cross section of 4 inches at different lengths.

For TDGLC cross section 6 inch type C601-603 Analysis of the ultimate capacity and strain from the test results as shown in Fig. 14. The TDGLC test results were divided into three groups; the high capacity loads were C801, C802, and C803, Loads with a medium capacity were C601, C602, and C603, and the last group were loads with lower capacity were C401, C402, and C403. High strain occurred in specimens subjected to a high load.

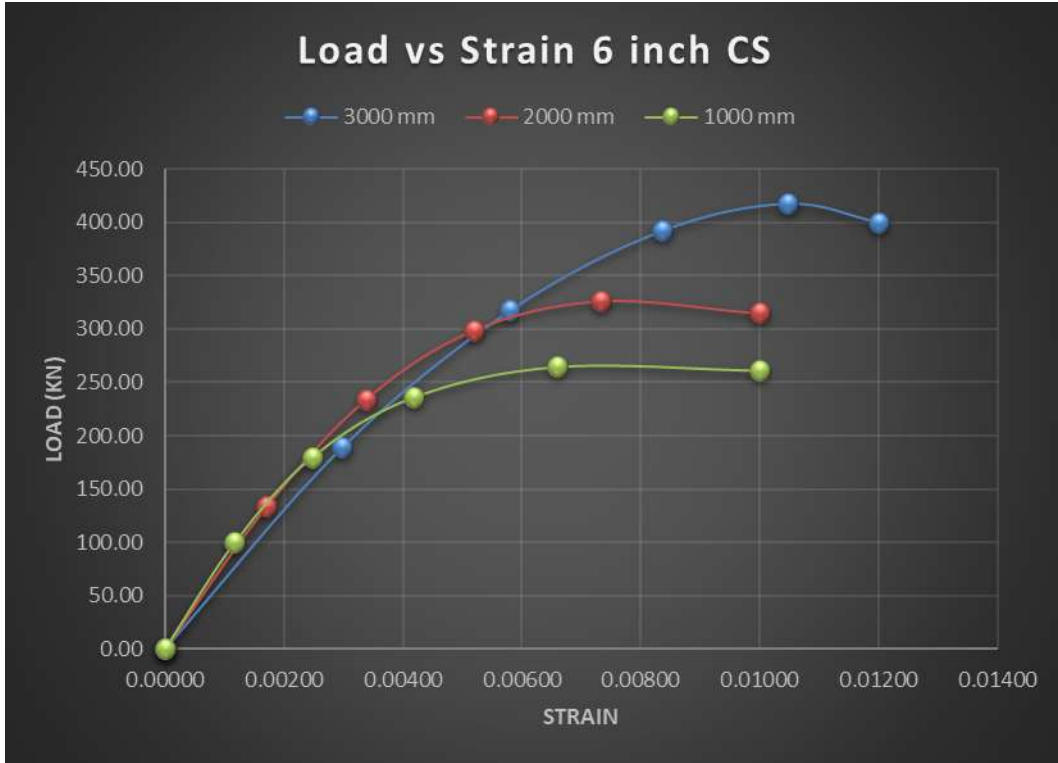


Fig. 14:- Load vs. strain with a cross section of 6 inches at different lengths.

For TDGLC cross section 6 inch type C801-803 Analysis of the ultimate capacity and strain from the test results as shown in Fig. 15. The TDGLC test results were divided into three groups; the high capacity loads were C801, C802, and C803, Loads with a medium capacity were C601, C602, and C603, and the last group were loads with lower capacity were C401, C402, and C403. High strain occurred in specimens subjected to a high load.

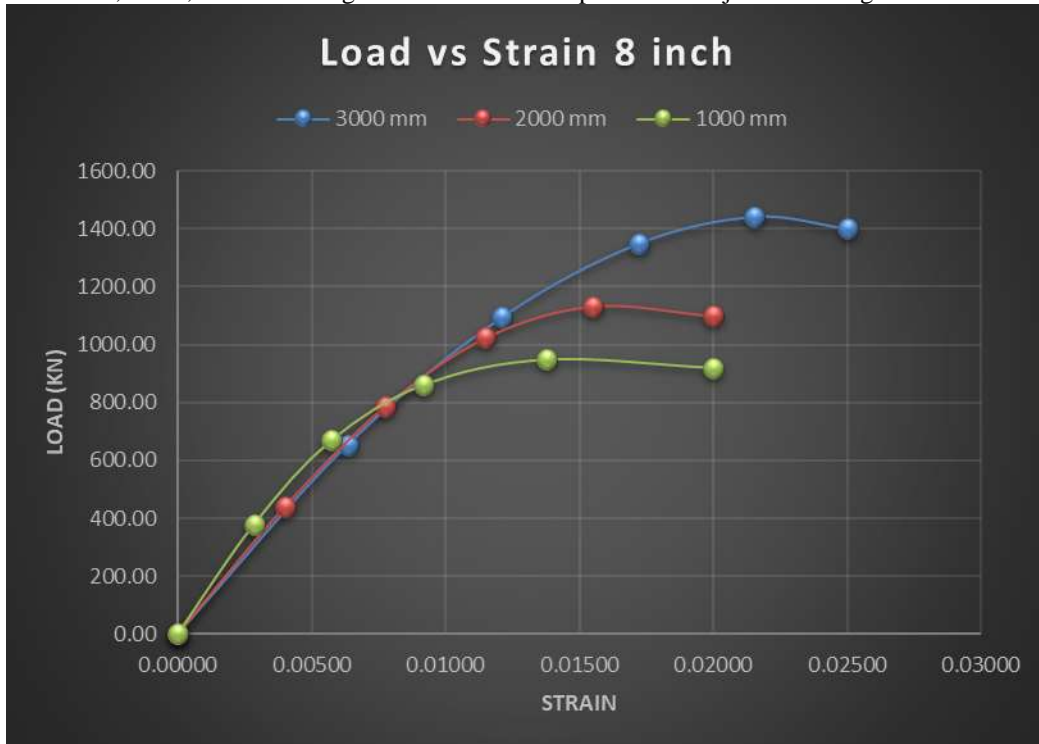


Fig. 15:- Load vs. strain with a cross section of 8 inches at different lengths.

Comparison of TDGLC with different cross-sections, the test results showed that

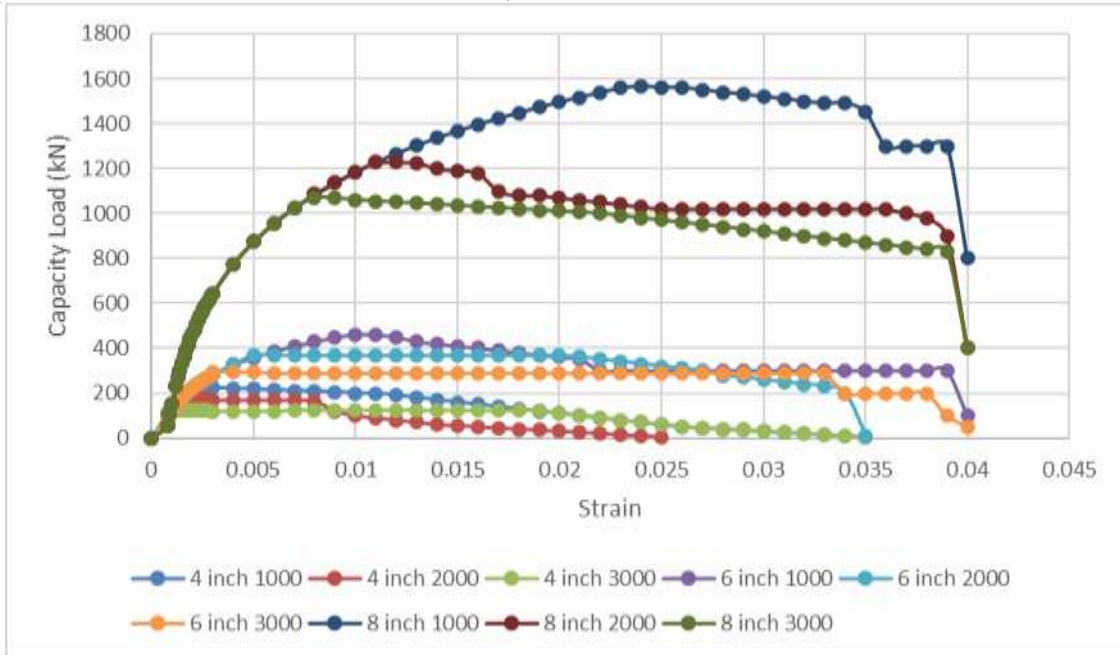


Fig 16:- Load vs. Strain of TDGLC with different cross-sections.

Ultimate capacity and Slenderness

Study the relationship of the test result between load and the Slenderness ratio. The test results were used to find the equation by regression method. The results obtained from the test are as follows: **4-inch** cross-section, the test results are shown in Equation 1, **6-inch** cross-sections shown in Equation 2 and **8 inch** cross section, the equation is shown in Equation 3. Where the Slenderness ratio is calculated from Equation 4.



Fig 17:- Load vs. Slenderness ratio of TDGLC with different cross-sections.

$$P = -0.0005 \lambda^2 - 1.3908\lambda + 275.15(3)$$

$$P = 0.0216 X^2 - 5.6215X + 578.7(4)$$

$$P = 0.1156 \lambda^2 - 22.842\lambda + 1916.3 (5)$$

Where λ is slenderness ratio

$$\lambda = L/\sqrt{I/A}(6)$$

Where L is length of the column (m); I and A are moment of Inertia and area (m^4) of column cross-section (m^2)

Stress vs. Strain analysis

Stress – strain relationships of TDG laminated column in figure 18 shown stress –strain curve of all specimens, where the y axis corresponds to the normal stress and the x axis represents the longitudinal strain

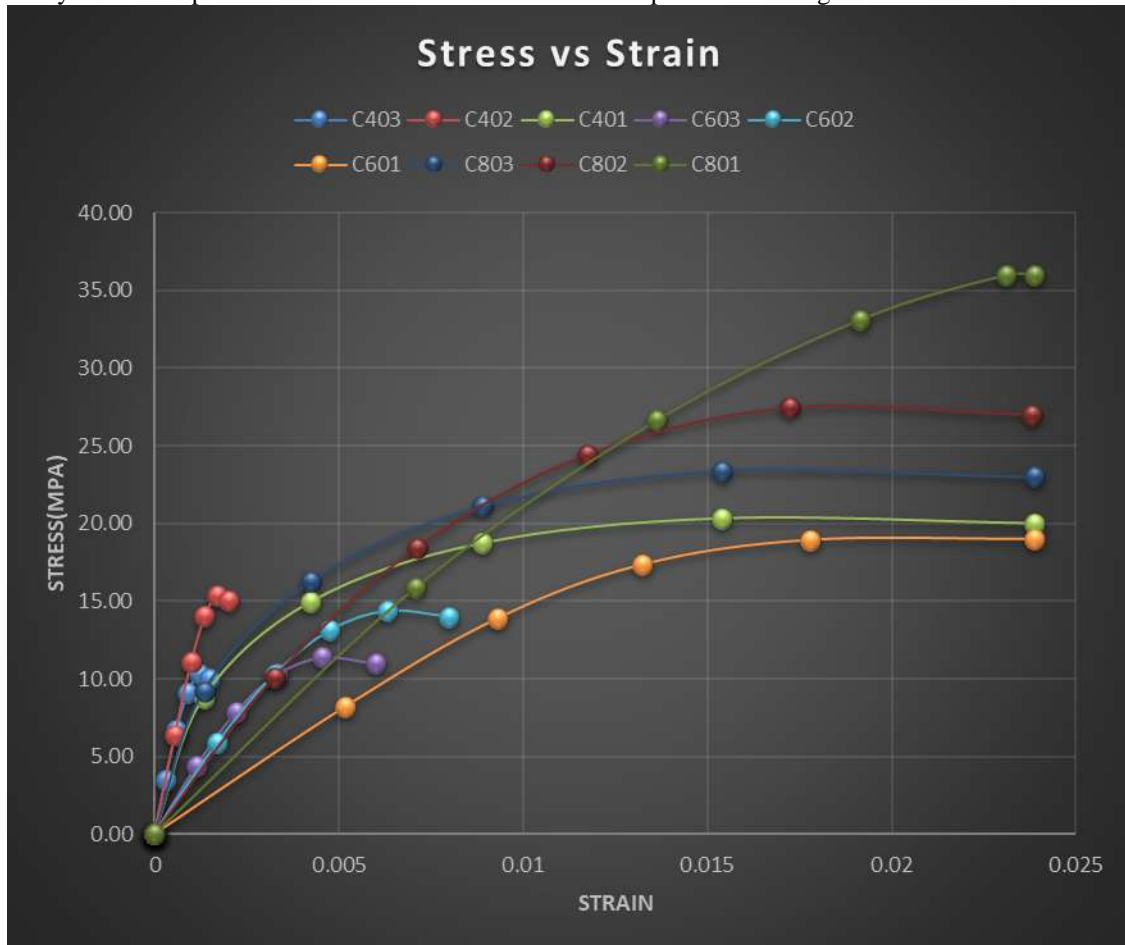


Fig 18:- Stress vs. Strain of TDGLC with different cross-sections.

Discussion:-

Maximum longitudinal/transverse strain of each group are summarized in Table 4. Maximum longitudinal of TDG column were reduced as slenderness ratio increased. For the short column C801-C803 and C601-C603 .Fig 19 show maximum strain versus slenderness ratio. The usable strain was significantly reduced as the length of column increased. Relationship between longitudinal and slenderness ratio can be summarized by statistics regression analysis, as shown in Eq. 5 for TDG laminated column with cross section 8 inches , Eq. 6 for TDG laminated column with cross section 6 inches and Eq. 7 for TDG laminated column with cross section 4 inches ,

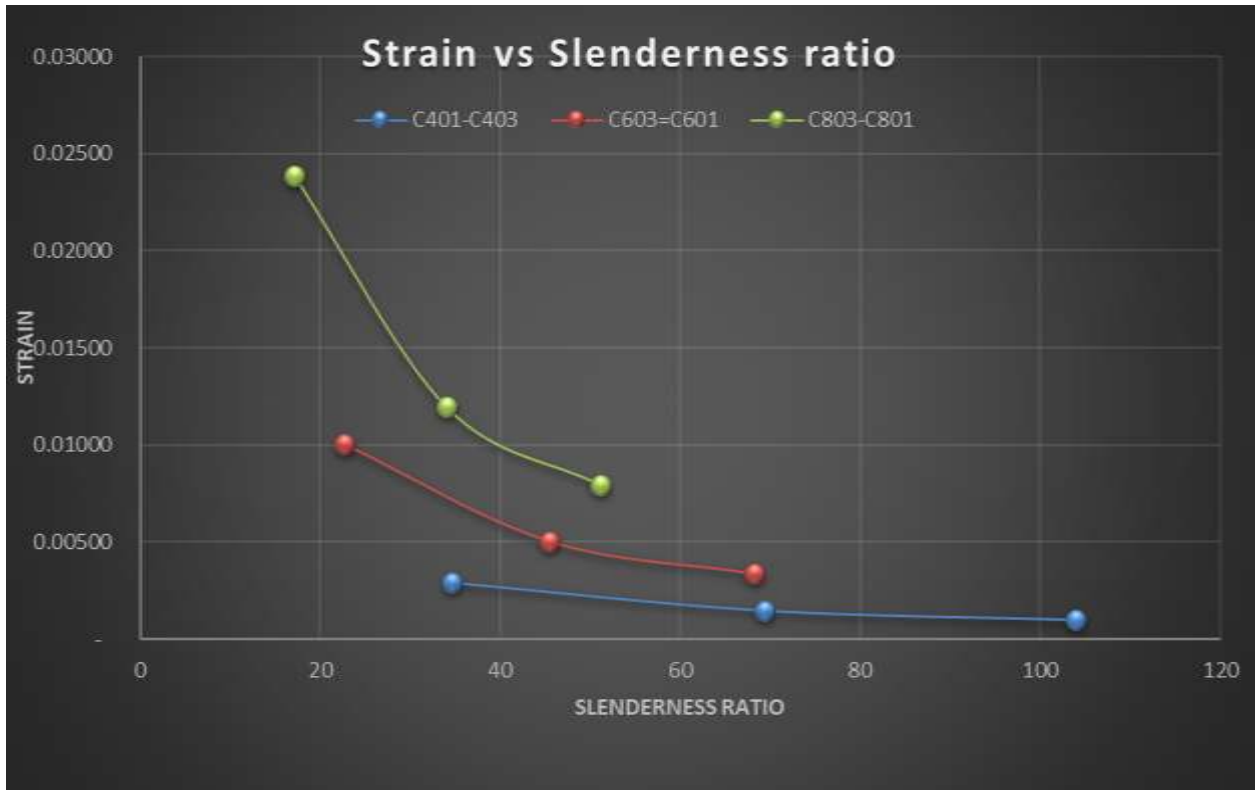


Fig 19:- Strain vs. Slenderness ratio of TDGLC with different cross-sections.

For cross-section 8 inch.

$$\epsilon_l = 0.00001\lambda^2 - 0.00140\lambda + 0.04378 \quad (7)$$

For cross-section 6 inch.

$$\epsilon_l = 0.000003\lambda^2 - 0.000443\lambda + 0.018470 \quad (8)$$

For cross-section 4 inch.

$$\epsilon_l = 0.0000004\lambda^2 - 0.0000850\lambda + 0.0053939 \quad (9)$$

Where ϵ_l is the maximum longitudinal strain at mid height; and λ is slenderness ratio

Table 4:- Test results.

Specimens	Length(mm)	Strain	Slenderness ratio	Ultimate Capacity(k N)
C801	1000	0.02388	17.05	1566.56
C802	2000	0.01194	34.10	1284.06
C803	3000	0.02388	51.14	1068.89
C601	1000	0.01007	22.73	462.07
C602	2000	0.00504	45.46	367.74
C603	3000	0.01007	68.19	295.72
C401	1000	0.00294	34.64	226.44
C402	2000	0.00147	69.28	176.63
C403	3000	0.00098	103.92	125.75

Summary and Conclusion:-

Axial compressive test were conducted for TDGLC with various slenderness ratios and cross-section Failure mode, ultimate capacity and load strain response were reported. For columns with slenderness ratio lower than 60, strength failure was the typical failure mode according to Engineering Institute of Thailand (ETI) 1007-34 No. 5303 a . $\lambda \leq 60$

was short column .However in this test only C403 Failed by buckling which slenderness ratio 103.92 . C603 and C402 even the result shown that $\lambda \geq 60$ but the Failure model was Strength Failure mode .To use the TDG laminated column, set safety factor 2 From the summary in table 4, short columns and long columns can be divided as follows:

1. Short column test specimen C801-C803 has a slenderness ratio of between 17.50 and 51.14, C601-C602 has a slenderness ratio of between 22.73 and 45.46, and test specimen C603 is approximately 60%, although the slenderness ratio is 69.19. It was found that specimen failure occurred without deflection and C401 had a slenderness ratio of 34.64.
2. Long column test specimens C403 have a slenderness ratio of 103.92 test specimens had a total deflection. Specimen C402 with a slenderness ratio of 69.28. Part specimens have a partial deflection of approximately 67%, and part specimens of C603 have a partial deflection of approximately 33.3%.

This paper tested only mechanical properties on TDGLC. From the test results, it was found that in the production process of test samples for testing, it took a long time to produce because all test samples were mostly labor-intensive. For the environment, collecting all the data in the production process in this research can be further applied to environmentally important matters such as the analysis of the carbon footprint released into the environment. Or the production and development of environmentally friendly production tools that can increase the efficiency of the work of processing bamboo in the future.

References:-

1. Office of the Nation Economic and Social Development Council,(2022).Sustainable Agriculture Report under the 12 National Economic and Social Development Plan.depa.or.th/tn/article-view/agriculture-alternative-way-of-survival
2. The Engineering Institute of Thailand under H.M. The King’s Patronage (EIT) 1007-34 (2021).Construction Safety Standards1007-34 Article 5303 (a).Thailand
3. P. van Der Lugt, J. Vogtlander, H. Brezet, Bamboo, a Sustainable Solution for Western Europe Design Cases, LCAs and Land-Use. Beijing, China: INBAR Technical Report No. 30, 2009
4. H.Li, Q. Zhang ; D. Huang, A.J. Deeks. Compressive performance of laminated bamboo. Composite Part B: engineering, 2013; Volume 3, pp. 319-328.
5. De Flander, K. The Role of Bamboo in Global Modernity: From Traditional to Innovative Construction Material. Master’s Thesis, Wageningen University, Wageningen, The Netherlands, 2005.
6. Liese, W. Research on bamboo. Wood Science and Figure 7. Load-displacement relations in split tensile tests for FRBC and PCC. Adv. Sci. Technol. Res. J. **2022**, 16, 165–175.
7. Sharma, B.; van der Vegte, A. Engineered bamboo for structural applications. In Nonconventional and Vernacular Construction Materials; Elsevier: Amsterdam, the Netherlands, 2020; pp. 597–623.
8. Muhammad, F.; Haris, M.; Khan, W.; Zaman, S. Bamboo as a construction material: Prospects and challenges. Adv. Sci. Technol. Res. J. **2022**, 16, 165–175.
9. Habibi, S. Design concepts for the integration of bamboo in contemporary vernacular architecture. Archit. Eng. Des. Manag. **2019**, 15, 475–489.
10. Thammapornram, C. (2019), July 20 2019.Why the Bamboo. Retrieved from megabamtech1212: <https://megabamtech1212.com/why-the-bamboo/>
11. Thammapornram, C. (2020), March 16 2020.TDG bamboo. Retrieved from megabamtech1212: <https://megabamtech1212.com/tdg-bamboo/>
12. Chaleeporn, T. (2019), May 13 2019. Design Idea for bamboo laminate. Retrieved from megabamtech1212: <https://megabamtech1212.com/design-idea-for-laminate/>
13. Chaleeporn, T. (2019), May 13 2019. Carbon Footprint. Retrieved from megabamtech1212: <https://megabamtech1212.com/carbo-credit/>
14. Songkarn, K. The Innovation of Dendrocalamus Giganteus Bamboo Column. Ph.D. Thesis, Faculty of Engineering Law and Inspection, Ramkhamhaeng University, Bangkok, Thailand, 2019.
15. Thammapornram C, Kongsong, & Buranakarn V (2018) .Thai Dendrocalamus Giganteus .Science, Technology, and Architecture. ESTCON Thailand
16. Kongsricharoen, S; Kongsong, W; Tuprakay, S; Tuprakay, S; Thammapornram, C. Analysis the shear strength of Thai Dendrocalamus Gigantues (TDG) laminated bamboo by the factor of glue and location of the strips. Int. J. Civ. Eng. Technol. **2019**, 10, 253–262

17. Kitiyanun, K.; Kongsong, W.; Tuprakay, S.; Tuprakay, S.R.; Harnphanich, B.; Poowarakulchai, C.; Thammapornram, C. Mechanical Properties of Parallel TDG Bamboo Laminated Columns with Tough and Grove Joints. **Designs** **2022**, **6**, 107. <https://doi.org/10.3390/designs6060107>
18. Krittapat, K., Waranon K., Chaleeporn T. (2022), Analysis of physical properties The Dendrocalamus Gigantues (TDG) bamboo case study the factor of differnt location Node and Internode .International Journal of management (IJM), pp 308-318
19. KongsrichareanSongkarn, (2019). The Innovation of Dendrocalamus Giganteus bamboo Column, PhD. Dissertation of Engineering Law and Inspection: Faculty of Engineering Ramkhamhaeng University
20. KongsrichareanSayan , (2019). The innovation of Thai Dendrocalamus Giganteus bamboo joints according to building control Act and safety standard, PhD. Dissertation of Engineering Law and Inspection: Faculty of Engineering Ramkhamhaeng University
21. ASTM D143-09. (2009). Standard test method for small clear specimens of timber. West Conshohocken, PA, USA: ASTM international
22. DPT 1221-51. (2002). Standards Test of wood. Thailand: The Bureau of Building Inspection and Control Department of Public Works and Town & Country planning
23. DPT 1225-51. (2002). Standards Test Method for tensile test of wood. Thailand: The Bureau of Building Inspection and Control Department of Public Works and Town & Country planning.
24. DPT 1224-51. (2002). Standards Test for bending test of wood. Thailand: The Bureau of Building Inspection and Control Department of Public Works and Town & Country planning
25. DPT 1222-51. (2002). Standards Test for compressive strength of wood. Thailand: The Bureau of Building Inspection and Control Department of Public Works and Town & Country planning
26. Kongsricharoen, S., Kongsong, W., Tuprakay, S., Tuprakay, S., & Thammapornram, C. (2019). Analysis the shear strength of Thai Dendrocalamus Gigantues (TDG) lamed bamboo by the factor of glue and location of the strips. International Journal of Civil Engineering and Technology (IJCIET), 253-262
27. Chaleeporn Thammapornram, Waranon Kongsong, Vorasun Buranakarn, effecting Factors of mechanical Properties of Thai Dendrocalamus Giganteus Bamboo, International Journal of Civil Engineering and Technology (IJCIET) 9(13), 2018, pp. 1457-1467
28. Thammapornram C, (2018). The Innovation of Dendrocalamus Giganteus bamboo beam, PhD. Dissertation of Engineering Law and Inspection: Faculty of Engineering Ramkhamhaeng University
29. Chaleeporn Thammapornram, (2022) , July 21 2019. Bamboo column. <https://megabamtech1212.com/bamboo-column/>
30. Rachata, P., Waranon K., Chaleeporn T. (2021), Analysis of physical properties Thai Dendrocalamus Gigantues (TDG) bamboo case study strips making. International Journal of Advanced Research in Engineering and Technology (IJARET), pp 816-828
31. Rachata, P., Waranon K., Chaleeporn T., Analysis (2021) of emission factor in Thailand for vehicle transportation that affects the carbon footprint in production process of Thai Dendrocalamus Gigantues (TDG) laminated. International Journal of Advanced Research in Engineering and Technology (IJARET), pp 816-828
32. Krittapat, K., Waranon K., Chaleeporn T. (2021), Analysis of Thai Dendrocalamus Gigantues bamboo (TDG) strip method of production a different method. International Journal of Advanced Research in Engineering and Technology (IJARET), pp 75-87
33. Thammapornram C, (2018). The Innovation of Dendrocalamus Giganteus bamboo beam, PhD. Dissertation of Engineering Law and Inspection: Faculty of Engineering Ramkhamhaeng University
34. Zhang, J.P., Wang, S.S., Gong, S. G., Zuo, Q.S., & Hu, H.y. (2019). Thermo-mechanical coupling analysis of the orthotropic structures by using element-free Galerkin method .Engineering Analysis with Bounday Element, 101, 198-213.
35. Kabir, H., & Aghdam, M.M. (2021). A generalized 2D Bezier based solution for stress analysis of notch epoxy resin plates reinforced with graphene nanoplatelets. Thin-Walled Structures, 169, 108484.