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Engineering Properties of Solid and Laminated Glulam of *Acacia mangium* superbulk Planted in Sarawak

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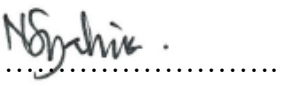
DECLARATION

I declare that the work in this thesis entitled "Engineering Properties of Solid and Laminated Glulam of *Acacia mangium* superbulk Planted in Sarawak" was carried out in accordance with the regulations of Universiti Malaysia Sarawak. Expect where due acknowledgements have been made, the work is that of the author alone. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.



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ABSTRACT

The slow growth rate of primer species has had an impact on the quantity available to meet market demand. To address this issue, a study was conducted to fully employ fast-growing timber as the principal resource in order to ensure that demand for timber logs remains stable. The purpose of this research was to study the engineering properties of *Acacia mangium* superbulk, a fast-growing timber species that planted in Daiken Plantation Bintulu, Sarawak with age groups of 7, 10 and 13 years old at air-dry moisture content. The small-clear samples were prepared in the form of solid and laminated (same age groups and different age groups) and set into untreated and treated for both solid and laminated sample products. The type of preservative and adhesive glue that have been used are *Copper Chrome Arsenic* (CCA) and *Phenol-resorcinol Formaldehyde* (PRF), respectively. The mechanical strength testing conducted are modulus of rupture (MOR), modulus of elasticity (MOE), compression parallel to grain and shear parallel to grain. This study also established the end-user applications in the timber industry based on density, hardwood category, strength grouping and hazard class. From the study, the maximum strength value of solid untreated is obtained by 10 years old, which is recorded the MOR, MOE, compression parallel to grain and shear parallel to grain are 115.11 N/mm^2, 14945 N/mm^2, 57.57 N/mm^2 and 14.24 N/mm^2, respectively. Besides that, the maximum strength value of solid treated is also obtained by 10 years old, which is recorded 118.76 N/mm^2, 15020 N/mm^2, 57.82 N/mm^2 and 13.67 N/mm^2 for MOR, MOE, compression parallel to grain and shear parallel to grain, respectively. For laminated samples, there is no significant difference in strength from laminated untreated products 10 // 10 years old when compared to solid untreated 10 years old, and the percentage differences obtained by MOR, MOE, compression parallel to grain and shear parallel to grain are 2.45%, 0.31%, 3.58% and 3.37%, respectively. Meanwhile,

the strength properties between laminated treated products 10 // 13 years old and solid treated 10 years old do not have any significant difference, and the percentage differences obtained by MOR, MOE, compression parallel to grain and shear parallel to grain are 3.37%, 0.06%, 3.91% and 1.17%, respectively. The treatment by CCA preservative shows the *Acacia mangium* superbulk is classified as moderately difficult to treat and hazard class of H4 (±14 litre/m^3). The density of *Acacia mangium* superbulk at air- dry condition is 0.61 g/cm^3 and its categorised as light hardwood. Moreover, the *Acacia mangium* superbulk is classified as Group B based on compression strength and Group A based on basic grading. The end-user utilisations of *Acacia mangium* superbulk are recommended for structural components, roofing, staircase, flooring, walling, door, window, and decorative panelling.

Keywords: fast-growing timber, small-clear, laminated glulam, modulus of rupture, modulus of elasticity, compression parallel to grain, shear parallel to grain, *Copper Chrome Arsenic* (CCA), *Phenol-resorcinol Formaldehyde* (PRF)

Sifat Kejuruteraan Pepejal dan Glulam Berlamina* Acacia mangium superbulk *yang ditanam di Sarawak

ABSTRAK

Kadar pertumbuhan perlahan species primer telah memberi kesan kepada kuantiti yang tersedia untuk memenuhi permintaan pasaran. Untuk menangani isu ini, satu kajian telah dijalankan untuk menggunakan sepenuhnya kayu yang tumbuh cepat sebagai sumber utama bagi memastikan permintaan terhadap kayu balak kekal stabil. Tujuan penyelidikan ini adalah untuk mengkaji sifat kejuruteraan Acacia mangium superbulk*, species kayu yang cepat tumbuh yang ditanam di* Daiken Plantation Bintulu, Sarawak *dengan kumpulan umur 7, 10, dan 13 tahun pada kandungan lembapan kering udara. Sampel-sampel ini disediakan dalam bentuk pepejal, berlamina (produk berlamina dengan kumpulan umur yang sama dan produk berlamina dengan kumpulan umur yang berbeza) dan juga disediakan dalam keadaan tidak dirawat dan dirawat. Bahan kimia yang digunakan untuk proses merawat sampel ialah* Copper Chrome Arsenic (CCA) *dan bahan gam yang digunakan untuk proses lamina ialah* Phenol-resornicol Formaldehdye (PRF). *Ujian-ujian mekanikal yang dijalankan ke atas sampel kayu adalah modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari. Kajian ini juga menetapkan aplikasi penggunaan kayu dalam industri kayu berdasarkan kepada ketumpatan kayu, kategori kayu keras, kumpulan kekuatan kayu dan kelas bahaya. Daripada kajian ini, nilai kekuatan maksimum sampel pepejal yang tidak dirawat adalah diperoleh daripada kumpulan umur 10 tahun yang masing – masing mencatatkan modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari sebanyak 115.11 N/mm^2, 14945 N/mm^2, 57.57 N/mm^2 dan 14.24 N/mm^2. Selain itu, nilai kekuatan maksimum bagi sampel pepejal yang dirawat juga diperoleh daripada kumpulan umur 10 tahun dengan mencatatkan nilai masing-masing iaitu 118.76*

N/mm^2, 15020 N/mm^2, 57.82 N/mm^2 dan 13.67 N/mm^2 untuk modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari. Untuk sampel berlamina, tiada perbezaan sifat kekuatan yang signifikan diantara sampel tidak dirawat yang berumur 10 // 10 tahun dengan sampel pepejal yang tidak dirawat yang berumur 10 tahun dan peratusan perbezaan kekuatan tersebut ialah 2.45%, 0.31%, 3.58% dan 3.37% masing-masing untuk modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari. Sementara itu, sifat kekuatan diantara sampel produk berlamina dirawat yang berumur 10 // 13 tahun dan sampel pepejal dirawat yang berumur 10 tahun juga tidak mempunyai perbezaan yang signifikan, dan perbezaan peratusan yang diperoleh oleh modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari adalah 3.37%, 0.06%, 3.91% dan 1.17%. Disamping itu, rawatan yang menggunakan CCA menunjukkan Acacia mangium superbulk *diklasifikasikan sebagai kelas agak sukar dirawat dan kelas bahaya H4 (± 14 liter/m^3). Ketumpatan* Acacia mangium superbulk *dalam keadaan udara kering adalah 0.61 g/cm^3 dan dikategorikan sebagai kayu keras ringan. Pokok* Acacia mangium superbulk *dikelaskan dalam kumpulan kekuatan B berdasarkan kekuatan mampatan dan kumpulan A berdasarkan gred asas. Penggunaan* Acacia mangium superbulk *di dalam industri perkayuan disyorkan untuk digunakan sebagai komponen struktur, atap, tangga, lantai, dinding, pintu, tingkap dan panel hiasan.*

Kata kunci: *kayu cepat tumbuh, pepejal, glulam berlamina, modulus pecah, modulus keanjalan, mampatan ira selari dan ricih ira selari*, Copper Chrome Arsenic (CCA), Phenol-resorcinol Formaldehyde (PRF)

TABLE OF CONTENTS

		Page
DECLARATION		i
ACKNOWLEDGEMENTS		ii
ABSTRACT		iv
ABSTRAK		vi
TABLE OF CONTENTS		ix
LIST OF TABLES		xiii
LIST OF FIGURES		xxvi
LIST OF ABBREVIATION		xli
CHAPTER 1: INTRODUCTION		1
1.1	Background	1
1.2	Problem Statement	3
1.3	Objectives of Study	5
1.4	Chapter Outline	6
CHAPTER 2: LITERATURE REVIEW		7
2.1	Background	7
2.2	*Acacia mangium*	9
2.3	Physical Properties of *Acacia mangium*	13
2.4	Mechanical Properties of *Acacia mangium*	18
2.5	Strength Group	20
2.6	Treatment of *Acacia mangium*	23
2.7	Lamination of Acacia mangium	27

2.8 Decay and Damage Protection 31

2.9 The Applications of *Acacia mangium* 37

CHAPTER 3: METHODOLOGY 40

3.1 Background 40

3.2 E-numeration and Selection of Trees 40

3.3 Preparation of Sample 48

3.4 Physical Testing 58

3.5 Mechanical Testing 61

3.5.1 Static Bending 63

3.5.2 Compression Parallel to Grain 65

3.5.3 Shear Parallel to Grain 66

3.6 Treatability 68

3.7 Lamination 73

3.7.1 Tree's Pairing 78

3.8 Method to Rank the Strength Differences 79

3.9 Method of Analysis 79

CHAPTER 4: RESULTS, ANALYSIS AND DISCUSSIONS 81

4.1 Background 81

4.2 Solid-untreated of *Acacia mangium* superbulk 83

4.2.1 Moisture Content 83

4.2.2 Density 86

4.2.3 Basic Density 88

4.2.4 Static Bending 90

4.2.5 Compression Parallel to Grain 99

4.2.6 Shear Parallel to Grain 105

4.3 Solid-treated of *Acacia mangium* superbulk 113

4.3.1 Moisture Content 114

4.3.2 Density 114

4.3.3 Static Bending 118

4.3.4 Compression Parallel to Grain 126

4.3.5 Shear Parallel to Grain 132

4.4 Laminated-untreated Products of *Acacia mangium* superbulk 142

4.4.1 Moisture Content 143

4.4.2 Density 147

4.4.3 Basic Density 150

4.4.4 Static Bending by the Same Age Groups 155

4.4.5 Static Bending by the Different Age Groups 163

4.4.6 Compression Parallel to Grain by the Same Age Groups 171

4.4.7 Compression Parallel to Grain by the Different Age Groups 177

4.4.8 Shear Parallel to Grain by the Same Age Groups 182

4.4.9 Shear Parallel to Grain by the Different Age Groups 189

4.5 Laminated-treated Products of *Acacia mangium* superbulk 194

4.5.1 Moisture Content 194

4.5.2 Density 195

4.5.3 Static Bending by the Same Age Groups 202

4.5.4 Static Bending by the Different Age Groups 213

4.5.5 Compression Parallel to Grain by the Same Age Groups 223

4.5.6 Compression Parallel to Grain by the Different Age Groups 230

4.5.7 Shear Parallel to Grain in Tangential Direction by the Same Age Groups 236

4.5.8 Shear Parallel to Grain in Tangential Direction by the Different Age Groups 242

4.6 Treatability Retention of *Acacia mangium* superbulk 248

4.6.1 Solid 248

4.6.2 Laminated 252

4.7 Summary of Results 257

4.8 Factors Affecting Mechanical Strength Properties 260

4.8.1 Effect of Physical Properties 260

4.8.2 Effect of Maturity 264

4.8.3 Effect of Miscellaneous 265

4.9 Treatability Evaluation and Hazard Classification 266

CHAPTER 5: UTILISATION OF ACACIA MANGIUM SUPERBULK 271

5.1 Background 271

5.2 Percentage Difference of Mechanical Strength Properties to the Reference Point 271

5.3 Strength Grouping 275

5.3.1 Strength Grouping Based on Compression Parallel to Grain (Burgess, 1958) 275

5.3.2 Strength Grouping Based on Basic Grade (Air-dry Condition) (Chik, 1988) 276

5.4 The Recommendation for End-user Applications 277

CHAPTER 6: CONCLUSION AND RECOMMENDATION 283

6.1 Conclusions 283

6.2 Recommendations 287

REFERENCES 289

APPENDICES 306

LIST OF TABLES

		Page
Table 2.1	Classification of Malaysian Hardwood (Malaysia Timber Industry Board, 2019c)	8
Table 2.2	Growth characteristics of *Acacia mangium* superbulk at Different Ages (Adam et al., 2012)	14
Table 2.3	Mechanical Properties of *Acacia mangium* and *Acacia mangium* superbulk from Prior Study	19
Table 2.4	Dry-grade Stress for Various Strength Groups of Timber	20
Table 2.5	Strength Grouping (Burgess, 1958; Ashaari, 2017)	20
Table 2.6	Probability Values for Determination of Basic Stresses (Chik, 1988a)	21
Table 2.7	Factors of Safety for Determining Basic Stresses (Chik, 1988a)	21
Table 2.8	Strength Ratio (Pun et al., 1997)	22
Table 2.9	Strength Groups Based on Basic Grade (Air-dry Condition) (Chik, 1988a)	23
Table 2.10	Treatability Classification (Malaysian Standard, 2006)	24
Table 2.11	Hazard Class Selection Guide Extracted from Malaysian Standard (2003) and Malaysian Standard (2006)	25
Table 2.12	Treatability Retention of *Acacia mangium* (Lai and Sammy, 2014)	26
Table 2.13	Treatability Retention of *Acacia mangium* (Salmiah et al., 2011)	26
Table 2.14	Mechanical Properties of Lamination of *Acacia mangium* (Suryono, 2015)	31
Table 2.15	Strength Groups of Timber and Applications, (Malaysia Timber	38

Industry Board, 2019b)

Table 2.16 Density Groups of Hardwood and its Applications (Sulaiman and Lim, 2004) 39

Table 3.1 Description of Locality and Plot Area of 7, 10, and 13 Years Old 43

Table 3.2 Summary of the Inventoried Trees 44

Table 3.3 Grouping and Batches of *Acacia mangium* superbulk Plot 1 45

Table 3.4 Grouping and Batches of *Acacia mangium* superbulk Plot 2 46

Table 3.5 Grouping and Batches of *Acacia mangium* superbulk Plot 3 47

Table 3.6 Tree's Pairing for Lamination 78

Table 4.1 Moisture Content (Solid-untreated) of *Acacia mangium* superbulk 84

Table 4.2 One-way ANOVA Moisture Content (Solid-untreated) of *Acacia mangium* superbulk 84

Table 4.3 DMRT of Moisture Content (Solid-untreated) of *Acacia mangium* superbulk 85

Table 4.4 DMRT of Moisture Content (Solid-untreated) of *Acacia mangium* superbulk 86

Table 4.5 One-way ANOVA Density (Solid-untreated) of *Acacia mangium* superbulk 87

Table 4.6 DMRT of Density (Solid-untreated) of *Acacia mangium* superbulk 87

Table 4.7 One-way ANOVA of Basic Density (Solid-untreated) of *Acacia mangium* superbulk 89

Table 4.8 DMRT of Basic Density (Solid-untreated) of *Acacia mangium* superbulk 89

Table 4.9 One-way ANOVA of MOR and MOE (Solid-untreated) of *Acacia* 92

mangium superbulk

Table 4.10 DMRT of MOR (Solid-untreated) of *Acacia mangium* superbulk 93

Table 4.11 DMRT of MOE (Solid-untreated) of *Acacia mangium* superbulk 93

Table 4.12 Maximum Load of Static Bending (Solid-untreated) of *Acacia mangium* superbulk 94

Table 4.13 Comparison of Static Bending between *Acacia mangium* and *Acacia mangium* superbulk (Solid-untreated) 98

Table 4.14 One-way ANOVA of Compression Parallel to Grain (Solid-untreated) of *Acacia mangium* superbulk 101

Table 4.15 DMRT of Compression Parallel to Grain (Solid-untreated) of *Acacia mangium* superbulk 101

Table 4.16 Maximum Load of Compression Parallel to Grain (Solid-untreated) of *Acacia mangium* superbulk 102

Table 4.17 Comparison of Compression Parallel to Grain between *Acacia mangium* and *Acacia mangium* superbulk (Solid-untreated) 104

Table 4.18 One-way ANOVA of Shear Parallel to Grain (Solid-untreated) of *Acacia mangium* superbulk 108

Table 4.19 DMRT of Shear Parallel to Grain in Radial Plane (Solid-untreated) of *Acacia mangium* superbulk 108

Table 4.20 DMRT of Shear Parallel to Grain in Tangential Plane (Solid-untreated) of *Acacia mangium* superbulk 109

Table 4.21 Maximum Load of Shear Parallel to Grain (Solid-untreated) of *Acacia mangium* superbulk 109

Table 4.22 Density Before and After Treatment (Solid-treated) of 115

Acacia mangium superbulk

Table 4.23 One-way ANOVA of Density Before Treatment (Solid-treated) of *Acacia mangium* superbulk 116

Table 4.24 DMRT of Density Before Treatment (Solid-treated) of *Acacia mangium* superbulk 116

Table 4.25 One-way ANOVA of Density After Treatment (Solid-treated) of *Acacia mangium* superbulk 117

Table 4.26 DMRT of Density After Treatment (Solid-treated) of *Acacia mangium* superbulk 117

Table 4.27 One-way ANOVA of MOR and MOE (Solid-treated) of *Acacia mangium* superbulk 120

Table 4.28 DMRT of MOR (Solid-treated) of *Acacia mangium* superbulk 120

Table 4.29 DMRT of MOE (Solid-treated) of *Acacia mangium* superbulk 120

Table 4.30 Maximum Load of Static Bending (Solid-treated) of *Acacia mangium* superbulk 121

Table 4.31 One-way ANOVA of Compression Parallel to Grain (Solid-treated) of *Acacia mangium* superbulk 128

Table 4.32 DMRT of Compression Parallel to Grain (Solid-treated) of *Acacia mangium* superbulk 128

Table 4.33 Maximum Load of Compression Parallel to Grain (Solid-treated) of *Acacia mangium* superbulk 129

Table 4.34 One-way ANOVA of Shear Parallel to Grain (Solid-treated) of *Acacia mangium* superbulk 134

Table 4.35 DMRT of Shear Parallel to Grain in Radial Plane (Solid- 135

	treated) of *Acacia mangium* superbulk	
Table 4.36	DMRT of Shear Parallel to Grain in Tangential Plane (Solid-treated) of *Acacia mangium* superbulk	135
Table 4.37	Maximum Load of Shear Parallel to Grain (Solid-treated) of *Acacia mangium* superbulk	136
Table 4.38	Moisture Content of the Same Age Groups of *Acacia mangium* superbulk (Laminated-untreated Products)	144
Table 4.39	One-way ANOVA of Moisture Content by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	144
Table 4.40	DMRT of Moisture Content by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	145
Table 4.41	Moisture Content of the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	145
Table 4.42	One-way ANOVA of Moisture Content by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	146
Table 4.43	DMRT of Moisture Content by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	146
Table 4.44	One-way ANOVA of Moisture Content by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	148
Table 4.45	DMRT of Density by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	148
Table 4.46	One-way ANOVA of Density by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	150
Table 4.47	DMRT of Density by the Different Age Groups (Laminated-	150

	untreated Products) of *Acacia mangium* superbulk	
Table 4.48	One-way ANOVA of Basic Density by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	152
Table 4.49	DMRT of Basic Density by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	152
Table 4.50	One-way ANOVA of Basic Density by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	154
Table 4.51	DMRT of Basic Density by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	154
Table 4.52	One-way ANOVA of MOR and MOE by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	157
Table 4.53	DMRT of MOR by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	158
Table 4.54	DMRT of MOE by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	158
Table 4.55	Maximum Load of Static Bending by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	158
Table 4.56	One-way ANOVA of MOR and MOE by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk	166
Table 4.57	DMRT of MOR by the Different Age Groups (Laminated-Untreated Products) of *Acacia mangium* superbulk	167
Table 4.58	DMRT of MOE by the Different Age Groups (Laminated-Untreated Products) of *Acacia mangium* superbulk	167
Table 4.59	Maximum Load of Static Bending by the Different Age Groups	167

(Laminated-untreated Products) of *Acacia mangium* superbulk

Table 4.60 One-way ANOVA of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 173

Table 4.61 DMRT of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 173

Table 4.62 Maximum Load of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 174

Table 4.63 One-way ANOVA of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 178

Table 4.64 DMRT of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 179

Table 4.65 Maximum Load of Compression Parallel to Grain by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 180

Table 4.66 One-way ANOVA of Shear Strength by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 184

Table 4.67 DMRT of Shear Strength by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 185

Table 4.68 Maximum Load of Shear Strength by the Same Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 186

Table 4.69 One-way ANOVA of Shear Strength by the Different Age Groups 191

(Laminated-untreated Products) of *Acacia mangium* superbulk

Table 4.70 DMRT of Shear Strength by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 192

Table 4.71 Maximum Load of Shear Strength by the Different Age Groups (Laminated-untreated Products) of *Acacia mangium* superbulk 192

Table 4.72 One-way ANOVA of Density Before Treatment by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 196

Table 4.73 DMRT of Density Before Treatment by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 197

Table 4.74 One-way ANOVA of Density After Treatment by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 198

Table 4.75 DMRT of Density After Treatment by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 198

Table 4.76 One-way ANOVA of Density Before Treatment by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 200

Table 4.77 DMRT of Density Before Treatment by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 200

Table 4.78 One-way ANOVA of Density After Treatment by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 202

Table 4.79 DMRT of Density After Treatment by the Different Age Groups 202

(Laminated-treated Products) of *Acacia mangium* superbulk

Table 4.80 One-way ANOVA of MOR and MOE by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 205

Table 4.81 DMRT of MOR by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 205

Table 4.82 DMRT of MOE by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 206

Table 4.83 Maximum Load of Static Bending by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 206

Table 4.84 One-way ANOVA of MOR and MOE by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 215

Table 4.85 DMRT of MOR by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 216

Table 4.86 DMRT of MOE by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 216

Table 4.87 Maximum Load of Static Bending by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 217

Table 4.88 One-way ANOVA of Compression Parallel to Grain by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 225

Table 4.89 DMRT of Compression Parallel to Grain by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 225

Table 4.90 Maximum Load of Compression Parallel to Grain by the Same Age Groups (Laminated-treated Products) of 226

Acacia mangium superbulk

Table 4.91 One-way ANOVA of Compression Parallel to Grain by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 231

Table 4.92 DMRT of Compression Parallel to Grain by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 232

Table 4.93 Maximum Load of Compression Parallel to Grain by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 233

Table 4.94 One-way ANOVA of Shear Parallel to Grain in Tangential Direction by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 237

Table 4.95 DMRT of Shear Parallel to Grain in Tangential Direction by the Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 238

Table 4.96 Maximum Load of Shear Parallel to Grain in Tangential Direction by The Same Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 238

Table 4.97 One-way ANOVA of Shear Parallel to Grain in Tangential Direction by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 244

Table 4.98 DMRT of Shear Parallel to Grain in Tangential Direction by the Different Age Groups (Laminated-treated Products) of 244

Acacia mangium superbulk

Table 4.99 Maximum Load of Shear Parallel to Grain in Tangential Direction by the Different Age Groups (Laminated-treated Products) of *Acacia mangium* superbulk 245

Table 4.100 Treatability Retention Level on Solid *Acacia mangium* superbulk 249

Table 4.101 Dry-salt Retention on Solid *Acacia mangium* superbulk 249

Table 4.102 One-way ANOVA of Treatability Retention on Solid *Acacia mangium* superbulk 250

Table 4.103 DMRT of Treatability Retention on Solid *Acacia mangium* superbulk 251

Table 4.104 Comparison of Treatability Retention between Solid *Acacia* and *Acacia mangium* superbulk 251

Table 4.105 Treatability Retention Level on Laminated Products by the Same Age Groups of *Acacia mangium* superbulk 252

Table 4.106 Dry-salt Retention on Laminated Products by the Same Age Groups *Acacia mangium* superbulk 253

Table 4.107 One-way ANOVA of Treatability Retention on Laminated Products by the Same Age Groups of *Acacia mangium* superbulk 254

Table 4.108 DMRT of Treatability Retention on Laminated Products by the Same Age Groups of *Acacia mangium* superbulk 254

Table 4.109 Treatability Retention Level on Laminated Products by the Different Age Groups of *Acacia mangium* superbulk 255

Table 4.110 Dry-salt Retention on Laminated Products by the Different Age Groups of *Acacia mangium* superbulk 255

Table 4.111 One-way ANOVA of Treatability Retention on Laminated Products 256