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Structural Design in Timber

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Abstract:
Timber is a hard log or dressed piece of wood ready for use or forming part of a structure. These woods are prepared to be used in building construction. Timber construction can be a huge asset to the residential building industry. It provides great benefits when combined with clever planning, high precision, well-monitored construction and high quality implementation. The use of timber frames around the world is very popular. A timber framed structure can be used in conjunction with in any other building material like bricks or stone to build economical houses. Transportation costs are lower due to the fact that timber is lightweight and it is locally available. In this thesis work an attempt to formulate the methodology to use timber as a flexural member. These design procedure has been automated in Visual Basic software. Nomograms as recokners are prepared which will ease out selection and design of flexural members for different types of timber.

Keywords: Beam, Bending Moment, Shear Force, Depth, Flexural Member, etc.,

1. INTRODUCTION

Timber is a material used for building construction. It is natural and can be reused. They come on different species and are easily available. They are supplied as softwoods and hardwoods in standard size and used in constructions. It has many uses and most of the time used for structural purpose. It's obtained as softwood and hardwood and 80% of timber comes from softwood. It is a fibrous rigid material of plant origin. Strength to weight ratio is high and working with timbers are easy. Timber is used for building purpose and has qualities including good physical and aesthetic qualities, and their availability is high, easy to work and is versatile, environmental sustainability, flexible, industrial production and less cost effective. One of the best part of timber is that they absorb carbon dioxide and release oxygen into atmosphere during photosynthesis with a comparatively low thermal conductivity. These are readily available and have high sustainability. Preservatives can protect timbers from the attack of organisms for certain period of time. Preservatives should be well applied with proper amount so as to penetrate into timber.

1.1 THE OBJECTIVE OF THE STUDY

Formulation of methodology to use timber. Study of Indian and International codal provisions for timber design. Analysis and design of structural components made of timber. The above methods are automated in Visual Basic environment. Nomograms and handbooks with Ready reckoners will be formulated flexural, compression and tension members for different species of timber.

2. METHODOLOGY

2.1 DESIGN OF FLEXURAL ELEMENT

Design of timber is difference from regular material like concrete and steel. Concrete and steel have properties like homogenous, isotropic. But timbers differ with the properties like capacity to resist the forces parallel to grain and perpendicular to the grain.

1. Effective span
It is taken as distance from the face of supports plus one half of the length of bearing at each end except for continuous beam and joists.

2. Width
The minimum width of the beams shall not be less than 5cm or 1/50 of span, whichever is greater.

3. Depth
The depth of beams shall not be more than three times of its width without lateral stiffening.

4. Deflection

The deflection of beams, supporting brittle material like gypsum ceiling, slates, tiles, and asbestos sheets shall not exceed 1/360 of span. In other cases shall not exceed 1/240 of span. 1/180 of freely hanging length in case of cantilever. The below formula is used to calculate the deflection

$$\delta_{max} = -\frac{5}{385} \times \frac{wl^3}{EI} \quad \text{................Eqn 1.1}$$

Where,
E = Young's modulus in N/mm^2
I = Moment of inertia in mm^4
w = total load in N
l = Effective span in mm

5. Shear
For rectangular beam,

$$H = \frac{3V}{2bD} \quad \text{......................Eqn. 1.2}$$

Where,
H = Horizontal shear stress in N/mm^2
V = Shear at the section in N
b = Breadth in mm
D = Depth in mm

Example:
Consider a floor having a span of 4000 mm and where beams are spaced at 1500 mm. The beams are seasoned cypress with the following properties:

f_w = 15.5 N/mm^2, tw = 0.64 MPa (N/mm2), E = 9970 Mpa (N/mm2), density 660 kg/m3. Loading on floor and including floor is 2 kPa. Allowable deflection is $L/240$

(i) Beam loading: w = 1.5 m × 2 kN/m2 = 3 kN/m.

Assume a 100 mm by 250 mm beam cross-section

(ii) dead load= 0.1 × 0.25 × 660 × 9.81 = 161.86 N/m

= 0.162 kN/m

Total w = 3 + 0.162 = 3.162 kN/m

iii) Calculate maximum bending moment (*Mmax*) using the equation for a simple beam, uniformly loaded.

$$M_{max} = \frac{wl^{\wedge}2}{8} = \frac{3.162\times4^{\wedge}2}{8} = 6.324 \text{ kNm} = 6.324\times10^6/\text{Nmm}$$

iv) Find the required section modulus *(Z)*

$$Z_{req} = \frac{M_{max}}{f_w} = \frac{6.324\times10^{\wedge}6}{15.5} = 0.41\times10^6\ mm^3$$

v) Find a suitable beam depth, assuming 100 mm breadths:

The section modulus for a rectangular shape is

$$z = \frac{1}{6}\times bd^2$$

$$d = \sqrt{\frac{6Z}{b}} = \sqrt{\frac{6\times0.41\times10^{\wedge}6}{100}} = 157\text{mm} \approx 200\text{mm}$$

Choose a 100 mm by 200 mm timber. The timber required is a little less than that assumed. If it is assumed that a smaller size timber would be adequate if a smaller size had been assumed initially then no recalculation is required.

vi) Check for shear loading:

$$Q_{max} = \frac{wl}{2} = 6.24 \text{ kN}$$

$$\tau = \frac{3Q_{max}}{2A} = \frac{3\times6.24\times10^{\wedge}3}{2\times100\times200} = 0.468 \text{ MPa} < 0.64 \text{ MPa}$$

As the safe load for the timber is 0.64 N/mm2 (MPa) the section is adequate in resistance to horizontal shear.

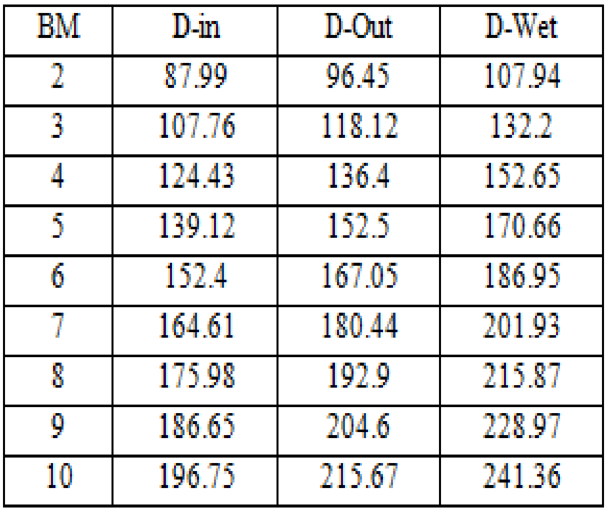
3. RESULTS AND DISCUSSION

The following are the results obtained from the timber design, which are automated in Visual Basic software. Results obtained are plotted in the form of tables and graph. Discussions will be held and the conclusion will be drawn.

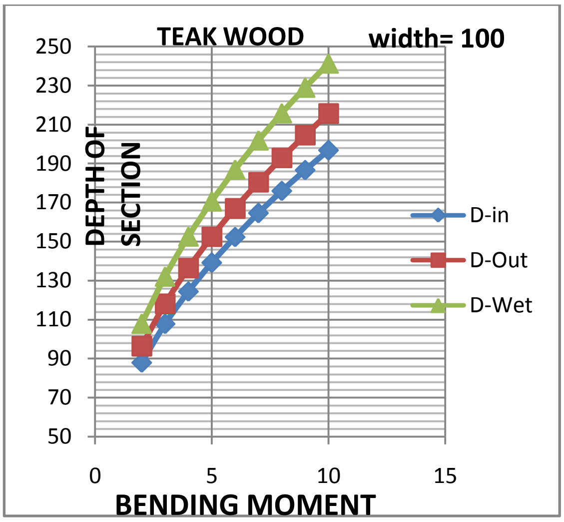
3.1 Bending Moment Along Depth For Flexural Member.

Table below shows the variation of bending moment along the depth of flexural member, where X axis represents the bending moment and Y axis represents depth of different species of timber and the conditions such as inside location, outside location and wet condition.

Table.1. Bending Moment along with depth of teak for different stress condition.



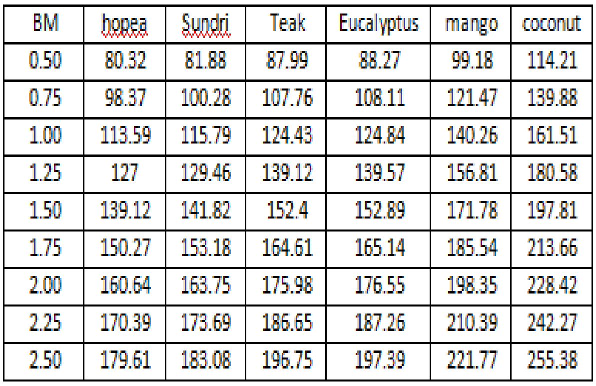
BM	D-in	D-Out	D-Wet
2	87.99	96.45	107.94
3	107.76	118.12	132.2
4	124.43	136.4	152.65
5	139.12	152.5	170.66
6	152.4	167.05	186.95
7	164.61	180.44	201.93
8	175.98	192.9	215.87
9	186.65	204.6	228.97
10	196.75	215.67	241.36



Graph.1. Bending Moment Vs depth for teak wood with different stress condition

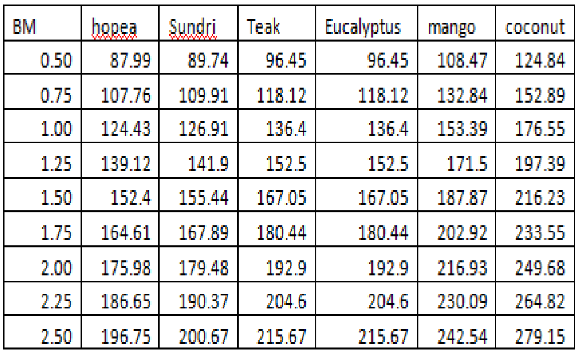
3.1.1 Bm Along With Depth of Timbers Taking Width As 25mm

Table.2. Inside condition for 25mm width



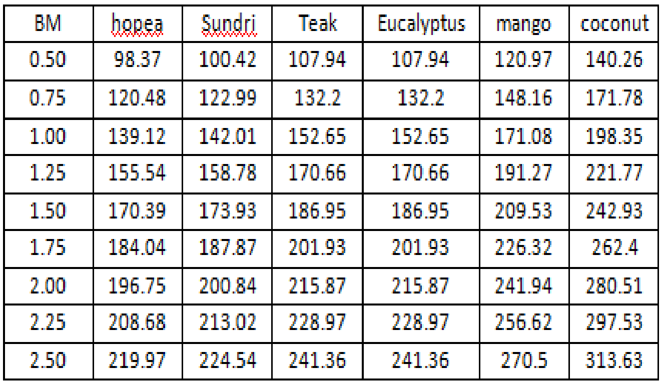
BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
0.50	80.32	81.88	87.99	88.27	99.18	114.21
0.75	98.37	100.28	107.76	108.11	121.47	139.88
1.00	113.59	115.79	124.43	124.84	140.26	161.51
1.25	127	129.46	139.12	139.57	156.81	180.58
1.50	139.12	141.82	152.4	152.89	171.78	197.81
1.75	150.27	153.18	164.61	165.14	185.54	213.66
2.00	160.64	163.75	175.98	176.55	198.35	228.42
2.25	170.39	173.69	186.65	187.26	210.39	242.27
2.50	179.61	183.08	196.75	197.39	221.77	255.38

Table.3. Outside condition for 25mm width

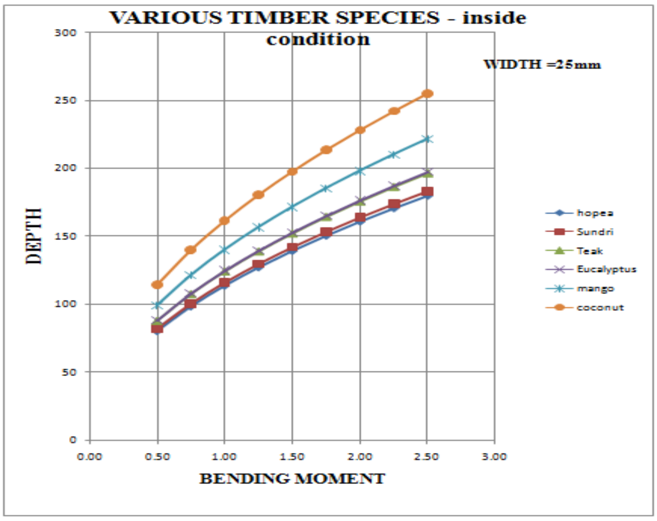


BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
0.50	87.99	89.74	96.45	96.45	108.47	124.84
0.75	107.76	109.91	118.12	118.12	132.84	152.89
1.00	124.43	126.91	136.4	136.4	153.39	176.55
1.25	139.12	141.9	152.5	152.5	171.5	197.39
1.50	152.4	155.44	167.05	167.05	187.87	216.23
1.75	164.61	167.89	180.44	180.44	202.92	233.55
2.00	175.98	179.48	192.9	192.9	216.93	249.68
2.25	186.65	190.37	204.6	204.6	230.09	264.82
2.50	196.75	200.67	215.67	215.67	242.54	279.15

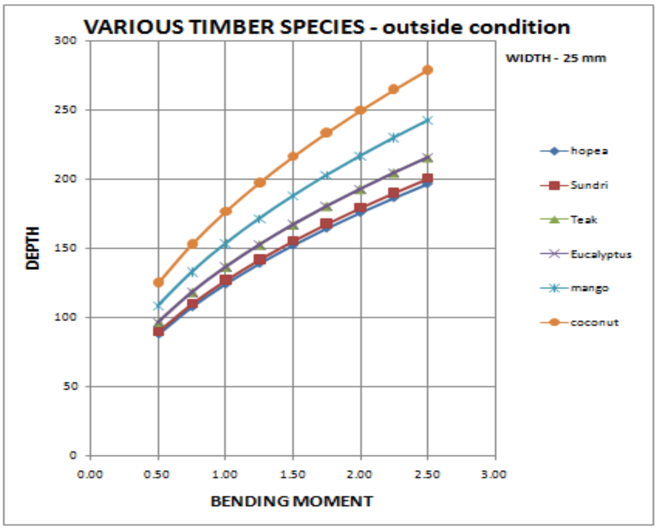
Table.4. Wet condition for 25mm width



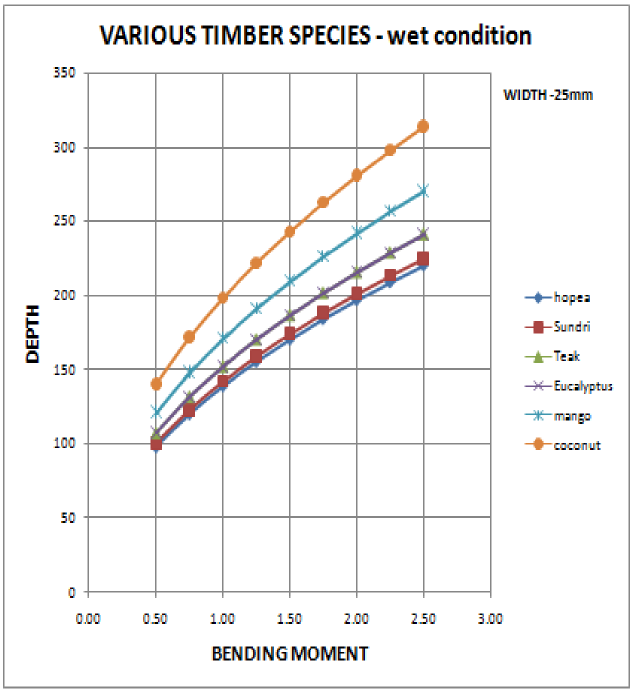
BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
0.50	98.37	100.42	107.94	107.94	120.97	140.26
0.75	120.48	122.99	132.2	132.2	148.16	171.78
1.00	139.12	142.01	152.65	152.65	171.08	198.35
1.25	155.54	158.78	170.66	170.66	191.27	221.77
1.50	170.39	173.93	186.95	186.95	209.53	242.93
1.75	184.04	187.87	201.93	201.93	226.32	262.4
2.00	196.75	200.84	215.87	215.87	241.94	280.51
2.25	208.68	213.02	228.97	228.97	256.62	297.53
2.50	219.97	224.54	241.36	241.36	270.5	313.63



Graph.2. Bending Moment Vs depth for inside condition for 25mm width



Graph.3. Bending Moment Vs depth for outside condition for 25mm width



Graph.4. Bending Moment Vs depth for wet condition for 25mm width

3.1.2 Bm Along With Depth of Timbers Taking Width As 50mm

Table.5. Inside condition for 50mm width

BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
1.00	80.32	81.88	87.99	88.27	99.18	114.21
1.50	98.37	100.28	107.76	108.11	121.47	139.88
2.00	113.59	115.79	124.43	124.84	140.26	161.51
2.50	127	129.46	139.12	139.57	156.81	180.58
3.00	139.12	141.82	152.4	152.89	171.78	197.81
3.50	150.27	153.18	164.61	165.14	185.54	213.66
4.00	160.64	163.75	175.98	176.55	198.35	228.42
4.50	170.39	173.69	186.65	187.26	210.39	242.27
5.00	179.61	183.08	196.75	197.39	221.77	255.38

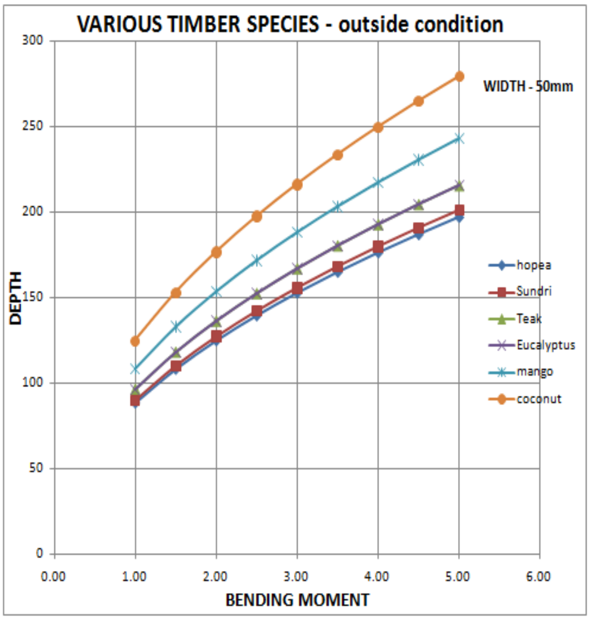
Table.6. Outside condition for 50mm width

BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
1.00	87.99	89.74	96.45	96.45	108.47	124.84
1.50	107.76	109.91	118.12	118.12	132.84	152.89
2.00	124.43	126.91	136.4	136.4	153.39	176.55
2.50	139.12	141.9	152.5	152.5	171.5	197.39
3.00	152.4	155.44	167.05	167.05	187.87	216.23
3.50	164.61	167.89	180.44	180.44	202.92	233.55
4.00	175.98	179.48	192.9	192.9	216.93	249.68
4.50	186.65	190.37	204.6	204.6	230.09	264.82
5.00	196.75	200.67	215.67	215.67	242.54	279.15

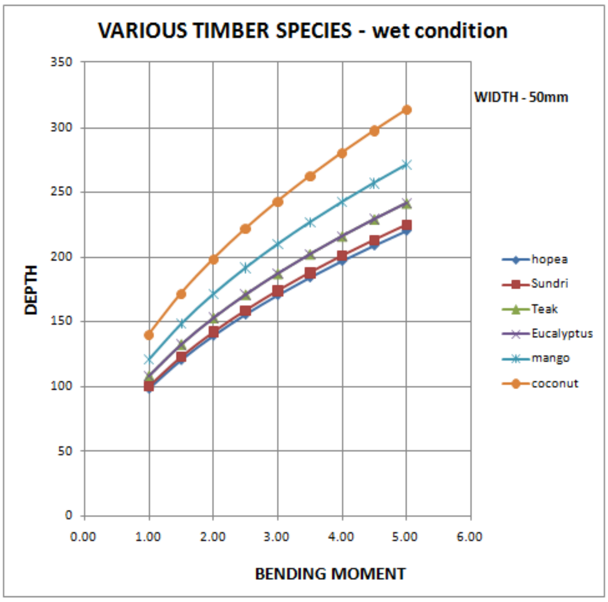
Table.7. Wet condition for 50mm width

BM	hopea	Sundri	Teak	Eucalyptus	mango	coconut
1.00	98.37	100.42	107.94	107.94	120.97	140.26
1.50	120.48	122.99	132.2	132.2	148.16	171.78
2.00	139.12	142.01	152.65	152.65	171.08	198.35
2.50	155.54	158.78	170.66	170.66	191.27	221.77
3.00	170.39	173.93	186.95	186.95	209.53	242.93
3.50	184.04	187.87	201.93	201.93	226.32	262.4
4.00	196.75	200.84	215.87	215.87	241.94	280.51
4.50	208.68	213.02	228.97	228.97	256.62	297.53
5.00	219.97	224.54	241.36	241.36	270.5	313.63

Graph.5. Bending Moment Vs depth for inside condition for 50mm width



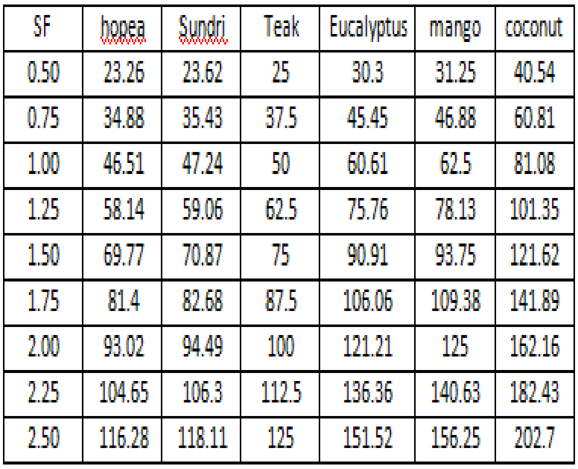
Graph.6. Bending Moment Vs depth for outside condition for 50mm width



Graph.7. Bending Moment Vs depth for wet condition for 50mm width

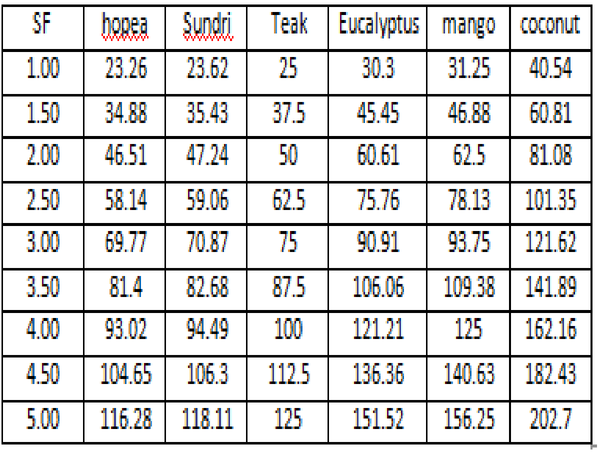
3.2 shear force Along With Depth parallel to grain

Table.8. SF along with depth of timbers taking width as 25mm

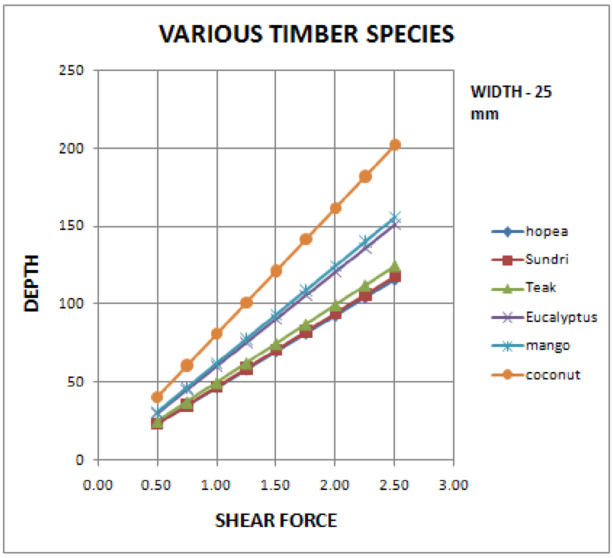


SF	hopea	Sundri	Teak	Eucalyptus	mango	coconut
0.50	23.26	23.62	25	30.3	31.25	40.54
0.75	34.88	35.43	37.5	45.45	46.88	60.81
1.00	46.51	47.24	50	60.61	62.5	81.08
1.25	58.14	59.06	62.5	75.76	78.13	101.35
1.50	69.77	70.87	75	90.91	93.75	121.62
1.75	81.4	82.68	87.5	106.06	109.38	141.89
2.00	93.02	94.49	100	121.21	125	162.16
2.25	104.65	106.3	112.5	136.36	140.63	182.43
2.50	116.28	118.11	125	151.52	156.25	202.7

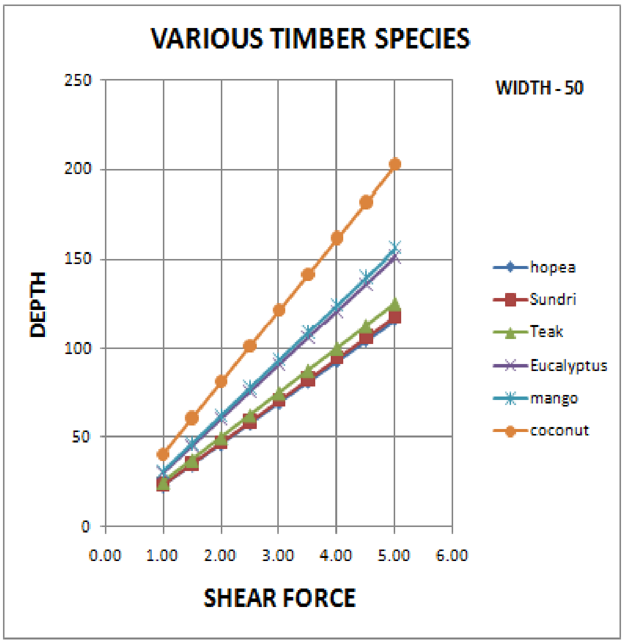
Table.9. SF along with depth of timbers taking width as 50mm



SF	hopea	Sundri	Teak	Eucalyptus	mango	coconut
1.00	23.26	23.62	25	30.3	31.25	40.54
1.50	34.88	35.43	37.5	45.45	46.88	60.81
2.00	46.51	47.24	50	60.61	62.5	81.08
2.50	58.14	59.06	62.5	75.76	78.13	101.35
3.00	69.77	70.87	75	90.91	93.75	121.62
3.50	81.4	82.68	87.5	106.06	109.38	141.89
4.00	93.02	94.49	100	121.21	125	162.16
4.50	104.65	106.3	112.5	136.36	140.63	182.43
5.00	116.28	118.11	125	151.52	156.25	202.7



Graph.8. Shear Force Vs depth for 25mm width



Graph.9. Shear Force Vs depth for 50mm width

4. CONCLUSION

1. Nomograms have been developed and represented in tables and graph formats for bending moment capacity for widths of 25mm and 50mm to find out depth required.

2. Nomograms have been developed and represented in tables and graph formats for shear force capacity for width 25mm and 50mm to find out depth required.
3. A generalised, user friendly algorithm, flow chart and source code have been developed in Visual Basic for design of flexural members.

5. ACKNOWLEDMENT

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