Comparative Reliability Assessment of A Solid and Nail-jointed I-Section of Nigerian-Grown African Birch (*Anogeissus leiocarpus*) Timber Column

*[1]WILSON Uwemedimo Nyong, [2]ADEDEJI Adeola A.,[3]ORIOLA F.O.P, [4]SANI, John E., [5]ALOMAJA Jonathan A.

*[1,3,4]Department of Civil Engineering, Nigerian Defence Academy Kaduna, Nigeria.

[2]Department of Civil Engineering, University of Ilorin, Ilorin. Nigeria.

[5]Department of Civil Engineering, Adeleke University Ede, Nigeria.

Abstract

Analogous to the built-up sections in structural steel, built-up sections for timbers can be achieved by joining different timbers in any desired choice of geometry with the intent of primarily increasing the sections of the timber beyond the naturally existing ones thereby consequently improving their capacities. The Nigerian-grown African birch timber was used to prepareI- section specimens which were tested in the laboratory for their compressive strengths. This was done forsolid square sections of the same timber specie for an apt comparison of results. A structural reliability analysis was carried out for these two different sections to ascertain their performances as structural timber columns. Some statistical parameters were determined for the deterministic design of the timber column. A FORTRAN-based program was also developed and used for the reliability analysis of the Nigerian-grown African birch columns designed to ascertain their level of safety using First-Order Reliability Method (FORM). From the reliability analysis, the capacity of the nail-jointed I-section column (150 x 150mm) is half that of the solid section. The 'I'- section was also found unsafe to bear the design load unlike its corresponding solid section. An identified I- section (100 x 400mm) was found adequate(with $P_f = 1.22 \times 10^{-02}$) whose compressive capacity corresponds to (200 x 100mm) of the solid section(with $P_f = 7.76 \times 10^{-02}$)which is practically half the dimension of the I-section. This therefore confirmed that the solid section has a capacity twice that of the 'I'- section of equal dimension. However, considering the minimum dimension of the two sections capable of supporting the design load, the 'I'- section is more economical than the solid section since it offers a less effective area of 11,200mm^2 compared to the solid section with an effective area of 20,000mm^2. The 'I'-section was also found to have a higher capacity to bear the Euler load with greater lengths than the solid section because of its greater radius of gyration and rigidity value and would be rather preferable for long columns than the solid section. Also, considering the limited availability of larger dimensions of solid sections, the built-up I- section would be more relevant where large sized sections are required.

Keywords: Solid section, 'I' section, Compressive strength, Built-up sections, Timber column, Reliability, P_f= Probability of failure.

1.0 Introduction

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Structural steel produced from moulds in rolling mills have standard sections with their unique properties for specified uses. Sometimes, for some unique structural steel works (like deep beams or large columns), sections other than the standard ones are needed and this would require the fabrication of certain sections generally referred to as built-up sections. This is done by assembling flat steel plates and welding them together to form different geometric configurations for the desired structural element. Though these steel built-up sections could be prone to structural instability because of their unusual depths, in which case, stiffeners are usually used to compliment their stability and usability.

Timber as a natural construction material has some limitations to its use. First, it can to a little extent have its strength properties varied or improved knowing so well that it is anisotropic in nature. Second, owing to its natural occurrence, there is a limit to the availability of timber solid sections. This therefore shows that there could be reasons for which built-up sections would be required in timber akin to steel structures and this is apparently the best way of providing larger sections of timber. Analogous to the built-up sections in structural steel, built-up sections for timbers can be achieved by joining different timbers in any desired choice of geometry with the intent of primarily increasing the section of the timber beyond the naturally existing one. Laminated sections also exist which can be manufactured by joining several thin layers of timber parallel to each other to a certain thickness to form a complete section. The laminated section which is one of the available built-up sections can be fabricated using strong glues such that the entire section acts as a unit and any failure that must occur, should be only traceable to the timber and not the glue. Sometimes in the built-up sections, pins or nails may be used. This must be done in such a way that any failure must not be traceable to joint locations. The fact that possible failures must not be traceable to joints is necessary either for the case of glues or nails because, the timber material strength is of utmost importance to the Engineer since they are not intended or designed as composite materials so to speak in that the materials used are same. Usually, the individual members joined together to make up the laminated or built-up sections are carefully selected such that they are of excellent properties and truly representative of the ideal condition of the timber. This is done for the purpose of having a resultant section with equally excellent properties usually relative to the corresponding solid section. By doing these, timber as a material is to some extent made to become semi-artificial in that it can be fabricated into different geometrical configurations like I-sections, box-sections, T-sections, rectangular sections, square sections. Also, the size of the sections can be increased beyond the naturally available sizes of the timber or beyond the standard preferred sizes in which they are converted to. Consequently, the load carrying capacity (that is moment capacity for beams, compressive and buckling resistance for columns) of the timber would be increased thereby maximising the usability of the timber as a construction material.

In this work, a solid African birch column was compared to an I-section of corresponding dimension to evaluate the performance (that is from the reliability analysis) as well as their capacity.

Wilson et al (2018) in a study on a reliability-based design of a solid African birch timber column showed that the Nigerian-grown African-birch is a satisfactory structural material for use as solid timber columns at a depth and breadth of 150mm, effective length of 3600mm and an axial load of 260kN; with a probability of failure 8.85 x 10^{-3}. It was discovered that a column of similar effective length can at a depth of 400mm, breadth of 200mm support an axial load of 1000kN with a probability of failure of 4.85 x 10^{-2}. The reliability by failure rate method was also considered, it was observed that the Nigerian-grown African birch has a higher failure rate at an interval of 10 years over a 100 years expected lifespan in bending when compared to compression and this can be attributed to their respective basic compressive and bending strength values.

Aguwa and Sadiku (2011) revealedfrom a reliability studies that the Nigerian Ekki*(Lophira alata)* timber is a satisfactory structural material for timber bridge beams at depth of 400 mm, breadth of 150 mm and span of 5000 to 7000 mm under the ultimate limit state of loading. Its probability of failure in flexure under the specified operating conditions is 1.1 x 10^{-7}, that is, one in ten million. If an optimization was carried out, a more economical section and span would have been found.

Aguwa (2012) showed from a reliability studies that the Nigerian grown Apa*(Afzelia bipindensis)* timber is a satisfactory structural timber for bridge beams at depth of 400mm, breadth of 150mm and span of 5000mm under the Ultimate Limit State of Loading. The probabilities of failure of the Nigerian Apa timber bridge beam in flexure and deflection are 2.062×10^{-3} *and* 2.673×10^{-14}respectively, under the design conditions.

2.0 Methodology

A total of twenty specimens of I sections of 'Ayin' (*Anogeissus leiocarpus*) timber were prepared for testing by being sawn into specified sizes of 45 x 85 x 100mm for the compressive strength test. The specimens were systematically mounted on the machine, clamped and gradually loaded as readings were automatically taken by the machine. After taking the compressive strength of the specimens, their respective moisture contents were taken since the moisture content is a very consequential property upon which the strength of the timber is dependent.

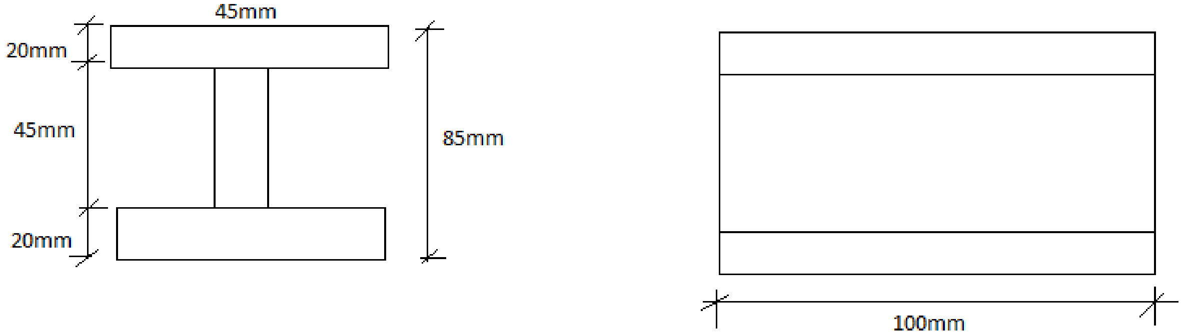

Fig 2.0Sketch of I-Section Test Specimen for Compression Test

Plate 1.0 Showing I-Section Test Specimen   **Plate 1.1 Showing Solid Section Test Specimen**

Table 1. Probability distribution and statistical parameters for the Basic Variables.

Parameter	Distribution	Mean	Standard deviation	COV
Load (N)	Log	250	35	0.14
Breadth(mm)	Normal	150	9	0.06
Depth (mm)	Normal	150	9	0.06
Young's Modulus (N/mm^2)	Log Normal	10,500	315	0.03
Length (mm)	Normal	3600	432	0.12
Radius of gyration (mm)	Normal	28.57	1.44	0.05

Wilson et al., (2018)

Table 2. Design Parameters for the Nigeria- grown African birch

Timber Specie	Span(mm)	Depth(mm)	Breadth (mm)	Design Load kN
Africa Birch	3600	150	150	260

Wilson et al., (2018)

Table 3 Probability distribution and Statistical parameters for the basic variables for I- Section of Timber.

S/N	Parameters	Distribution	Mean	Standard deviation	COV
1.	Load (N)	Log	250	35	0.14
2.	Breadth(mm)	Normal	150	9	0.06
3.	Depth (mm)	Normal	150	9	0.06
4.	Young's Modulus (N/mm^2)	Log Normal	10,500	315	0.03
5.	Length (mm)	Normal	3600	432	0.12
6.	Radius of gyration (mm)	Normal	37.12	1.86	0.05

The limit state or performance function in compression as given by (Nowak and Collins 2000)$g(x) = f_{p\,par} - f_{a\,par}$. (1)

$f_{p\,par}$= Permissible stress parallel to grain

$f_{a\,par}$= Actual stress parallel to grain

From the basic stress gotten for the solid timber, the limit state function can be written as $g(x) = 16.25 - \frac{N}{bh}$ (2)

Wilson et al., (2018)

To consider the reliability of the timber with an interest in considering the length in response to the performance, the limit state function formulated from the Euler load formula and can be given by

$$g(x) = 16.25 - \frac{9.88Er^2}{l^2} \quad (3)$$

E= Youngs' Modulus of elasticity

r= radius of gyration

l= length of the column

Wilson et al., (2018)

From the basic stress gotten for the I-section timber, the limit state function can be written as

$$g(x) = 9.23 - \frac{N}{bh} \quad (4)$$

To consider the reliability of the I-section timber column with an interest in considering the length in response to the performance, the limit state function formulated from the Euler load formula and can be given by

$$g(x) = 9.23 - \frac{9.88Er^2}{l^2} \quad (5)$$

Analysis of the column

When the column is considered as short, the axial stress is given by the expression

$$\sigma = \frac{P}{A} \quad (6)$$

where P is the load supported by the cross sectional area A. For long columns, the equation given by Euler is

$$P = \frac{\pi^2 EI}{L^2} \quad (7)$$

where P is the maximum critical load, E is the elastic modulus and I the moment of Inertia.

The radius of gyration is given by

$$r = \sqrt{\frac{I}{A}} \quad (8)$$

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The corresponding Euler stress experienced by the slender column can consequently be expressed by the expression

$$\sigma = \frac{\pi^2 E}{(L/r)^2} \qquad (9)$$

Jimoh (2005)

3.0 Results and Discussion

Results of Reliability Using A Fortran-Based First Order Reliability Method Program for Both The Solid and I-Section Column

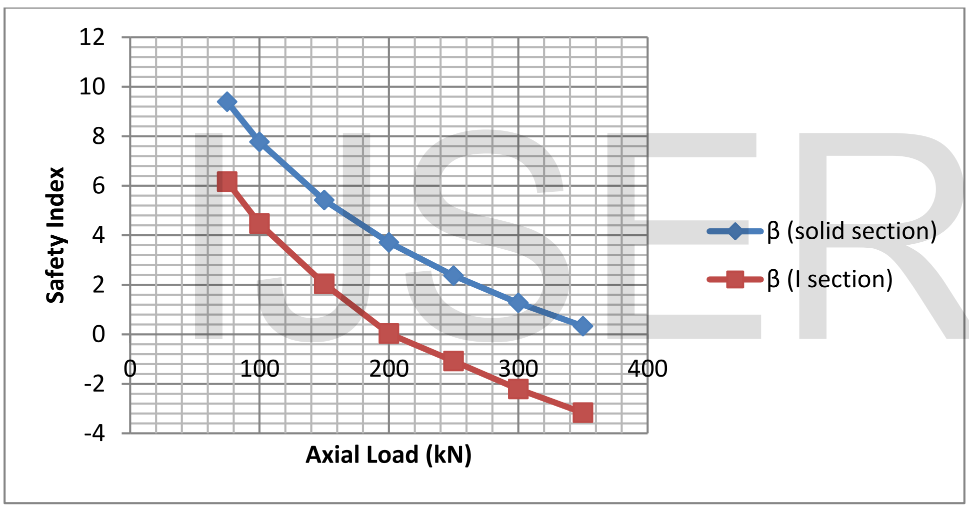

Figure 2.1 Safety Index- Axial Load Relationship for the Sections

Considering the design dimension- (150 x 150mm) for the I and solid section subjected to similar load ranging from 75kN to 350kN, it was observed that the solid section possesses a higher safety index than the 'I'- section by more than 3.0 and from a load of 200kN and above, the I- section begins to tend to failure..This is indicated by probability of failure gotten from the analysis- at 200kN, its P_f =0.386. At 250kN, a P_f value of 0.860; at 300kN the probability of failure is 0.986 and at 350kN, the probability of failure is 0.999. This is possibly traceable to the cross sectional area provided.The I-section can safely support a maximum load of 150kN at a probability of failure of 0.02. The solid section can safely support as much as 300kN, which is actually twice as much as the I-section of similar cross-section can support at a probability of failure 0f 0.103

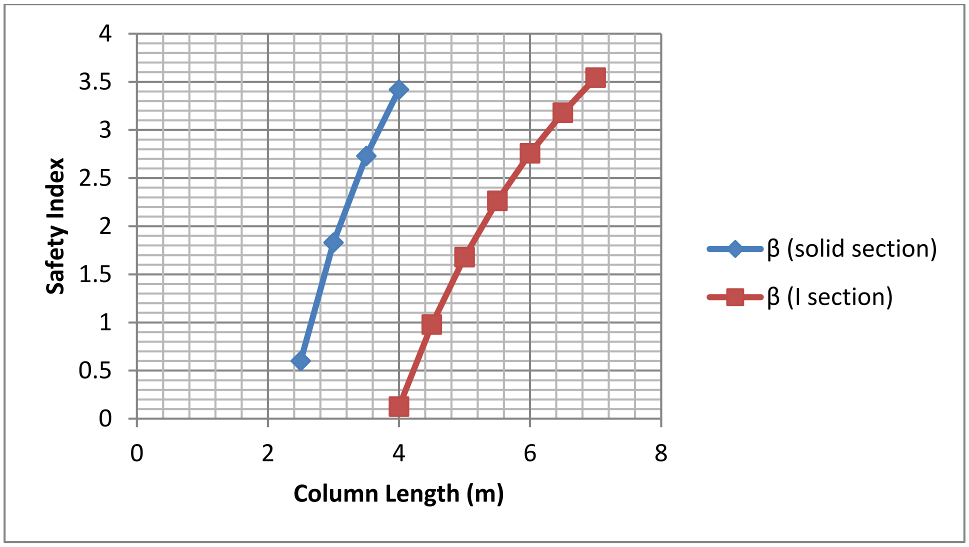

Figure 2.1 Safety Index- Column Length Relationships for the Sections

Figure 2.1shows the relationship between the safety index and column length under the Euler loading condition for the solid section and I-section. The graph shows a very safe maximum column height of up to 4.0m for the solid section. The I-section is capable of sustaining its Euler load to a safe maximum length of 7.0m with a probability of failure of 0.197 E-03.It can be deduced that the 'I'-section depicts a higher safety index at longer lengths than the solid section. This invariable translates to the suitability of the I-section for longer columns than the solid column. This is apparently owing to its greater radius of gyration than the solid section.

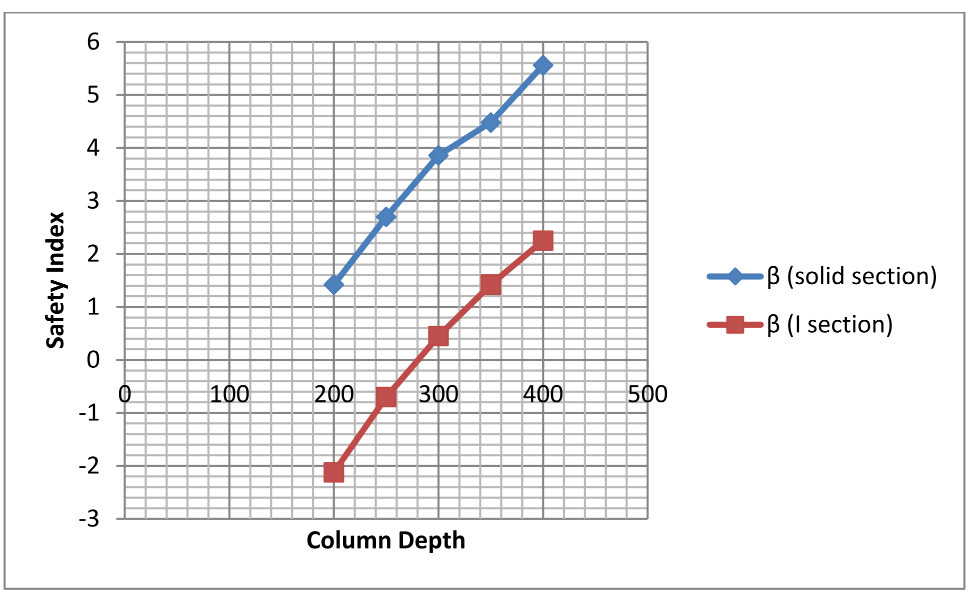

Figure 2.2 Safety Index-Column Depth Relationship at 100mm breadth

Figure 2.2 shows the relationship of the safety index with varied column depths for a constant breadth of 100mm to support the design load of 260kN.The safety index-column depth relation shown in the figure 2.2 above depicts the performance of the three different section geometries: the solid section, I-section and the box section under the design axial load of 260kN and a constant breadth of 100mm. It can be deduced that the I-section can safely support this load with a minimum depth of 400mm (that is a 100 x 400mm section) at a probability of failure of 0.122 E-01. It is noteworthy that the I-section can with a depth of 350mm perform for serviceability purpose since it has a safety index of 1.149 and a corresponding probability of failure value of 0.78 E-1 but, the negative safety indices show unsafe values for the depth. The solid section can support the design load with a minimum depth of 200mm (that is a 100 x 200mm section), actually half the size of the I-section at a probability of failure of 0.776 E-01

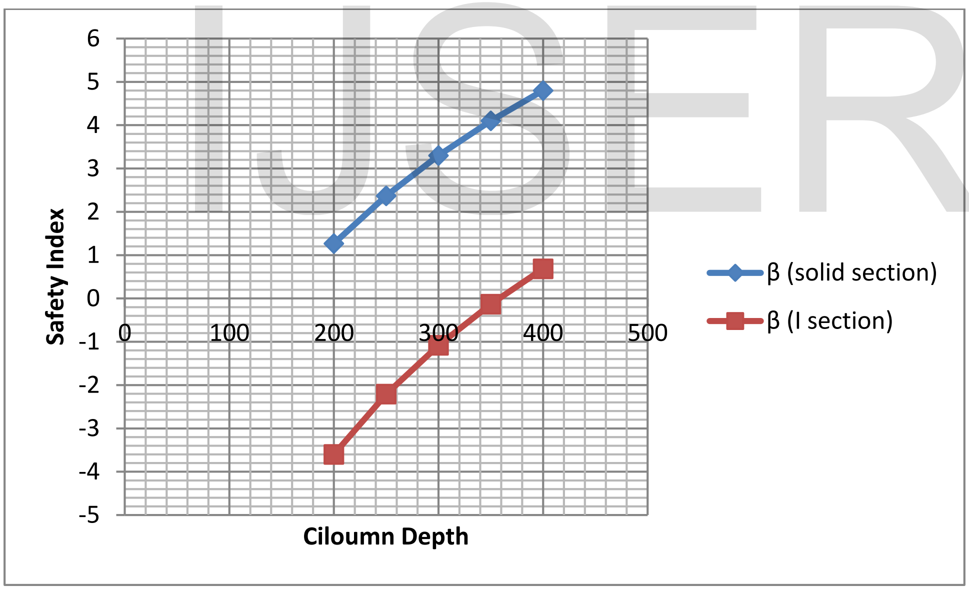

Figure 2.3 Safety Index-Column Depth Relationship at 150mm breadth

For a greater design load of 500kN with a constant column breadth of 150mm, it can be observed that the I-section would not safely bear this load even with a depth of 400mm (that is, a 150 x 400mm section). This is because it has a safety index value less than 1.0 which is indicative of an unsafe section (with $P_f = 0.247$) both at serviceability and ultimate limit state except the depth is increased. The solid section can on the other hand sustain this design load with a minimum depth of 300mm (that is, a 150 x 300mm section) or less at a probability of failure of 0.885 E-02.

Conclusion

From the reliability-based design carried out for the solid, box and I-section column of the African birch timber, the summary can be outlined as follows

1. For the design section (150 x 150mm) provided, the solid sections bears as much as twice the maximum load the I-section can. The I-section would therefore not be regarded adequate and suitable for the design load considering the safety index and probability of failure gotten from the reliability analysis.
2. Since the provided dimension (150 x 150 mm) for the I-section is unsafe to bear the design load, an identified minimum depth of 400mm (that is 100 x 400 mm section) was found adequate. This capacity was found to correspond to a minimum depth of 200mm (that is 200 x 100mm section) of the solid section which is practically half the dimension of the I-section. This therefore means that the solid section has a capacity twice that of the I- section of equal dimension. However, considering the minimum dimension of the of the two sections capable of supporting the design load, I- section is more economical, than the solid section since it offers a less effective area of 11,200mm^2 compared to the solid section with an effective area of 20,000mm^2.
3. I-sections have a higher capacity to bear the Euler load with greater lengths than the solid section because of its greater radius of gyration and rigidity value and would be rather preferable for long columns than the solid section.
4. Also considering the limited availability of larger dimensions of solid sections, the built-up I- section would be more relevant where large sized sections are required.

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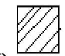
Appendix

GEOMETRICAL PROPERTIES OF SAWN NIGERIAN-GROWN AFRICAN BIRCH TIMBER (SOLID SECTION) 

Timber Section(mm)	Area (mm^2)	Unit Weight (N/m)	Section Modulus x-x (mm^3)	Section Modulus yy (mm^3)	I_{xx} (mm^4)	I_{yy} (mm^4)	r_{xx} (mm)	r_{yy} (mm)
50 x 50	2500	25.9	20833.33333	20833.33333	520833.333	520833.33	14.43376	14.43376
50 x 75	3750	38.85	46875	31250	1757812.5	781250	21.65064	14.43376
50 x 100	5000	51.8	83333.33333	41666.66667	4166666.67	1041666.7	28.86751	14.43376
50 x 125	6250	64.75	130208.3333	52083.33333	8138020.83	1302083.3	36.08439	14.43376
50 x 150	7500	77.7	187500	62500	14062500	1562500	43.30127	14.43376
50 x 175	8750	90.65	255208.3333	72916.66667	22330729.2	1822916.7	50.51815	14.43376
50 x 200	10000	103.6	333333.3333	83333.33333	33333333.3	2083333.3	57.73503	14.43376
50 x 250	12500	129.5	520833.3333	104166.6667	65104166.7	2604166.7	72.16878	14.43376
50 x 300	15000	155.4	750000	125000	112500000	3125000	86.60254	14.43376
75 x 75	5625	58.275	70312.5	70312.5	2636718.75	2636718.8	21.65064	21.65064
75 x 100	7500	77.7	125000	93750	6250000	3515625	28.86751	21.65064
75 x 125	9375	97.125	195312.5	117187.5	12207031.3	4394531.3	36.08439	21.65064
75 x 150	11250	116.55	281250	140625	21093750	5273437.5	43.30127	21.65064
75 x 175	13125	135.975	382812.5	164062.5	33496093.8	6152343.8	50.51815	21.65064
75 x 200	15000	155.4	500000	187500	50000000	7031250	57.73503	21.65064
75 x 225	16875	174.825	632812.5	210937.5	71191406.3	7910156.3	64.95191	21.65064
75 x 250	18750	194.25	781250	234375	97656250	8789062.5	72.16878	21.65064
75 x 300	22500	233.1	1125000	281250	168750000	10546875	86.60254	21.65064
100 x 100	10000	103.6	166666.6667	166666.6667	8333333.33	8333333.3	28.86751	28.86751
100 x150	15000	155.4	375000	250000	28125000	12500000	43.30127	28.86751
100 x 175	17500	181.3	510416.6667	291666.6667	44661458.3	14583333	50.51815	28.86751
100 x 200	20000	207.2	666666.6667	333333.3333	66666666.7	16666667	57.73503	28.86751
100 x 225	22500	233.1	843750	375000	94921875	18750000	64.95191	28.86751
100 x 250	25000	259	1041666.667	416666.6667	130208333	20833333	72.16878	28.86751
100 x 300	30000	310.8	1500000	500000	225000000	25000000	86.60254	28.86751

150 x 150	22500	233.1	562500	562500	42187500	42187500	43.30127	43.30127
150 x 200	30000	310.8	1000000	750000	100000000	56250000	57.73503	43.30127
150 x 250	37500	388.5	1562500	937500	195312500	70312500	72.16878	43.30127
150 x 300	45000	466.2	2250000	1125000	337500000	84375000	86.60254	43.30127
200 x 200	40000	414.4	1333333.333	1333333.333	133333333	133333333	57.73503	57.73503
200 x 250	50000	518	2083333.333	1666666.667	260416667	166666667	72.16878	57.73503
200 x 300	60000	621.6	3000000	2000000	450000000	200000000	86.60254	57.73503
250 x 250	62500	647.5	2604166.667	2604166.667	325520833	325520833	72.16878	72.16878
250 x 300	75000	777	3750000	3125000	562500000	390625000	86.60254	72.16878
300 x 300	90000	932.4	4500000	4500000	675000000	675000000	86.60254	86.60254

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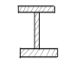
GEOMETRICAL PROPERTIES OF I-SECTION NIGERIAN-GROWN AFRICAN BIRCH TIMBER



Depth of Section (mm)	Breadth of flange (mm)	I section (mm)	Thickness (mm)	Area (mm^2)	Unit Weight (N/m)	Section Modulus x-x (mm^3)	Section Mod. y-y(mm^3)	I_{xx} (mm^4)	I_{yy} (mm^4)	r_{xx} (mm)	r_{yy} (mm)
150	150	150 x 150	20	8200	84.952	370666.6667	150666.6667	27800000	11300000	58.2258	37.12208
100	75	100 x 75	20	4200	43.512	105200	38666.66667	5.26E+06	1.45E+06	35.38899	18.58058
100	100	100 x 100	20	5200	53.872	137800	67400	6.89E+06	3.37E+06	36.40055	25.45735
150	100	150 x 100	20	6200	64.232	257333.3333	68200	1.93E+07	3.41E+06	55.7934	23.45208
175	100	175 x 100	20	6700	69.412	323428.5714	68400	2.83E+07	3.42E+06	64.99139	22.59309
200	100	200 x 100	20	7200	74.592	394000	68800	3.94E+07	3.44E+06	73.97447	21.85813
225	100	225 x 100	20	7700	79.772	468444.4444	69200	5.27E+07	3.46E+06	82.72941	21.19789
250	100	250 x 100	20	8200	84.952	548000	69400	6.85E+07	3.47E+06	91.39835	20.57111
275	100	275 x 100	20	8700	90.132	631272.7273	69800	8.68E+07	3.49E+06	99.88499	20.02872
300	100	300 x 100	20	9200	95.312	720000	70200	1.08E+08	3.51E+06	108.3473	19.53258
150	125	150 x 125	20	7200	74.592	313333.3333	105280	2.35E+07	6.58E+06	57.13046	30.2306
175	125	175 x125	20	7700	79.772	392000	105600	3.43E+07	6.60E+06	66.74238	29.277
200	125	200 x 125	20	8200	84.952	475000	105920	4.75E+07	6.62E+06	76.10968	28.41333
225	125	225 x 125	20	8700	90.132	562666.6667	106080	6.33E+07	6.63E+06	85.29866	27.6056
250	125	250 x 125	20	9200	95.312	653600	106400	8.17E+07	6.65E+06	94.23606	26.88543
275	125	275 x 125	20	9700	100.492	749090.9091	106720	1.03E+08	6.67E+06	103.0464	26.22268
300	125	300 x 125	30	14700	152.292	1146666.667	164800	1.72E+08	1.03E+07	108.1697	26.47037
175	150	175 x 150	30	12450	128.982	592000	228000	5.18E+07	1.71E+07	64.50304	37.06068
200	150	200 x 150	30	13200	136.752	726000	229333.3333	7.26E+07	1.72E+07	74.16198	36.09751
225	150	225 x 150	30	13950	144.522	866666.6667	229333.3333	9.75E+07	1.72E+07	83.60172	35.11374
250	150	250 x 150	30	14700	152.292	1016000	230666.6667	1.27E+08	1.73E+07	92.94867	34.30555
275	150	275 x 150	30	15450	160.062	1170909.091	232000	1.61E+08	1.74E+07	102.0819	33.55911
300	150	300 x 150	30	16200	167.832	1326666.667	232000	1.99E+08	1.74E+07	110.833	32.77307
325	150	325 x 150	30	16950	175.602	1495384.615	233333.3333	2.43E+08	1.75E+07	119.7342	32.13173
350	150	350 x 150	30	17700	183.372	1668571.429	233333.3333	2.92E+08	1.75E+07	128.4413	31.44361
375	150	375 x 150	30	18450	191.142	1850666.667	234666.6667	3.47E+08	1.76E+07	137.1408	30.88575
400	150	400 x 150	30	19200	198.912	2035000	234666.6667	4.07E+08	1.76E+07	145.595	30.2765

425	150	425 x 150	30	19950	206.682	2225882.353	236000	4.73E+08	1.77E+07	153.9782	29.78621
450	150	450 x 150	30	20700	214.452	2426666.667	237333.3333	5.46E+08	1.78E+07	162.4094	29.32411
450	175	450 x 175	30	22200	229.992	2720000	316571.4286	6.12E+08	2.77E+07	166.0348	35.32347
450	200	450 x 200	30	23700	245.532	3013333.333	409000	6.78E+08	4.09E+07	169.1378	41.54201
450	225	450 x 225	30	25200	261.072	3311111.111	513777.7778	7.45E+08	5.78E+07	171.9404	47.89207
450	250	450 x 250	30	26700	276.612	3604444.444	632000	8.11E+08	7.90E+07	174.2829	54.39487
450	275	450 x 275	30	28200	292.152	3897777.778	763636.3636	8.77E+08	1.05E+08	176.3499	61.0197
450	300	450 x 300	30	29700	307.692	4191111.111	906666.6667	9.43E+08	1.36E+08	178.1877	67.66923
450	325	450 x 325	30	31200	323.232	4488888.889	1064615.385	1.01E+09	1.73E+08	179.9216	74.4639
450	350	450 x 350	30	32700	338.772	4800000	1228571.429	1.08E+09	2.15E+08	181.7348	81.0859
450	375	450 x 375	30	34200	354.312	5066666.667	1408000	1.14E+09	2.64E+08	182.5742	87.85954
450	400	450 x 400	30	35700	369.852	5377777.778	1605000	1.21E+09	3.21E+08	184.102	94.82403
450	425	450 x 425	30	37200	385.392	5644444.444	1811764.706	1.27E+09	3.85E+08	184.7695	101.7323
450	450	450 x 450	30	38700	400.932	5955555.556	2031111.111	1.34E+09	4.57E+08	186.0788	108.6682
475	450	475 x 450	30	39450	408.702	6400000	2031111.111	1.52E+09	4.57E+08	196.2901	107.6303
500	450	500 x 450	30	40200	416.472	6840000	2031111.111	1.71E+09	4.57E+08	206.2458	106.6216
525	450	525 x 450	30	40950	424.242	7276190.476	2031111.111	1.91E+09	4.57E+08	215.9682	105.6407
550	450	550 x 450	30	41700	432.012	7709090.909	2031111.111	2.12E+09	4.57E+08	225.4758	104.6864
575	450	575 x 450	30	42450	439.782	8173913.043	2031111.111	2.35E+09	4.57E+08	235.2855	103.7574
600	450	600 x 450	50	70000	725.2	13100000	3400000	3.93E+09	7.65E+08	236.9448	104.5398
625	450	625 x 450	50	71250	738.15	13856000	3400000	4.33E+09	7.65E+08	246.5196	103.6187
650	450	650 x 450	50	72500	751.1	14615384.62	3400000	4.75E+09	7.65E+08	255.9634	102.7216
675	450	675 x 450	50	73750	764.05	15407407.41	3400000	5.20E+09	7.65E+08	265.5343	101.8473
700	450	700 x 450	50	75000	777	16171428.57	3404444.444	5.66E+09	7.66E+08	274.712	101.061
725	450	725 x 450	75	110625	1146.075	23034482.76	5155555.556	8.35E+09	1.16E+09	274.7366	102.4006
750	450	750 x 450	75	112500	1165.5	24186666.67	5155555.556	9.07E+09	1.16E+09	283.9405	101.5436
775	450	775 x 450	75	114375	1184.925	25367741.94	5155555.556	9.83E+09	1.16E+09	293.1644	100.7079
800	450	800 x 450	75	116250	1204.35	26500000	5155555.556	1.06E+10	1.16E+09	301.9649	99.89242
825	450	825 x 450	75	118125	1223.775	27636363.64	5155555.556	1.14E+10	1.16E+09	310.6573	99.09645
850	450	850 x 450	75	120000	1243.2	28941176.47	5155555.556	1.23E+10	1.16E+09	320.1562	98.31921
875	450	875 x 450	75	121875	1262.625	30171428.57	5155555.556	1.32E+10	1.16E+09	329.1013	97.55997

900	450	900 x 450	75	123750	1282.05	31555555.56	5200000	1.42E+10	1.17E+09	338.744	97.23449
925	450	925 x 450	75	125625	1301.475	32648648.65	5200000	1.51E+10	1.17E+09	346.6973	96.50613
950	450	950 x 450	75	127500	1320.9	34105263.16	5200000	1.62E+10	1.17E+09	356.4531	95.7939
975	450	975 x 450	75	129375	1340.325	35282051.28	5200000	1.72E+10	1.17E+09	364.6188	95.0972
1000	450	1000 x 450	75	131250	1359.75	36600000	5200000	1.83E+10	1.17E+09	373.4014	94.4155