

APPLICATION OF VISUAL BASIC PROGRAM TO ANALYSIS AND DESIGN OF TIMBER STRUCTURAL ELEMENTS

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Abstract

This work essentially illustrates the application of visual basic (VB) programming language in the development of a computer program for the analysis and design of timber structural elements (simply supported beam, compound beam and column) to BS5268. Flow charts for structural elements were designed and corresponding VB codes were developed. The program accepts data such as dimension of the elements, grade stresses, modification factors, span type, and load combination. Using these data, the program analyses and checks the adequacy of the given section in addition; it displays the maximum load the element can withstand before failure. To check the reliability and accuracy of the results obtained using the program, the same data was analysed manually and the results obtained were compared with analysed results obtained using the program. Obtained results (using manual as well as the developed program) were found to be similar with zero percentage error. However, the analysis done using the developed program was found to be speedier, easier and less cumbersome than the manual analysis.

Keywords: Analysis, Design, Flow chart, Timber Structural Elements, Visual Basic Program

1.0 Introduction

Computers are devices that can perform calculations and logical operations at a great speed, without human intervention through the action of internally stored program [1]. This brings about optimization and tremendous efficiency in performance of tasks. Some of the attributes of the computer are responsible for its wide application in engineering firms. These include among others, its ability to handle a very large amount of data accurately as long as the instructions given to it are reliable. Furthermore, its ability to perform task in repetition especially numerous arithmetic operations at a phenomenal speed are added advantages [2]. Computer applications (programs) has brought a paradigm shift in operations of virtually every profession including Civil Engineering. An increasing use is being made of computer applications in civil engineering design especially in structural analysis and design. Very few computer design programs have included timber as a design material option. In order to facilitate the analysis and design of timber structural elements, computerized design programs for timber must be developed that are comparable to those currently available for steel and concrete, otherwise designers may unjustifiably select steel or concrete on the basis of the design tools available [3].

The need for the use of locally available agricultural or forestry materials in construction industry as structural materials cannot be over emphasized due to their adequacy in performance, cost effectiveness as well as income generation and employment [4]. Most woods (timber) used in the building construction are softwoods but in structures like bridges and railway sleepers etc. hardwoods are specially used [5].

A number of programs for structural analysis and design have been created with various programming languages as reported in [5], [6], [7], [8], [9], [10], [11], [12], and [13]. However, little is documented in literature on the analysis and design of timber structural elements to BS5268 using VB program hence, the need to develop the program which can be

used in the analysis and design of timber structural elements (limited to solid beam and column only within the scope of this research work).

VB is derived from the BASIC programming language. It is a Microsoft window programming language, created in an integrated development environment (IDE). A program for the Simulation of Numerical Iterations using VB program was developed by [14]. In the research work undertaken, the merit of VB as a Program (developed and used for the simulation of numerical iteration) was highlighted in contrast to difficulties faced when solving numerical iterations analytically.

2.0 Methodology

The methodology adopted in carrying out this work includes: manual analysis and design of the timber structural elements (solid beam and column) in accordance with the procedures outlined in [15], designing of flow chart for the two structural elements and coding of the program using VB 2010. The main stages of timber structural element design process are summarized in the flowcharts in Figures 1 and 2 respectively.

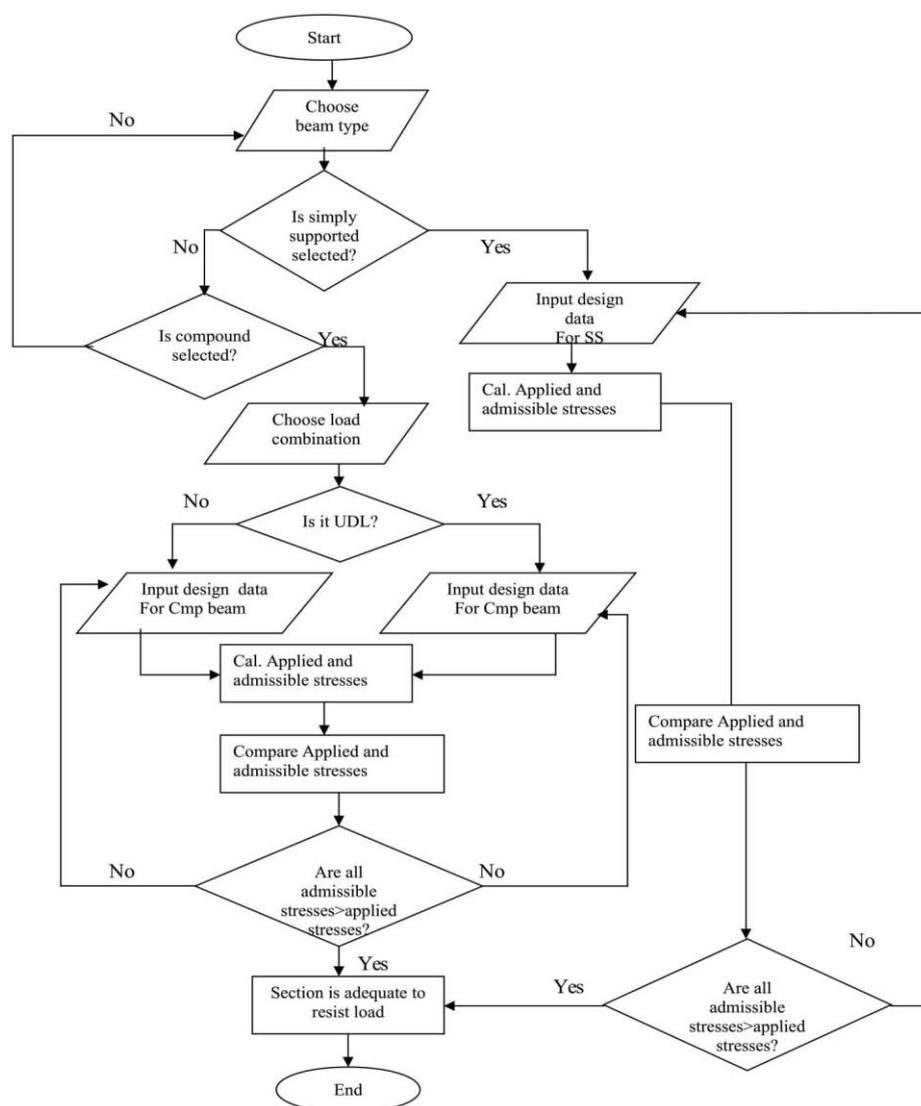


Figure 1. Summary of beam design process (Program sequence for beam design).

Where: SS means simply supported; Cmp: Compound; UDL: uniformly distributed load and Cal is calculate.

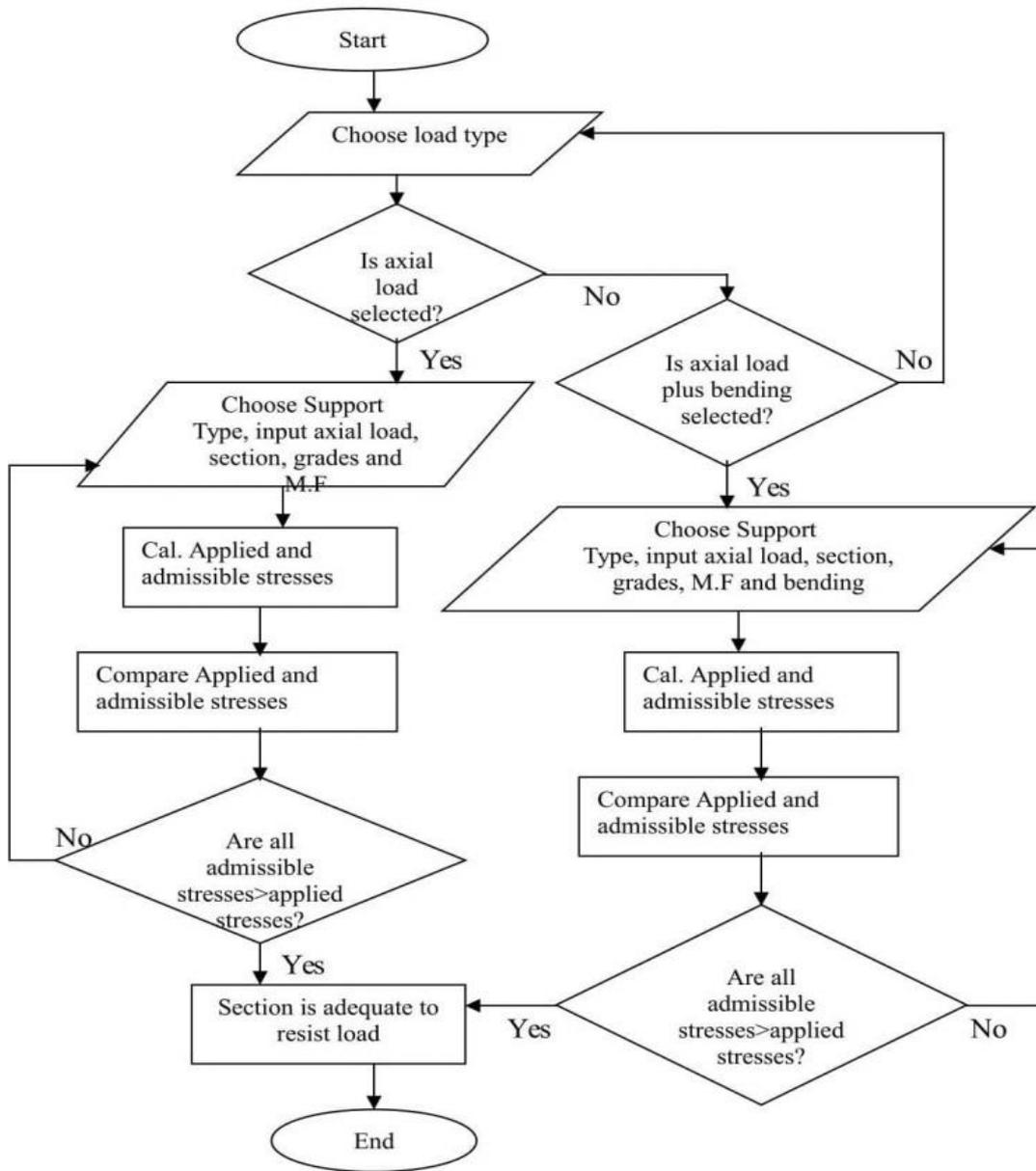


Figure 2. Summary of column design process (Program sequence for column design).

Where: MF means Modification Factor.

2.1 Design Parameters

2.1.1 Permissible Stress Design

When using permissible stress design, a margin of safety is introduced by considering structural behavior under working/service load conditions and comparing the stresses induced with permissible values. The permissible values are obtained by dividing the failure stresses by an appropriate factor of safety. The applied stresses are determined using elastic analysis techniques, i.e. $Stress\ induced\ by\ working\ loads \leq \frac{failure\ stress}{factor\ of\ safety}$.

This is the philosophy adopted in the timber design code according to BS 5268. Since BS 5268 is a permissible stress design code, mathematical modeling of the behavior of timber elements and structures is based on assumed elastic behavior. In general, when designing to satisfy strength requirements (e.g. axial, bending or shear strength) the following relationship must be satisfied: *Applied stress* ≤ *Permissible stress*.

The applied stresses are calculated using elastic theory, and the permissible stresses are determined from the code using the appropriate values relating to the strength classification multiplied by the modification factors which are relevant to the stress condition being considered [16].

Permissible stress = Grade Stress x Modification Factors (BS5268 designates the modification factors as k.).

2.1.2 Modes of Failure

The modes of failure of timber elements include failure due to the following: Bending failure, Shear failure, Bearing failure and Deflection failure.

In the design of each of the elements, the above failures are checked against the admissible stresses of each of the element under consideration.

The applied stresses are as given in [15] thus:

- $\sigma_{m,a,\perp} = \frac{6M}{bh^2}$ eqn 1
- $\tau_a \equiv = \frac{3V}{2bh}$ eqn 2 , where V is the maximum shear force of the section; b and h are the breadth and depth of section respectively.
- $\sigma_{c,a,\perp} = \frac{P}{\text{bearing area}}$ eqn 3 , where P is the applied point load
- $\delta_a = \frac{5WL^4}{384E_{min} I_{xx}} + \frac{12WL^2}{5 E_{min} A}$ eqn 4 , where w is uniformly distributed load, M is the maximum moment of the section, E_{min} is the minimum modulus of elasticity, A is the total cross-sectional area and I_{xx} is the moment of inertia about x-x axis

The Permissible stresses are given thus:

- $\sigma_{m,adm,\parallel} = \sigma_{m,g,\parallel} K_2 K_3 K_6 K_7 K_8$ (as appropriate)eqn 5
- $\sigma_{m,g,\parallel}$ Is the grade bending stress parallel to the grain,
- $\tau_{adm} = \tau_g K_2 K_3 K_5 K_8$ (as appropriate)eqn 6

Where τ_g is the grade shear stress parallel to the grain.

- $\delta_p = 0.003 \times \text{span}$ eqn 7
- $\sigma_{c,a,\perp} \leq \sigma_{c,adm,\perp}$
- $\sigma_{c,adm,\perp} = \sigma_{c,g,\perp} K_2 K_3 K_8$ eqn 8
- $\sigma_{c,\parallel} = \sigma_{c,g,\parallel} K_3$ eqn 9. Where;

K_2 , relates to the moisture content of the timber; K_3 , relates to the duration of the load on the timber; K_6 , relates to the shape of the cross-section of the element being considered; K_7 , relates to the depth of the section being considered; K_8 , relates to the existence of structural elements enabling load sharing and K_{12} , relates to the slenderness of columns.

- $\sigma_{m,a,\perp}$ = Applied bending stress perpendicular to the grain
- $\sigma_{m,adm,\perp}$ = Permissible bending stress perpendicular to the grain
- $\sigma_{c,a,\parallel}$ = Applied compressive stress parallel to the grain
- $\sigma_{c,adm,\parallel}$ = Permissible compressive stress parallel to the grain
- τ_a = Applied shear stress; $\tau_{adm,\parallel}$ = Permissible shear stress
- $\sigma_{c,a,\perp}$ = Applied bearing stress; $\sigma_{c,adm,\perp}$ = Permissible bearing stress

δ_a =Applied deflection; δ_p =Permissible deflection

2.2 Design Data: Data as given in tables 1-5 are design data/parameters adopted by the researcher.

Table 2: Design data for Compound solid beam under the action of uniformly distributed load throughout the length of the member

Width of section	75mm
Depth of section	250mm
Span of section	3000mm
Uniformly distributed load	3KN/m
Strength Class	C16

Table 3: Design data for Compound solid beam under the action of uniformly distributed load throughout the length of the member and a point load acting at mid span

Width of section	75mm
Depth of section	250mm
Span of section	3000mm
Uniformly distributed load	3KN/m
Point load	4KN
Strength Class	C16

Table 4: Design data for column under the action of axial load

Width of section	75mm
Depth of section	150mm
Span of section	3400mm
Axial load	12KN
GRADE (of Timber)	GS (RED WOOD)

Table 5: Design data for column under the action of axial load and bending

Width of section	100mm
Depth of section	100mm
Span of section	3700mm
Axial load	10KN
Bending	3KNm
GRADE (of Timber)	GS (RED WOOD)

3.0 Results and Discussion

3.1 **Results:** Results presented in tables 6-10 are results obtained from manual method vis-à-vis the developed program. It further highlights comparatively the error (%) using the two methods.

Table 6. Simply Supported beam subjected to point load at mid-span: Adequacy check

S/N	ADMISSIBLE/PERMISSIBLE STRESSES	MANUAL CALCULATION RESULT	PROGRAM RESULT	%ERROR
1	Admissible bending (N/mm^2)	5.41	5.41	0
2	Admissible shear (N/mm^2)	0.67	0.67	0
3	Admissible bearing (N/mm^2)	1.70	1.70	0
4	Admissible deflection (mm)	9.00	9.00	0
5	Applied bending (N/mm^2)	9.60	9.60	0
6	Applied shear (N/mm^2)	0.40	0.40	0
7	Applied bearing (N/mm^2)	0.89	0.89	0
8	Applied deflection (mm)	6.86	6.86	0
9	Max. bending moment (KNm)	7.50	7.50	0
10	Max. shear force (KN)	5.00	5.00	0

Table 7. Compound beam Subjected to UDL only: Adequacy check

S/N	ADMISSIBLE/PERMISSIBLE STRESSES	MANUAL CALCULATION RESULT	PROGRAM RESULT	%ERROR
1	Admissible bending (N/mm^2)	5.95	5.95	0
2	Admissible shear (N/mm^2)	0.74	0.74	0
3	Admissible bearing (N/mm^2)	1.87	1.87	0
4	Admissible deflection (mm)	9.00	9.00	0
5	Applied bending (N/mm^2)	4.32	4.32	0
6	Applied shear (N/mm^2)	0.36	0.36	0
7	Applied bearing (N/mm^2)	0.80	0.80	0
8	Applied deflection (mm)	6.18	6.18	0
9	Max. bending moment (KNm)	3.38	3.38	0
10	Max. shear force (KN)	4.50	4.50	0

Table 8. Compound beam Subjected to UDL and point load: Adequacy check

S/N	ADMISSIBLE/PERMISSIBLE STRESSES	MANUAL CALCULATION RESULT	PROGRAM RESULT	%ERROR
1	Admissible bending (N/mm^2)	5.95	5.95	0
2	Admissible shear (N/mm^2)	0.74	0.74	0
3	Admissible bearing (N/mm^2)	1.87	1.87	0
4	Admissible deflection (mm)	9.00	9.00	0
5	Applied bending (N/mm^2)	8.16	8.16	0
6	Applied shear (N/mm^2)	0.52	0.52	0
7	Applied bearing (N/mm^2)	1.16	1.16	0
8	Applied deflection (mm)	8.67	8.67	0
9	Max. bending moment (KNm)	6.38	6.38	0
10	Max. shear force (KN)	6.50	6.50	0

Table 9. Column Subjected to Compression only: Adequacy check

S/N	ADMISSIBLE/PERMISSIBLE STRESSES	MANUAL CALCULATION RESULT	PROGRAM RESULT	%ERROR
1	Admissible compression (N/mm^2)	3.05	3.05	0
2	Applied compression (N/mm^2)	1.10	1.10	0

Table 10. Column Subjected to Compression and Bending: Adequacy check

S/N	ADMISSIBLE/PERMISSIBLE STRESSES	MANUAL CALCULATION RESULT	PROGRAM RESULT	%ERROR
1	Admissible bending (N/mm^2)	5.98	5.98	0
2	Admissible compression (N/mm^2)	1.77	1.77	0
3	Applied bending (N/mm^2)	2.10	2.10	0
4	Applied compression (N/mm^2)	1.00	1.00	0

3.2 Discussion

Results presented in tables 6-10 are results obtained from manual method vis-à-vis the developed program. Comparatively, for all design parameters analysed using the adopted design data, the percentage error was found to be zero. This highlights the accuracy of the program which is of profound essence in design. It suffices to note that ease of use; speed and accuracy were major considerations in the development of this program. The whole process of the computerized analysis and design follows the same method and procedure as that done manually. It suffices, however to state that because of the language ability in presenting a

visually appealing and interactive graphical interface as well as powerful interface to create codes for correct execution; hence, visual basic was chosen as the programming language for this research study.

Furthermore, it can be observed from the tables that, comparison between the manual results and the results obtained using the developed program reveals that both results are essentially the same. This clearly highlights the accuracy and reliability of the developed program. Lastly, the essence of speed in the analysis and design as a key factor of consideration bearing in mind accuracy was justified. Thus in cases where there is need for the analysis and design of a large number of sectional elements for a timber structure, the speed and ease of doing this can obviously be justified using this program.

4.0 Conclusion

The following has been achieved in the development of this program

- i. The manual analysis and design of the two structural elements (beams and columns).
- ii. The development of algorithm for the program.
- iii. The development of visual basic code for the analysis and design of the two structural elements.

The program ran successfully with reasonable speed and reliability, thus achieving the basic aim of carrying out this research work. Furthermore, it is observed that it is less cumbersome, enormously saves time and reduces errors to its barest minimum level as compared with analytical approach which has a limiting point in cases of complex analysis and design.

5.0 Recommendation

It is recommended that a more extensive research be fashioned out using Visual Basic programming language to be used in the execution of complex timber structural analysis and design such as, analysis and design of wood bridges, timber piles, form work and false work as well as timber roof trusses.

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