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An Online Mechanical Design Application for Beams, Columns

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ABSTRACT

An online application software presented in this paper will aid quick design of mechanical components such as beams and columns. An online design Apps are facilitating productivity and design cycle of products including the design of mechanical components. Therefore, the implementation of the online application will give assess to designers and understudy students of engineering, thereby enhancing their knowledge and accessibility to design tool. The online application called BECOL is developed using the convectional engineering design approach. The design analysis of beam and column were coded HyperText Markup Language (HTML), Cascading Style Sheet (CSS) in conjunction with JavaScript (JS) and CSS developer software. The interface were loaded on a WAMP application server. The BECOL is tested with raw input data and the output results compared with numerical calculation and the results shows up to 98% agreement.

1. Introduction

Nowadays, there is a fast move from the conventional ways of doing things called digitalization in which day-to-day activities like reading, learning, working, playing, and discussions are done with computer [1]. This phenomenon is yet to be fully harvested for its potentials and one of the problems that lies in this is conversion of existing design procedures and formulas to computer programs and software that could be accessible globally to both students and engineers, thereby integrating the traditional procedures and formulas into the computerized medium, the internet [2].
The era of networked information has emerged as the most powerful tool for an instant access to information and engineering design data. Information is now just a 'finger touch' distance away from the user and it would not be inappropriate to say that the internet has become the biggest global digital information library which provides the fastest access to the right kind of information in nanoseconds to the end-user anywhere in the world. The Internet has become the most extensively used information source that empowers the design engineer to get in roaming with the latest information. Today's users can no longer depend on conventional information sources and methods for engineering design [3].
The Internet has emerged as a powerful educational and research tool. With the increasing impact of information and communication technologies on the way we live, learn and perform tasks.

Engineers, educationist and researchers are attempting to grasp how ICT could help in modernizing the process of designing, producing, teaching, learning and researching.
Engineering systems and their components require fast and reliable means of designing that is ICT compliant. Hence, online design instruments for mechanical engineering will provide engineers all over the world including understudies engineers who learning is nearly ICT in nature.
The most frequent design components are beams, columns, and their joints. These engineering components form the major part of support structures and frames.
In software design, algorithm require design variable(s) (inputs), the processing formula of conditions and the output structure. The design of beams and columns that were given propriety in this online application required the determination of minimum safe structural dimensions for each components using existing formula.

1.1 Theoretical Background for Beam and Column Design

In all structural members (such as beams and column) that are subjected to internal or external loads load, stresses are developed. When the stress exceeds the material's own yield limits failure always occurs and a good design is focus on avoiding failure based on the Failure criteria.
Euler's beam equation shows the relationship between beams shear force, body moment and deflection. Equation 1, is the basis of the beam design used in the developed application.

$$EIy^{ii} = M \qquad (1)$$

Applying the conditions of equilibrium to determine the maximum bending moment for the beam and subsiding the maximum bending moment into equation 2, to obtain the moment of inertia for the beam. The moment of inertia depends on the beam geometry.

$$\frac{\sigma}{I} = \frac{M}{y^{ii}} \qquad (2)$$

Where

E – Elastic Modulus of beam material (GMPa)
I – Moment of Inertial of the beam (mm^4)
y^{ii} – slope of the beam (degree)
M – Maximum bending moment of the beam (N.m)
σ – Maximum shear stress of on the beam (MPa)

Short columns are designed using Euler's column equation (3) while medium and long columns are designed using Rankine's equations.

$$P_E = \frac{C\pi^2 EI}{L_e^2} \qquad (3)$$

$$P_R = \frac{P_E P_{CS}}{P_E + P_{CS}} = \frac{P_{CS}}{1 + \frac{P_{CS}}{P_E}} \qquad (4)$$

Where:

C – Column end condition as shown in table 1
L_e – Effective column length (see table 1)
P_E – Column crippling load by Euler
P_{CS} = Column crippling load by Rankine
P_R – Column crippling load by Rankine

Table 1: Relation between equivalent length (l_e) and actual length (l).

S. No.	End Condition	Relationship between equivalent length (l_e) and actual length (l)
1	Both the ends hinged	$l_e = 1$
2	Both the ends fixed	$l_e = \frac{1}{2}$
3	one end is fixed and the other hinged	$l_e = \frac{1}{\sqrt{2}}$
4	one end is fixed and the other free	$l_e = 2l$

2. Methodology

This online application was implemented using method mentioned by Alkali et al.

2.1 Sample Beam and Column Analysis

2.1.1 Beam – Simply Supported Beam

Consider a simple supported beam in Figure 1, as a sample analysis having beam of length L(m) and single point load P(N) and beam location X_1(m) as a sample analysis used in the programming. The end condition are a roller support and fixed support.

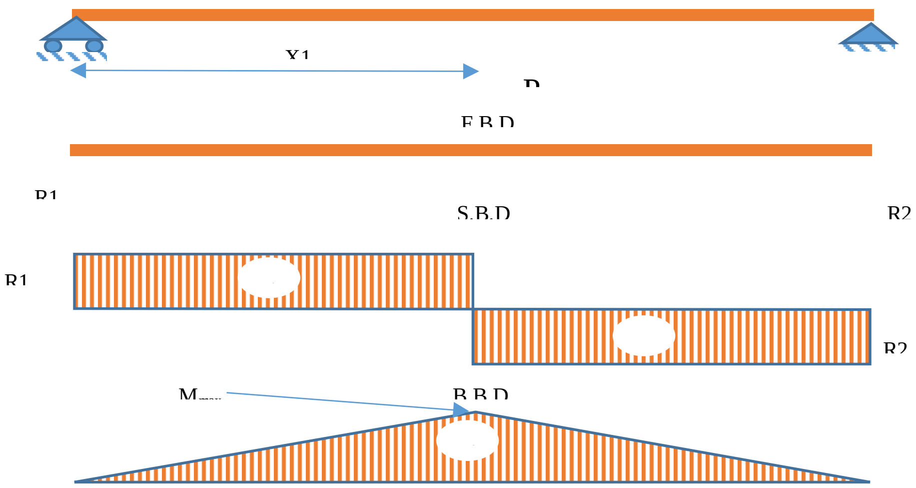

Figure 1: Shear force and Bending Moment Diagram for a simply Support Beam.

Considering the equilibrium of forces and the moment of the beam about the supports.
The reactions at the support, the forces and moments in the beam were determine using equations 5 – 10.

$$R_1 = \frac{P(l-x)}{l} \quad (5)$$

$$R_2 = P - \frac{P(l-x)}{l} = P - R_1 \quad (6)$$

The shear force equations for 1st and 2nd loaded section:

$$R_1 = \frac{P(l-x)}{l} \quad (5)$$

$$R_2 = P - \frac{P(l-x)}{l} = P - R_1 \quad (6)$$

$$Q_1 = \frac{P(l-x)}{l} = R_1 \quad (7)$$

$$Q_2 = \frac{P(l-x)}{l} - P = R_1 - P \quad (8)$$

The Moment equation for 1st and 2nd loaded section:

$$M_1 = R_1 * x \quad (9)$$

$$M_2 = R_1 * x - P(x - x_1) \quad (10)$$

The maximum bending moments M_{max} was determined from equations 9 and 10.

2.1.2 Column

Columns that carry axial loads failure by buckling, therefore, Euler's equations 3 and Rankine's equation 4 are relevant in the design analysis of the column as a components. The column's end conditions stated in Table 1 affects the shape of the column's effective length and deflection of the column. As stated by Khurmi and Gupta, (2008), the Euler's column equation has a limitation and this were observed during the development of the application.

2.2 Program Algorithm

2.2.1 Algorithm for Beam Analysis

The program flow chart adapted for the design of beams online application is presented in Figure 2.

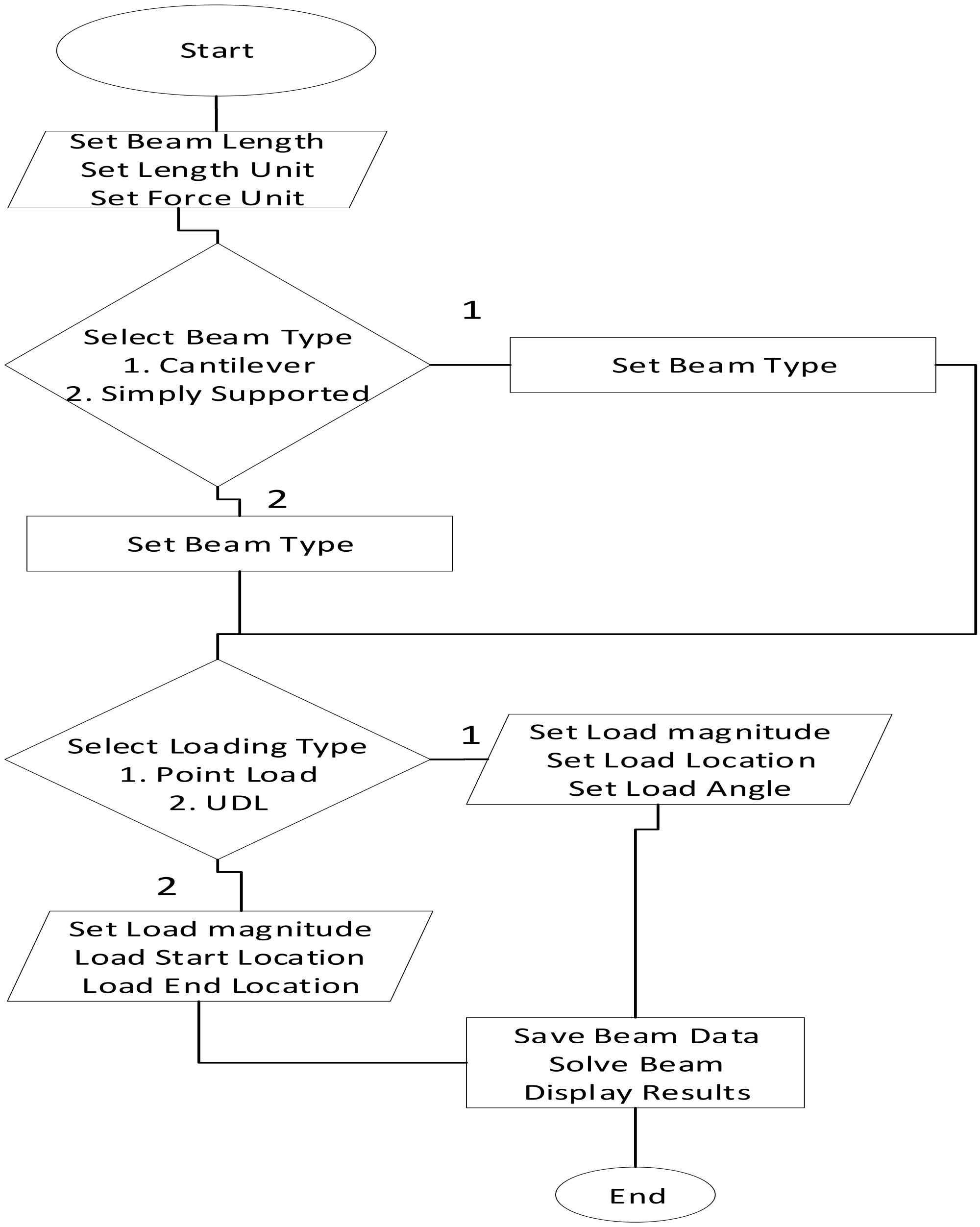

Figure 2: Program Flow Chart for the Beam design

2.2.1 Algorithm for Column Analysis

The algorithm of the online column App is shown in the flow chart (Figure 3). The algorithm make use of equations 2-4.

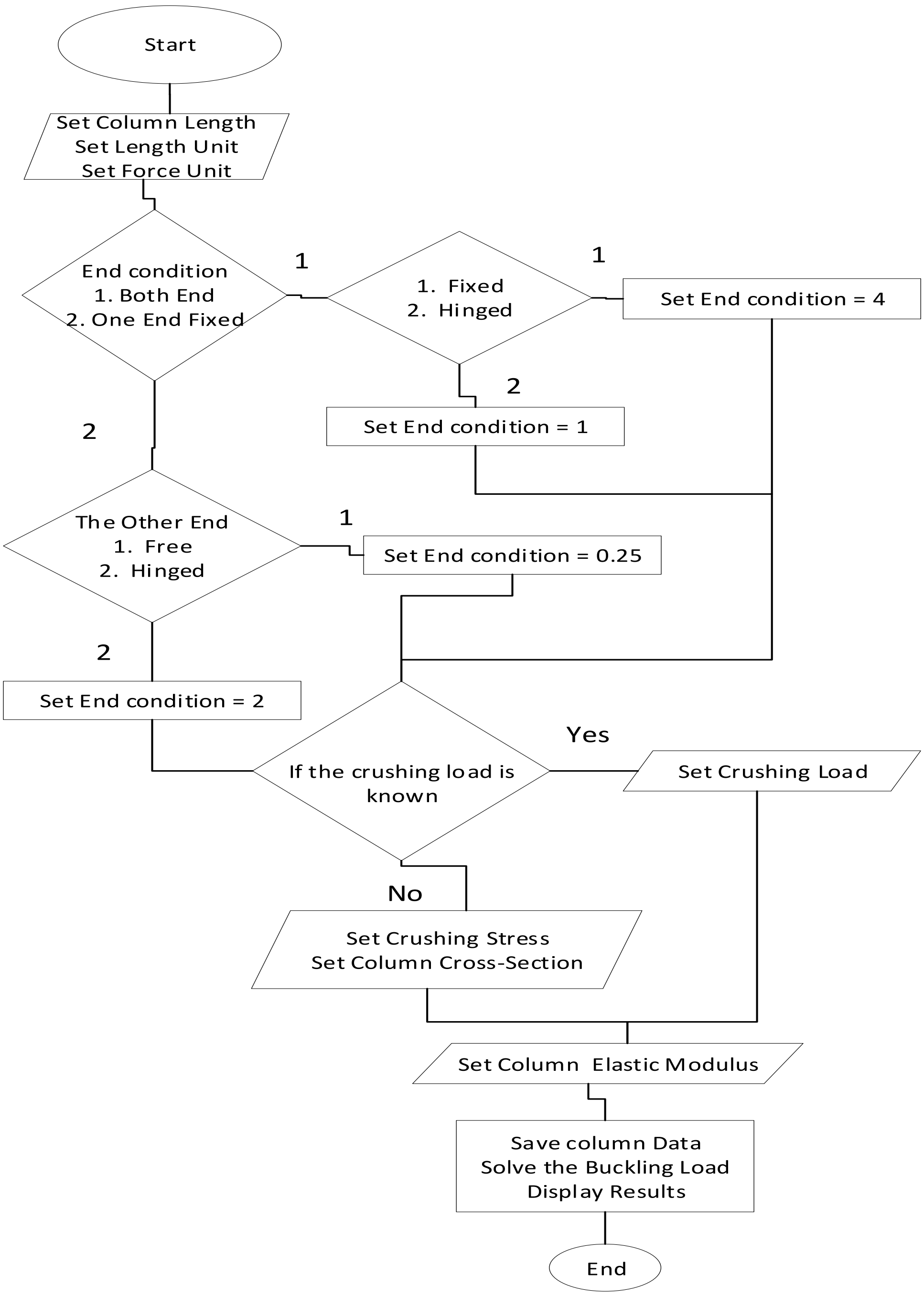

Figure 3: Flow Chart used for Column Design

2.3 Application Implementation

The algorithms shown in Figures 4 and 5 were implemented using HyperText Markup Language (HTML), Cascading Style Sheet (CSS) in conjunction with JavaScript (JS) and CSS software. The user interface were fashioned in an interactive manner so as to ease the use of the application. The developed online mechanical design application for beams and column is called BECOL hosted by WAMP serve application.

3. Results and Discussion

3.1 The Interface

The result of the coding are display in Figures 4 and 5, the interface were rendered on the chrome web browser for aesthetic purposes.

Figure 5: The web interface for column analysis

3.2 Interface Testing

The BECOL application was tested with the inputs in Figure 6 and 7. The application was tested with sample questions in both (Khurmi & Gupta, 2008) and (Rajput, 2008) Strength of Materials textbooks.

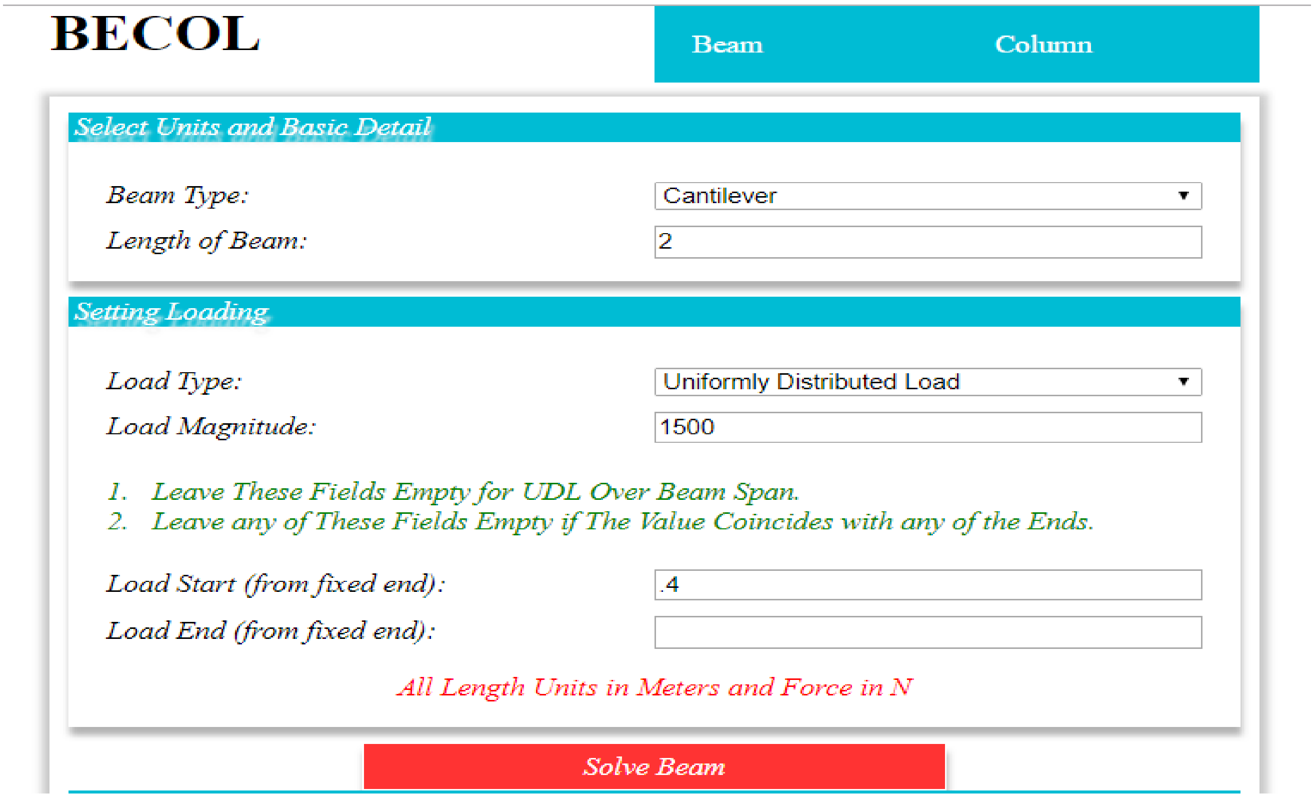

Figure 6: Uniformly Loaded Cantilever Beam Test Question Answer Parameter Input on BECOL

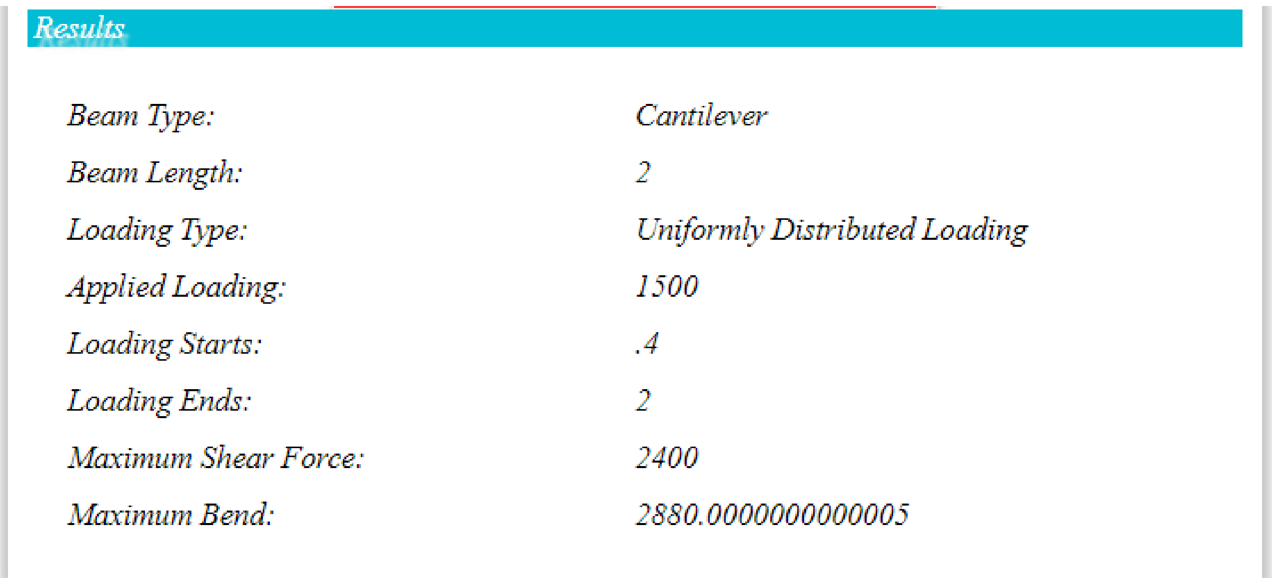

Figure 7: Uniformly Loaded Cantilever Beam Test Question Answer from BECOL.

The output from the application agrees with the numerical calculation results over 98%. And this shows that the developed application (BECOL) is reliable. Comparing the results from the source and the result from the developed application, the percentage error or percentage different is 0.03%. The difference in the answer of the question source and that of the BECOL is as a result of approximation of the answer at some step in the calculation from the source.

4. Conclusion

The light weight approach to the interface development aid the accessibility as the loading time of application and the request to the server are minimized. The modern approach to the application logic through object oriented programming concept, improves the robustness of the application and extensibility through application programming interface. The results from the analysis through the application is reliable and provides higher precision as the errors relating human imperfection is eliminated by precisely implementing the engineering formulae.

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