



International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 8, Issue 3, March 2019)

Computer Based Demonstrations of Structural Analysis for Engineering Students

M.C Arimanwa¹, I.E Umeonyiagu², N.P Ogbonna³

¹*Department of Civil Engineering, Federal Polytechnic Nekede, Owerri, Nigeria*

²*Department of Civil Engineering, Chukwuemeka Odumegwu Ojukwu University, Uli, Nigeria*

³*Department of Civil Engineering, Federal Polytechnic Nekede, Owerri, Nigeria*

¹mikarimanwa@yahoo.com

²umeonyiaguikuchukwu@gmail.com

³nopsoftinc@yahoo.com

Abstract—This study developed a standalone application as replacement for over a hundred existing Structural analysis applets, to serve as an interactive learning environment for engineering students in structural engineering course in any tertiary institution. The developed standalone application consist of series of Java based lessons and exercises as well as simulation program, designed to explore, communicate, and test various aspects of Structural Analysis curriculum. It can be installed as a normal program through its executable file (.exe) or shared over the internet in zip format. Examples of the structural analysis topics covered include: Analysis of trusses and framed structures, shear, moment and deflection analysis of beams; analysis of determinate and indeterminate trusses, influence lines for beams, analysis of Dams and Retaining Walls. The developed program eliminates the security issues posed by the inability of Java applets to run smoothly on recent versions of most web browsers as a result of the deprecation of the applet tags which is present in old web browsers that supports Java.

Validation of the developed program was done by comparing its results with standard literatures which confirmed that the results are very close and accurate.

Keywords—Java Applets, Standalone Application, Teaching and Learning, Structural Analysis, Web-based, instructional units.

I. INTRODUCTION

The last two decades have seen a rapid emergence and broad acceptance of the internet as a global medium for disseminating and processing information that is accessible in multiple formats and at high speeds. This has opened new opportunity in education by taking full advantage of our basic "senses" of learning such as visualizing 3D objects and nonlinear nature of thought processes. Recent years have also seen the inception and development of Java, a powerful programming language from SUN Microsystems [1].

Java programming language is a cross-platform, object-oriented computer language that is ideally suited for either stand-alone applications or Web-based programs called applets. Use of applets as an instructional tool has been emphasized by many researchers in the past few years as a vital instructional tool used in promoting teaching and learning, yet the future of applets are no longer guaranteed due to security concerns and compatibility issues with modern devices which do not support Java. Hence the need to explore other alternatives of providing workable instructional materials aimed at permitting an interactive exploration of the behavior of physical systems. Similar to the applets, the standalone application focused on several topics or aspects of the course content, and provides an interactive exercise that is suitable either for in-class demonstrations by an instructor or out-of-class problem solving by students.



International Journal of Recent Development in Engineering and Technology

Website: www.ijrdet.com (ISSN 2347 - 6435 (Online)) Volume 8, Issue 3, March 2019)

[2], introduced Java Applets as Powerful tools for interactive learning in the college curriculum. They noted that traditional methods and materials for teaching and learning at the college and university level often fail to satisfy both teacher and student and created a series of exercises, written in Java, to explore, communicate, and test various aspects of the biochemistry curriculum.

[3], worked on Computer Based Demonstrations of Statistical Quality Control for Engineering Students. They demonstrated that Computer based education approach is used as a learning tool to demonstrate Metrology and statistical quality control concepts and their industrial applications for engineering students.

[4], developed Java applets to assist in the learning of basic structural analysis concepts. The applets include truss and frame determinacy applets; a three-hinged arch bridge applet; determinate and indeterminate truss analysis applets; They also serve as excellent tools that facilitate the understanding of structural engineering concepts utilizing a medium that allows independent learning at an individual pace.

According to [5], Instructors can use interactive Java applets to present science in a concrete and meaningful manner to non-science majors. He showed how applets can take the place of laboratory work and gave examples and benefits of using applets.

Despite the aforementioned benefits of Applets in teaching and learning, the non support for the use of applets by other non Java browsers and modern mobile devices is a major concern. Many web browser vendors are deprecating applet Netscape Plug-in Application Programming Interface (NPAPI) due to its age and security issues. In January 2016, Oracle announced that Java runtime environments based on JDK 9 will discontinue the browser plug-in.

This work developed several applets and a standalone application as an alternative and complementary instructive tool for demonstrating structural analysis. The standalone application can be installed as a computer program and also downloaded through the internet in form of a Zip file.

II. LITERATURE REVIEW

A. *Limitation of the Current Educational Practices*

The processes of teaching and learning are complex and challenging. The traditional teaching methods such as the use of Textbooks and classroom lectures are not adequate for students especially those in the science and engineering disciplines. As a result, the teaching enterprise is often an ongoing search for strategies and devices that will convey understanding, rather than merely communicate information [2]

Most science and engineering educators contend that learning best occurs when students are engaged in active manipulation of their environment they learn best when content is presented in a concrete fashion and incorporates equipment-based demonstrations to complement the lecture. Yet time constraints and lack of available equipment may prevent instructors from using demonstrations.

[1], stressed that the use of Java applets can encourage asynchronous distance learning and thus help overcome the limitations (involving both time and space) inherent in traditional instructional techniques. Information available to students can be in a dynamic, multimedia or Interactive format but cannot be represented, distributed and communicated in paper form and even using a blackboard or overhead-projector with transparencies due to various limitations. Although animations can be created using other techniques (for example, GIF animation tool), they lack interaction. The "mental picture" that a teacher has is better conveyed to a learner if the information is presented in its appropriate form. Java applets and Standalone applications can complement a lecture and sessions with such information which is difficult to convey in the traditional manner.

Another areas to consider, are in preparing assessment, traditional methods such as in-class quizzes can be replaced or supplemented with simple Java applets-based multiple-choice on-line tests. This can increase the range of questions that can be asked, as now one is not restricted to the paper format. Such tests can give learners a measure of their understanding of the subject and thus develop confidence [1].

Considering cost, Java compilers and run-time environments are also freely available for various architectures secondly in terms of transferability and adaptability, The results of development of Java applets in one instance can be transferable and adaptable to various other learning situations.

B. Java programming language

Java Programming Language was developed by Sun Microsystems in 1996 and later acquired by Oracle Corporation. Its properties such a simple, object-oriented, distributed, interpreted, robust, secure, architectural neutral, portable, high-performance, multithreaded, and dynamic language, makes it popular on the web. Other advantages of Java over existing programming languages include speed, interoperability, user interaction, platform independence and portability etc

C. Java Applets

Java applets are an excellent means for delivering dynamic interactive graphical content over the Internet [5]. An applet is a computer program which is usually embedded in web-pages using the <APPLET> tag and can run on any Java compliant web browser.

D. Standalone Applications

This is an application which needs the assistance of the Java interpreter, such as the Java Runtime Environment (JRE) to run. Several versions and updates of JRE exists such as JRE 1.5, 1.6 and currently 1.9. Standalone applications can be converted into executable files (.exe) and installed on the client machine provided that JRE is also installed in it., They can also be converted into applets using the init () method in java and can be downloaded from the internet in compressed ZIP formats (.zip).

III. MATERIALS AND METHODS

A. Program Description

A set of Java based instructional units where developed to interactively and dynamically illustrate the fundamental concepts of structural analysis. These instructional units are centered on existing but deprecated Java applets and a standalone application. Both incorporates a wide range of structural elements, truss, beam and frame, dams and retaining walls and also has features for entering the properties of the structure such as applied loads, sectional

dimensions and other parameters needed to perform analysis. The program simulates the behavior of the structure instantly therefore, helping to reinforce the user's understanding of the subject under consideration.

B. Structural Analysis

A variety of basic structural elements are incorporated in the program. The elements are typical of those studied under finite element analysis course

i. Shearing Forces and Bending Moment:

Loading a structure causes the induction of stresses in the various parts of the structure. For a cantilever with uniformly distributed load and a concentrated load at the free end , the following relationship is true:

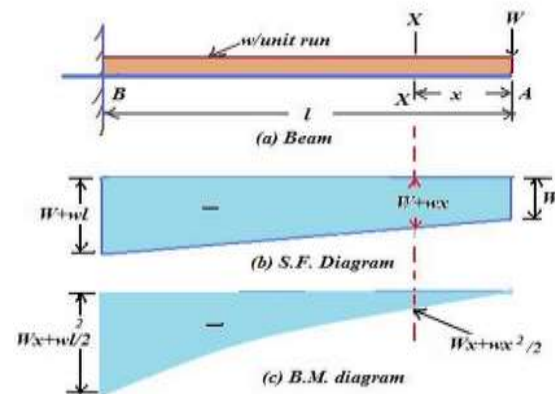


Figure 3.1: cantilever with uniformly distributed load and a concentrated load at the free end

Consider any section XX between the free end and the fixed end of the cantilever, The shear force and bending moment expression for the section X is given as

$$S_x = -(W + wx) \text{ and } M_x = -\left(Wx + \frac{wx^2}{2}\right) \quad 3.1$$

Where S_x is Shear force, M_x is Bending moment W is the concentrated load, w is the uniformly distributed load , l is span length and x is the sectional distance

ii. Deflection of beams

The deflection of a beam or cantilever subjected to load depends upon bending moment and the beam's cross section. Two main criteria used in the design of beams includes strength and stiffness. The strength criteria

assumes that the beam should be strong enough to resist shear force and bending moment.

Consider a cantilever l carrying a UDL w per unit run over the whole length,

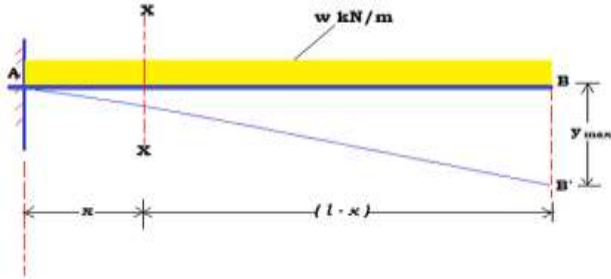


Figure 3.2: cantilever l carrying a UDL w per unit run over the whole length

Under this section, We present a cantilever of length l carrying a UDL w per unit run over whole length as shown in figure 3.32

The slope equation is given as

$$EI \frac{dy}{dx} = \frac{w(l-x)^3}{6} - \frac{wl^3}{6} \quad 3.2$$

Slope at B substituting $x=l$, we have

$$\theta_B = wl^3/6EI \quad 3.3$$

The deflection equation can be obtained by integrating the slope equation

$$EI y = -\frac{w}{24(l-x)^4} - \frac{wxl^3}{6} + \frac{wl^4}{24} \quad 3.4$$

Substituting $x=l$ equation 3.4 We have

$$y_B = -\frac{wl^4}{8EI} \quad 3.5$$

Therefore, the slope and deflection at B is the maximum

iii. Analysis of Continuous Beams

A continuous beam is a statically indeterminate structure which is supported on more than two supports. Common methods of analyzing continuous beams include slope

deflection method, Clapeyron's theorem of three moments, moment distribution method and slope deflection methods.

Considering a continuous beam with two spans and pinned supports at both ends, carrying uniformly distributed load,

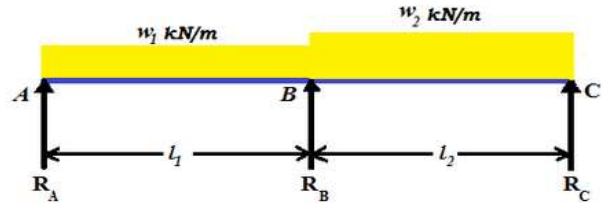


Figure 3.3: continuous beam with two spans and pinned supports at both ends, carrying uniformly distributed load

Using Clapeyron's theorem of three moments:

$$M_A l_1 + 2M_B (l_1 + l_2) + M_C l_2 = -\left(\frac{6a_1 \bar{x}_1}{l_1} + \frac{6a_2 \bar{x}_2}{l_2}\right)$$

This equation is true provided that the flexural rigidity of the spans are the same and the supports are at the same level.

Where l_1 is length of span AB, l_2 is length of span BC,

$a_1 =$

area of the bending moment diagram for span AB

$a_2 =$ area of the bending moment diagram for span BC

$\bar{x}_1 =$ Distance of the centroid of a_1 from A

$\bar{x}_2 =$ Distance of the centroid of a_2 from C

$M_A =$ Support moment A

$M_B =$ Support moment B

$M_C =$ Support Moment C

C. Program Structure

The applets and the standalone application were written in Java using the object-oriented approach. The classes developed were divided into two categories: (1) structural classes for representing the various elements of the structure, and the interface classes for interacting with the user. Common example includes SliderC1 structure class and the SliderApplet for the interface class for a case of a continuous beam analysis.

SAApplet is the main class of the standalone application. This class has methods for reading the input

data. The graphical user interface of the applet is mainly provided by the `SAApplet` class which is created by extending the `JApplet` class of the Java class library.

This class contains the required code for controlling the behavior of components contained in main applet window. Various components such as `JTextBox`, `JLabel`, `JList`, `JScrollPane`, `JTextArea`, `JButton`, `JCheckBox` and `JRadioButton` from the Java class library are used for developing the user interface of the applet. Also, several inner classes are provided for event handling operations of the above mentioned components.

i. Input And Output Classes

The required input for the Structural Analysis program is a `Scrollbar` which is used to enter the input date visible on the `JTextField` and `JPanel` components of the interface of the program. The choice of using `Scrollbar` for data input is to control the type of data the user input into the program and also to speed up the time of analysis.

ii. Interface Classes

The graphical user interface of the applet is provided by the `SAApplet` class. This class contains methods for displaying the structure, concentrated loads, uniformly distributed loads and sectional properties as well as the required graphical representation of the structure under the applied loads.

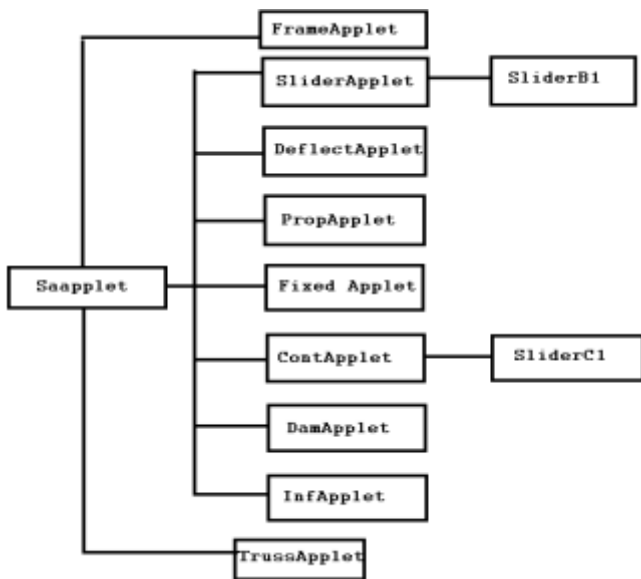


Figure 3.4: Structural Classes in the Applet.

IV. NUMERICAL ANALYSIS

A. Verification of Problem

To verify the accuracy of the program, results obtained from the applet are compared with those obtained from (11), [4] and other commercial Structural Analysis Software SAP 2000. Series of test problems were analyzed using the both applet and comparing the result obtained showed that they are accurate. The following example problems were solved with the applet

Example 1

Find the resultant lateral pressure and the distance of the point of application from the bottom in the case of a retaining wall as shown in figure 4.1. Take weight of upper soil as $2,00\text{kg/m}^3$ and $\phi = 30^\circ$ weight of lower soil as $2,400\text{kg/m}^3$ and $\phi = 30^\circ$ [10]

Solution

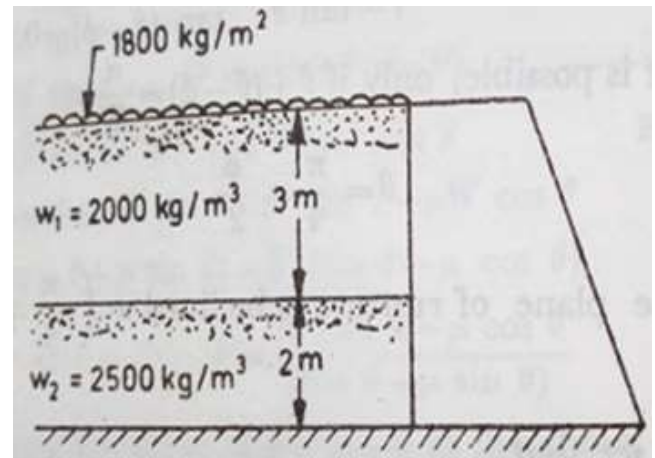


Figure 4.1: Analysis of a retaining wall [9]

The input values in kg were converted to kN by multiplying with 0.00981

$$\text{Surcharge} = 1800 \times 0.00981 = 17.7 \text{ kN}$$

$Weight\ of\ Upper\ Soil = 2000 \times 0.00981 = 19.6\ kN$

$Weight\ of\ Lower\ Soil = 2500 \times 0.00981 = 24.5\ kN$

Let the total pressure due to upper soil = P_1
Total pressure due to lower soil = P_2
Pressure due to surcharge = P_3
Resultant Lateral Pressure = P
Height of the point of application of the resultant pressure from the bottom of the wall = y

Results from [9] and the Program (Saapplet v-1.5) are given in table 4.1

Table 4.1: Result of analysis from example 1

Analysis Results	[9]	Saapplet v-1.5	% Difference
P (kN)	113.80	114.43	0.5510
P_1 (kN)	29.43	29.40	0.1020
P_2 (kN)	54.94	55.53	0.0110
P_3 (kN)	29.43	29.40	0.1020
y (m)	1.860	1.850	0.5380

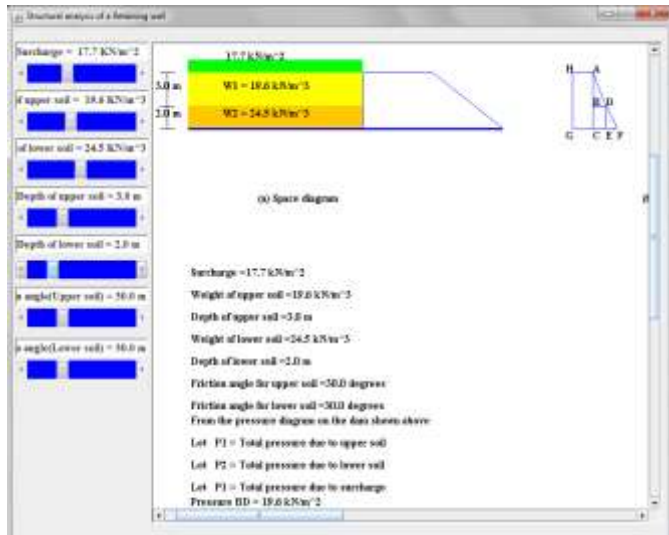


Figure 4.2: Analysis of a retaining wall from the test program.

The results from [9] and the test program are close, the differences are due to conversion from kg to kN for the weights of the upper soil, lower soil and the surcharge.

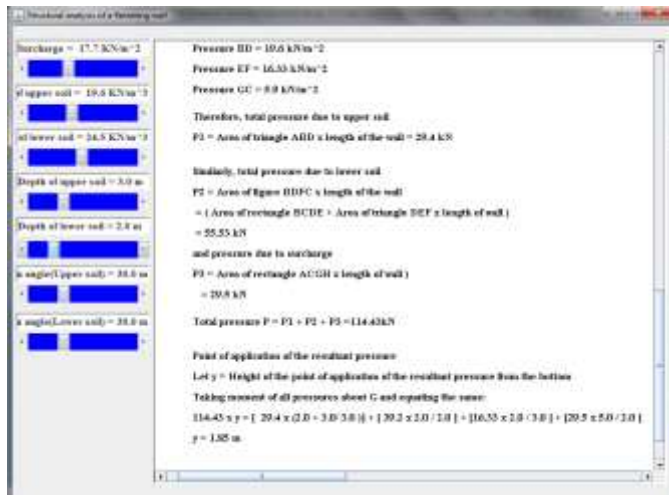


Figure 4.3: Analysis of a retaining wall with the test program.

Example 2

A cantilever truss Warren type is loaded as shown in figure 4.4, find the forces in all the members of the truss by method of joints or by method of sections [10].

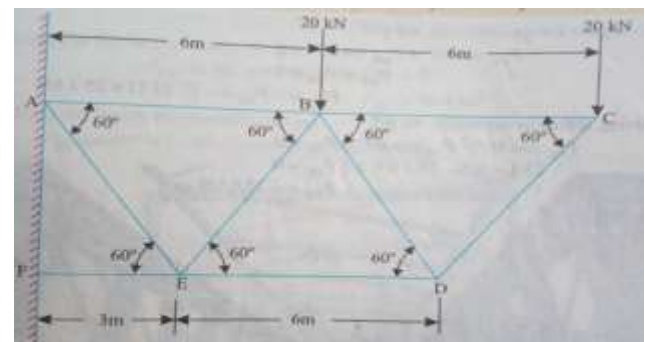


Figure 4.4: Analysis of a Warren Truss [10]

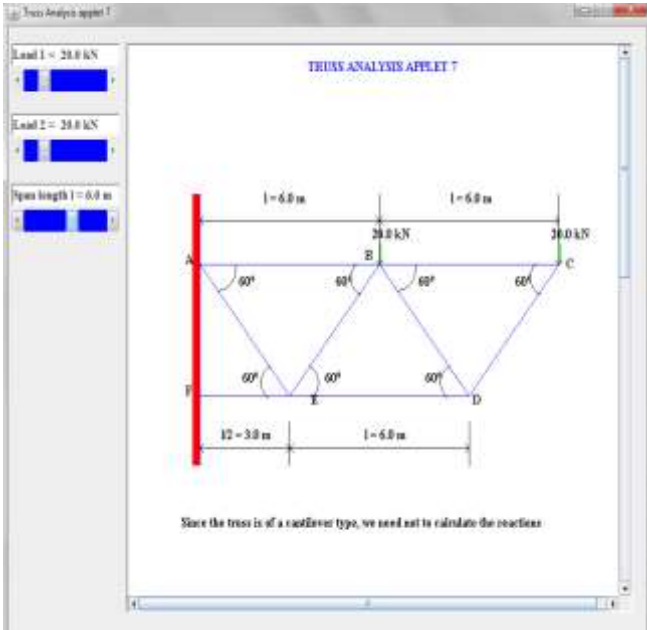


Figure 4.5: Analysis of a Warren Truss wall from the test program.

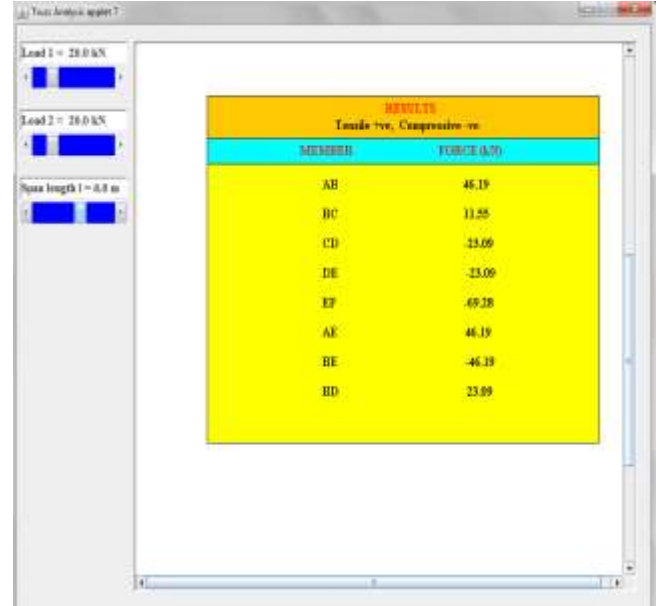
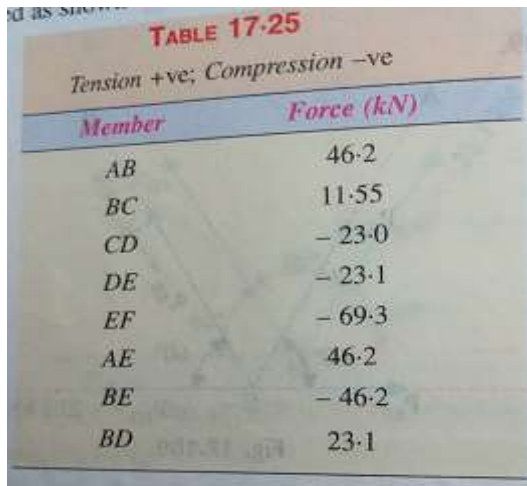


Figure 4.7: Results of the analysis of a Warren Truss from the test program

Results from [10] and the Program (Saapplet v-1.5) are given in table 4.2

Table 4.2: Results of Analysis from example 2



The photograph shows a printed table titled 'TABLE 17-25' with the subtitle 'Tension +ve; Compression -ve'. The table lists the force in kN for various members of the truss.

Member	Force (kN)
AB	46.2
BC	11.55
CD	- 23.0
DE	- 23.1
EF	- 69.3
AE	46.2
BE	- 46.2
BD	23.1

Figure 4.6: Results of the analysis of a Warren Truss [10]

Analysis Results	[10]	Saapplet v-1.5	% Difference
AB (kN)	46.2	46.19	0.0216
BC (kN)	11.55	11.55	0.0000
CD (kN)	-23.0	-23.09	0.3900
DE (kN)	-23.1	-23.09	0.1020
EF (kN)	-69.3	-69.28	0.5380
AE (kN)	46.2	46.19	0.0432
BE (kN)	-46.2	-46.19	0.0216
BD (kN)	23.1	23.09	0.0432

Example 2 indicates that the results from [10] and the test program are close and accurate.



V. CONCLUSION

The standalone application gives simple and interactive approach for teaching structural analysis as a course in tertiary institutions. Its features make it very attractive in teaching. The graphical user interface combined with the various input forms makes it easy to simulate sample problems with immediate solutions. Students can use the standalone application as an alternative option when there are security or compatibility issues with non Java supported browsers and mobile devices. The developed program can also serve as a means for checking student's work, reinforcing fundamental concepts learned in class, and also enhancing student's learning experience.

References

- [1] Kamthan J. 1999. Dynamical Systems Education on the WWW, Master's Thesis, Concordia
- [2] O'Neil E.K. and Grisham, 2000, Java Applets: Powerful Tools for Interactive Learning in the College Curriculum, Journal of Computing in Higher Education Spring
- [3] Rojiani K.B and Schottler 2004, Java Applets for Structural Analysis, Department of Civil and Environmental Engineering, Blacksburg, Virginia
- [4] Mohamed Othman et al 2000, Computer Based Demonstrations of Statistical Quality Control For Engineering Students, Journal of Computing in Higher Education.
- [5] Corder .G, 2005, Teaching With Applets, Journal of Science College Teaching.
- [6] Rojiani K.B and Raju S.V.N, Java Applets for Teaching Finite Element Analysis, 2006. Joint International Conference on Computing and Decision Making in Civil and Building Engineering.
- [7] SAP-2000 (1997). Integrated Finite Element Analysis and Design of Structures, Input File Format, Computer and Structures, Inc., Berkeley, California
- [8] Brown, L. D., Hua, H., and Gao, C. 2003. A widget framework for Augmented interaction in SCAPE.
- [9] Khurmi, R.S, Theory of Structures, S. Chand
- [10] Rajput, R. K. 2004. Strength of Materials (Mechanics of Solids) S. Chand