Plastic Analysis of Beams using Python Programming

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Abstract:- **In this growing modern era, everything is shifting to software programming. This software programming is now-a-days being used in every department of work such as by scientist mathematicians and engineering works. Like many fields of engineering, civil engineering also involve data science applications. Hence an attempt has been made in this paper to use Python programming to study the behavior of beams under plastic stage. The results obtained from Python program is compared with STAAD-Pro software and Manual calculations, it was observed that results are almost matching. Hence this Program can be easily used in our Civil Engineering applications.**

Keywords—Beam, Plastic analysis, Python, STAAD-Pro.

1. INTRODUCTION

When we hear of software programming, we get many names like C+, C++, Python, Java, Perl and Lisp. Out of these, Python is the most popular programming language in data science and we found python it easy for learning for non-technical branch as it is easily accessible and has user-friendly syntax.

The earlier use of elastic design method does not take into account the strength of the material beyond the elastic stress. Therefore, the structure designed according to this method will be heavier than that designed by plastic method. In this method of plastic design of structures, the ultimate load rather than the yield load is considered as the design criteria.

Plastic analysis is defined as the analysis in which the criterion for the design of structures is the ultimate load. Actually, the ultimate load is found from the strength of steel in plastic range. This method of analysis is quite rapid and has rational approach for analysis of structure. It controls the economy regarding to weight of steel since the sections required by this method are smaller than those required by the method of elastic analysis. Plastic analysis has its applications in the analysis and design of indeterminate structures.

2. INTRODUCTION TO PLASTIC ANALYSIS

Plastic design method has its main application in the analysis and design of statically indeterminate framed structures.In plastic design of a structure, the ultimate load rather than the yield stress is regarded as the design criterion. The term plastic has occurred due to the fact that the ultimate load is found from the strength of steel in the plastic range.

This method is also known as method of load factor design or ultimate load design. The strength of steel beyond the yield stress is fully utilised in this method [5].

This method is rapid and provides a rational approach for the analysis of the structure. Plastic design method has its main application in the analysis and design of Statically Indeterminate Structures. In the analysis of structures by plastic theory, the following conditions must be satisfied

(i)Equilibrium Condition
(ii) Mechanical Conditions
(iii) Yield Condition

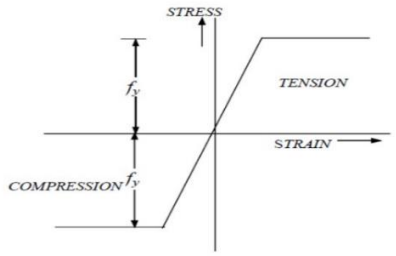


Fig.1 Stress-Strain curve for perfectly plastic materials

From the conditions given above we get two methods of analysis by plastic theory, which are based on the following theorems

(i). Lower bound theorem
(ii). Upper bound theorem
(iii). Uniqueness theorem

3. LITERATURE REVIEW

Pramod [1]-The study was done to develop a software for minimum weight designof steel structures by using python programming. Plastic analysis was carried out for portal frames using the principal of kinematic theorem of minimum weight design. Graphical method of linear programming was used for optimization of weight. A single frame was considered and compared with manual calculations and concluded that software takes less time as compared to manual calculation.

J.M. Djokovice [2]- The load carrying capacity or limiting load at which the structure collapses is determined and presented a C++ program which computes the value of the load factor and determined whether the static distribution of the bending moment is safe, using method of plastic analysis. The program has the capability of generating the possible mechanisms of collapse visually

4. PYTHON PROGRAMMING

Python is a simple, easy to learn, powerful, high level andobject-oriented Programming language. Python is invented by Guido Van Rossum at CWI in Netherland in 1989. It is binding of C, C++ and Java. It works on different platforms (Windows, Mac, Linux, etc. Python has a simple syntax similar to the English language. It also has syntax that allows the developers to write programs with less lines than some other programming languages like c+, java etc. Python runs on an interpreter system, meaning that code can be executed as soon as it is written. This means that prototyping can be very quick.

4.1Application of python

- Easy to learn
- Easy to read
- Portable and Extendable
- A broad standard library

4.2 Application of python in civil engineering

- Population forecasting for urban planning, water supply & sewerage system.
- Risk assessment and mitigation such as prediction of floods, earthquakes, cyclones.
- Predicting traffic trends in Highway engineering.
- Soil simulation and modeling in Geotechnical engineering
- Finite element applications in Structural engineering
- Construction management.
- ML (Machine Learning) applications such as automation in structural design and drawings.

4.3 Running the Python IDE

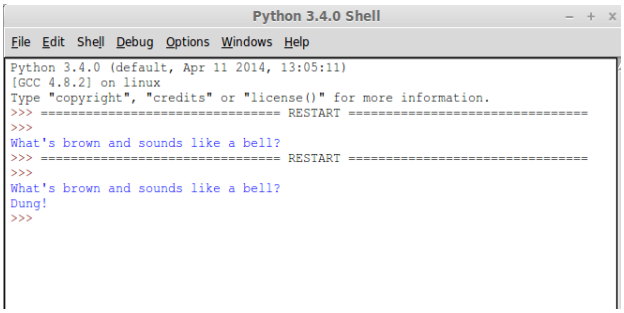
- Now that we have successfully completed the installation process and added our Environment Variable, you are ready to create your first basic Python script. Let's begin by opening Python's GUI by pressing "Start" and typing "Python" and selecting the "IDLE (Python GUI)."
- Once the GUI is open, we will begin by using the simplest directive possible. This is the "print" directive which simply prints whatever you tell it to, into a new line. Start by typing a print directive like the one shown in the image below or copy and paste this text then press "Enter": print ("Congratulations on executing your first print directive!").
- 

Fig. 2. Running the python IDE

4.4 Python Code Execution

Python's traditional runtime execution model: source code you type is translated to byte code, which is then run by the Python Virtual Machine. Your code is automatically compiled, but then it is interpreted. Source code extension is .py Byte code extension is .pyc (compiled python code)

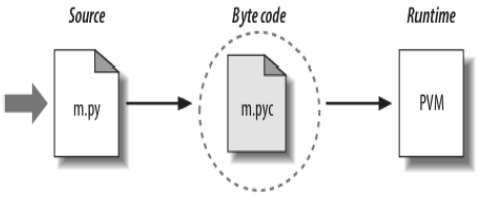


Fig. 3 Python code execution process

4.5 Data type

- Booleans are either True or False.
- Numbers can be integers (1 and 2), floats (1.1 and 1.2), fractions (1/2 and 2/3), or even complex numbers. Strings are sequences of Unicode characters, e.g., an HTML document.
- Bytes and byte arrays, e.g., a JPEG image file.
- Lists are ordered sequences of values.
- Tuples are ordered, immutable sequences of values.
- Sets are unordered bags of values

4.6 Loop definition

Programming languages provide various control structures that allow for more complicated execution paths. A loop statement allows us to execute a statement or group of statements multiple times. The following diagram illustrates a loop statement [3]

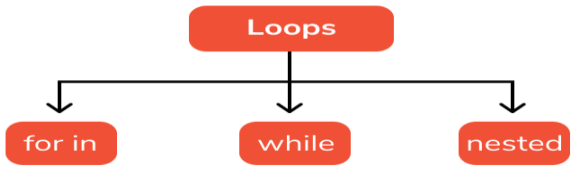


Fig. 4 Loop types

- *while loop*: Repeats a statement or group of statements while a given condition is TRUE. It tests the condition before executing the loop body.
- *for loop:* Executes a sequence of statements multiple times and abbreviates the code that manages the loop variable.
- *nested loops*: In this you can use one or more loop inside any another while, for or do. While loop.

4.7 Statement and Description

if statements: An if statement consists of a Boolean expression followed by one or more statements [4].

if...else statements: An if statement can be followed by an optional else statement, which executes when the Boolean expression is FALSE[4].

nested if statements: You can use one if or else if statement inside another if or else if statement(s)[4].

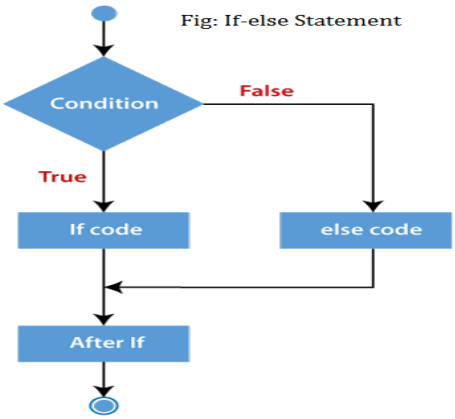


Fig. 5 Condition statement

5. ANALYTICAL INVESTIGATION

A beam with simple supported and carrying a single concentrated load is analyzed by plastic analysis using python programming language and is compared with the manual calculations and using STAAD-Pro software.

5.1 Beam Diagram

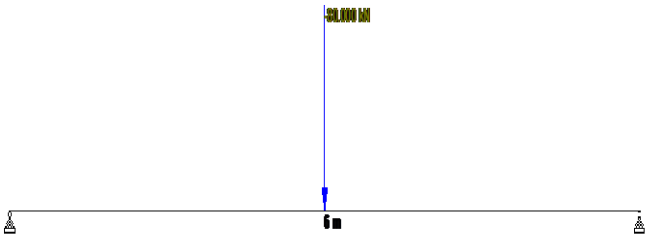


Fig.6Beam subjected to point load

5.2 STAAD-Pro results

1. STAAD SPACE
INPUT FILE: C:\Users\91734\Desktop\New folder (2)\staad pro\beam 43.STD
2. START JOB INFORMATION
3. ENGINEER DATE 16-JUN-21
4. END JOB INFORMATION
5. INPUT WIDTH 79
6. UNIT METER KN
7. JOINT COORDINATES
8. 1 0 0 0; 2 6 0 0
9. MEMBER INCIDENCES
10. 1 1 2
11. DEFINE MATERIAL START
12. ISOTROPIC STEEL
13. E 2.05E+008
14. POISSON 0.3
15. DENSITY 76.8195
16. ALPHA 1.2E-005
17. DAMP 0.03
18. TYPE STEEL
19. STRENGTH FY 253200 FU 407800 RY 1.5 RT 1.2
20. END DEFINE MATERIAL
21. MEMBER PROPERTY INDIAN
22. 1 TABLE ST ISHB150
23. CONSTANTS
24. MATERIAL STEEL ALL
25. SUPPORTS
26. 1 2 PINNED
27. LOAD 1 LOADTYPE DEAD TITLE LOAD CASE 1
28. SELFWEIGHT Y -1 LIST ALL
29. LOAD 2 LOADTYPE LIVE REDUCIBLE TITLE LOAD CASE 2
30. MEMBER LOAD
31. 1 CON GY -80 3 0
32. PERFORM ANALYSIS
33. PRINT ANALYSIS RESULTS
34. FINISH

STAAD SPACE

P R O B L E M S T A T I S T I C S

NUMBER OF JOINTS	2
NUMBER OF MEMBERS	1

NUMBER OF PLATES 0
NUMBER OF SOLIDS 0
NUMBER OF SURFACES 0
NUMBER OF SUPPORTS 2

SOLVER USED IS THE IN-CORE ADVANCED MATH SOLVER
TOTAL PRIMARY LOAD CASES = 2,
TOTAL DEGREES OF FREEDOM = 6
TOTAL LOAD COMBINATION CASES = 0

JOINT DISPLACEMENT (CM RADIANS) STRUCTURE

TYPE = SPACE

JOINT LOAD X-TRANS Y-TRANS Z-TRANS X-ROTAN Y-ROTAN Z-ROTA
1 1 0.0000 0.0000 0.0000 0.0000 0.0000 -0.0008
2 0.0000 0.0000 0.0000 0.0000 0.0000 -0.0603
2 1 0.0000 0.0000 0.0000 0.0000 0.0000 0.0008
2 0.0000 0.0000 0.0000 0.0000 0.0000 0.0603
STAAD SPACE
SUPPORT REACTIONS -UNIT KN METE
STRUCTURE TYPE = SPACE

JOINT LOAD FORCE-X FORCE-Y FORCE-Z MOM-X MOM-Y MOM Z

1 1 0.00 0.80 0.00 0.00 0.00 0.00
2 0.00 40.00 0.00 0.00 0.00 0.00
2 1 0.00 0.80 0.00 0.00 0.00 0.00
2 0.00 40.00 0.00 0.00 0.00 0.00
STAAD SPACE

MEMBER END FORCES STRUCTURE TYPE = SPACE

ALL UNITS ARE -- KN METE (LOCAL)

MEMBER LOAD JT AXIAL SHEAR-Y SHEAR-Z TORSION MOM-Y MOM-Z

1 1 1 0.00 0.80 0.00 0.00 0.00 0.00
2 0.00 0.80 0.00 0.00 0.00 0.00
2 1 0.00 40.00 0.00 0.00 0.00 -0.00
2 0.00 40.00 0.00 0.00 0.00 -0.00

********** END OF LATEST ANALYSIS RESULT **********

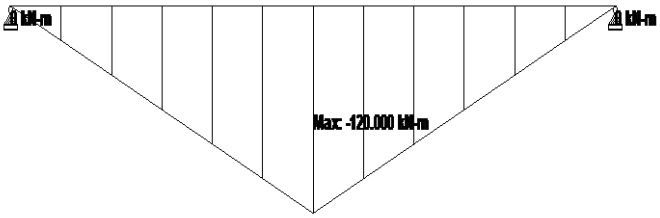


Fig.7 Bending moment diagram (from STAAD)

Maximum Bending moment through STAAD-Pro results = 120kN-m

5.3 Plastic Analysis Resultfrom Python programming

Load factor = 1.75
Plastic Moment = 105 kN-m

5.4Manual Results

Load factor = 1.75
Plastic Moment = 105kN-m

Table 1 Comparison of results

The results tabulated below gives the results for different cases worked out.

Sl. No	Manual (kN-m)	STAAD-Pro (kN-m)	Python (kN-m)
1	120	120	105
2	82.23	82,23	70
3	145.74	145.74	131.25
4	74.68	74.68	61.25

4.5 Flow Chart of Program

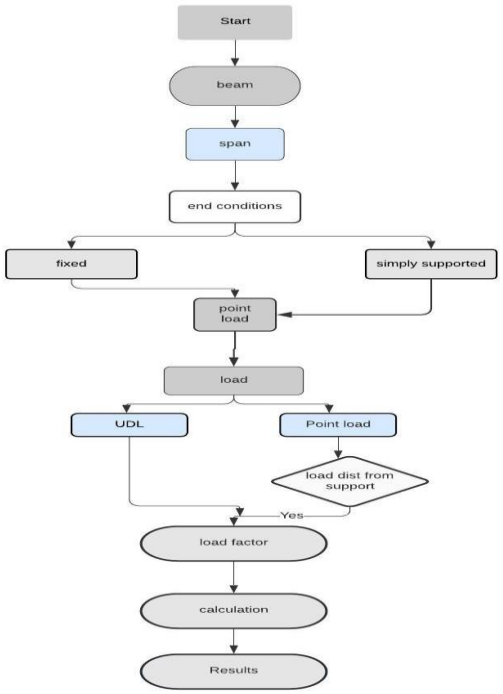


Fig. 8Python program 3.9 software version

The results which are getting from software calculation is more accurate than the manual calculation result.

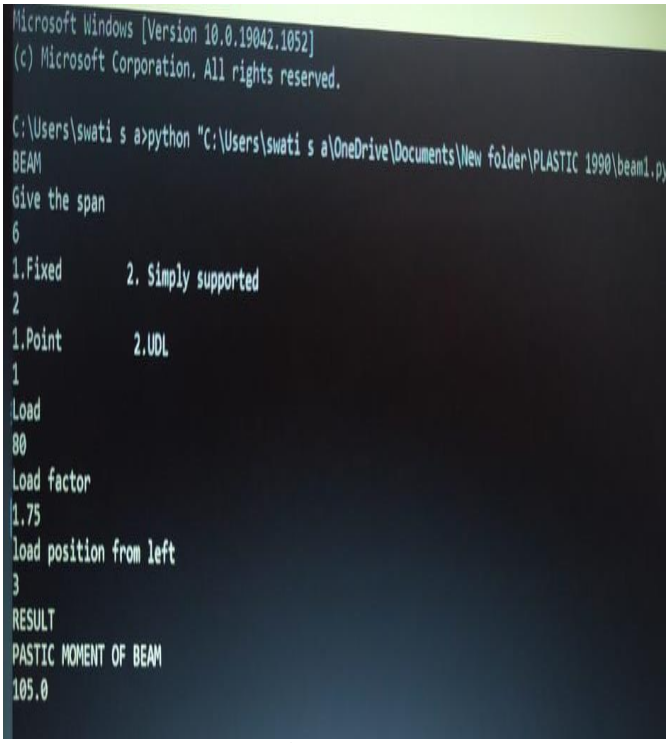


Fig.9 Results of python program on beam

6. CONCLUSIONS

The following conclusions can be drawn based on the work carried out

- An attempt is made to develop the software program by using python programming to get plastic moment.
- The elastic moments obtained by STAAD Pro and manual calculations are greater than the moments obtained by plastic analysis usingpython programming language and by manual calculations. From this we can say that, the steel sections by plastic analysis will be more economical than elastic analysis.
- Since the moment obtained with plastic analysis is less, hence the steel sections obtained in the design will be comparatively less, which lead in reduction of weight of steel.
- It is obviously true that the software takes less time compared to manual calculation. Hence by using python programming language, we get the plastic moments directly which avoids the tedious calculations if done manually.

7. REFERENCES

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