

# Response Spectrum Analysis of Tall Building using Python

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**Abstract:** *Response spectrum is a vital resource in the seismic analysis and design of structures. The accuracy and precision of the design becomes very important when it comes to big and tall structures. Therefore, over last few years a number of consulting structural engineers and construction firms have started using various user friendly software for carrying out such complex computations. We, through this paper, want to make an attempt to use programming language i.e. Python v3.7 for the dynamic analysis of a building using response spectrum method as per Indian standards 1893:2002: Part 1. A sequence of outcomes obtained are compared with the results obtained from ETABS.*

**Keywords-** *Structural Engineering; Response spectrum; Python; Etabs;*

## I. INTRODUCTION

Response spectrum is a tool having a vital role in the seismic analysis and design of structures. It describes the plots of maximum responses of a single degree of freedom system to a particular input motion at different natural periods. Response spectrum analysis is a condition that favors considering the frequency effects and provides a single suitable horizontal force for the design of structure. The basis of engineering seismology is the need to quantify how a given structure responds to complex ground motions. The structure's response is computed by its mass and stiffness distributions. The response spectrum method (RSM) was mentioned for the first time in 1932 in the doctoral dissertation of Maurice Anthony Biot at Caltech, US. It is an avenue of approach finding earthquake response of structures with the use of waves or vibration mode shapes. The mathematical principles of oscillations in n-degree-of-freedom systems were taken into consideration from the theories of acoustics developed by Rayleigh. Biot stated that a building has a certain number of so called normal modes of vibration, and to each of them corresponds a certain frequency. Biot took the effective use of Fourier amplitude spectrum to compute the maximum amplitude of motion of a system. Response spectrum method is useful in seismic study because it is a simple method making use of maximum values of stresses in design. It can be well used in conjunction with the mode. superposition method. The concept of mode superposition became relevant because of response spectrum.

Looking back at the previous work done linking Python with earthquake analysis, surprisingly there is almost none to the best of the information collected by the authors. However the usefulness of Python in static designing structures such as retaining walls are available. Shashank Bisen, through his paper made an attempt to use programming languages to make calculations for the design of retaining wall. However there has been none in earthquake resistant design and obviously in response spectrum analysis design also. Therefore the present work is taken up because, the paper is almost first of its kind in response spectrum analysis design. Even the detailed algorithm is given to facilitate the readers to make use of the code

## II. ABOUT THE PROGRAMMING LANGUAGE: PYTHON

Python is an elucidated high-level programming language for general-purpose programming in all field of engineering. It was coined and developed by Guido van Rossum in 1991. Python has a design philosophy that allows code readability, and a syntax allowing programmers to design and develop concepts in fewer lines of code, notably using significant whitespace. Python highlights a dynamic type system and automatic memory management. It supports multiple programming paradigms with object- oriented, imperative, functional, procedural, and facilitates huge as well as comprehensive standard library. Python interpreters are available for various operating systems. CPython is organised by the non-profit Python Software Foundation. Like many fields of engineering, the various branches of civil engineering also incorporate data science applications therefore Python becomes the most approved programming language in data science.

## III. APPLICATION OF PYTHON – IN CIVIL ENGINEERING:

Like many fields of engineering, Civil engineering also involve in data science applications. Python is the most popular programming language in data science. The applications of data science in civil engineering are as follows:

- Population forecasting for urban planning, water supply & sewerage system.
- Risk assessment and mitigation such as prediction of floods, earthquakes, cyclones.

- Structural Health Monitoring
  - To predict traffic trends in Highway engineering.
  - Soil simulation and modelling in Geotechnical engineering.
  - Finite element (FEM) applications in Structural engineering.
  - Construction management.
  - ML (Machine Learning) applications includes automation in structural design and drawings.

Python has also made its application in civil engineering for automation tasks like calculating bending moment, shear force, reactions at supports, you can use IS 456:2000 or any codes books as a module and can be used to refer while designing complex problems like analysis of multi-storey buildings, lot more can be done using Python. The world is changing fast and dynamically due to many factors. Artificial Intelligence & Machine Learning, dominates all branches of engineering and more in Civil engineering. We should be ready for the next big challenge - automation in the Civil engineering industry.

#### IV. OBJECTIVES:

This study is focused on bringing out advantages of using PYTHON over current practices of computations for different parameters.

A comparative study has been carried out for scrutinizing the results obtained during the analysis of various parameters of the structure from PYTHON along with those from manual as well as from ETABS.

#### V. METHODOLOGY

The work under consideration is focused on the response spectrum analysis of tall buildings using a programming language- PYTHON v3.7. Herewith we consider the analysis of a G+9 story building where the spacing of the frame is 6m along x-direction and 3.75m along y-direction.

Analysing the data:

Following data are used in the analysis:

##### Section Properties:

- Size of beam: 230×450mm.
- Size of column: 230×600mm.
- Depth of Slab: 150mm.
- Thickness of wall: 150mm

##### Storey Properties:

- Height between the floors: 3.5m.
- Number of storey: 10.

##### Load :

- Live load on each floors: 3kN/m<sup>2</sup>.
- Load on roof: 1.5kN/m<sup>2</sup>.

**Super dead load:** 1kN/m<sup>2</sup>

##### Concrete Properties :

- Density of Concrete: 25kN/m<sup>3</sup>.
- Density of infill: 20kN/m<sup>3</sup>.
- Concrete Grade: M20.

##### Plan Details :

**Length of plan:** 24m

**Breadth of plan:** 7.5m

**Number of columns:** 15

**Grids along X-axis:** 3

**Grids along Y-axis:** 5

**Type of soil:** Hard.

**Zone Type:** IV

**Building Type:** SMRF

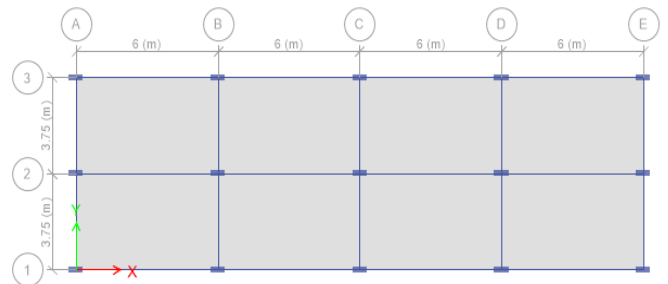


Fig.1. Plan of the building

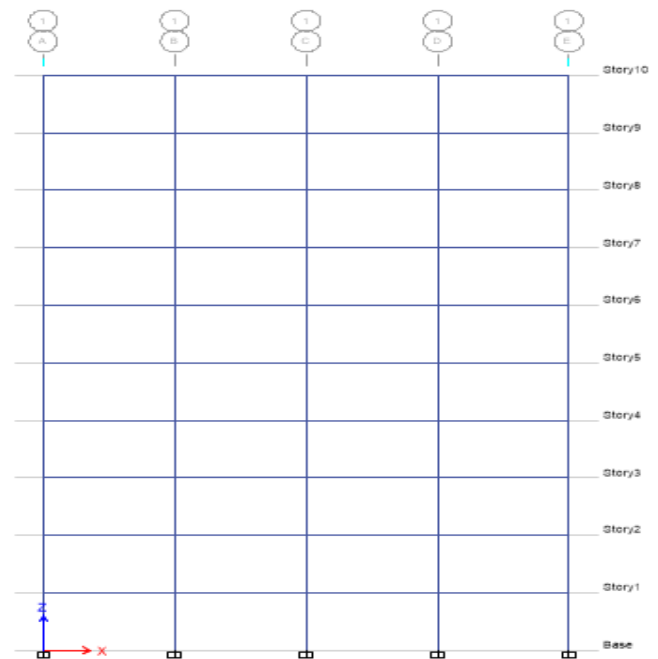


Fig.2. Elevation of the building



- B = Breadth of beam
- D = Depth of beam
- b = Width of column
- d = Depth of column
- S = Slab thickness
- LL = Live load
- FF = floor finish load
- Dc = Density of concrete
- Dw = Density of brick
- tw = Thickness of wall
- fck = Grade of concrete
- L = Height of each storey
- Lp = Length of plan
- Bp = Breadth of plan
- N = Number of columns
- Nx = Number of grids along x
- Ny = Number of grids along y
- E = modulus of elasticity
- I = moment of inertia
- SL = Self weight of slab
- SWc = Self weight of column
- SWb = Self weight of beam
- Wl = Wall load
- IL = Imposed load
- m = Load on each storey
- m1 = Load on roof
- k = Column stiffness of each storey
- K = Stiffness matrix of lumped mass modeled structure
- M = Mass matrix
- $\omega^2$  = Natural frequency
- $\Phi$  = Modal vector
- Pk = modal participation factor of mode k
- Mk = modal mass of mode k
- g = acceleration due to gravity
- Qik = Lateral force at each floor in each mode
- Vik = Storey shear force in each mode
- Vi = Storey shear force due to all modes

- Fi = Lateral shear forces at each storey

## VII. RESULTS

The results for the assumed data are tabulated and compared using Python and Etabs along with manual calculations:

TABLE.1. NATURAL FREQUENCY OF VARIOUS MODES.

Natural Frequency (rad/s)	PYTHON	ETABS	MANUAL
$\Omega_1$	1.13	3.37	5.53
$\Omega_2$	1.39	4.16	6.61
$\Omega_3$	1.13	3.37	5.53
$\Omega_4$	1.13	3.37	5.53
$\Omega_5$	1.39	4.16	6.61
$\Omega_6$	1.13	3.37	5.53
$\Omega_7$	1.13	3.37	5.53
$\Omega_8$	1.39	4.16	6.61
$\Omega_9$	1.13	3.37	5.53
$\Omega_{10}$	1.13	3.37	5.53

TABLE.2. NATURAL TIME PERIOD OF VARIOUS MODES.

Natural Time Period (sec)	PYTHON	ETABS	MANUAL
T1	1.13	3.37	5.53
T2	1.39	4.16	6.61
T3	1.13	3.37	5.53
T4	1.13	3.37	5.53
T5	1.39	4.16	6.61
T6	1.13	3.37	5.53
T7	1.13	3.37	5.53
T8	1.39	4.16	6.61
T9	1.13	3.37	5.53
T10	1.13	3.37	5.53

TABLE.3. MODAL PARTICIPATION FACTOR

MODE	Modal participation factor		
	PYTHON	ETABS	MANUAL
1	138.86	127.75	138.86
2	29.75	27.37	29.75
3	35.97	33.09	35.97
4	4.46	4.103	4.46
5	23.48	21.60	23.48
6	-3.21	-2.95	-3.21
7	17.67	16.25	17.67
8	-7.14	-6.56	-7.14
9	12.14	11.16	12.14
10	-17.57	-16.16	-17.57

TABLE.5. SHEAR FORCE AT EACH STOREY

STORY	STORY SHEAR FORCE (kN)		
	PYTHON	ETABS	MANUAL
1	558.20	513.54	558.20
2	365.06	335.85	365.06
3	332.12	305.28	332.12
4	310.98	286.10	310.98
5	297.77	273.94	297.77
6	311.43	286.51	311.43
7	280.10	257.69	280.10
8	282.60	260.00	282.60
9	286.40	263.48	286.40
10	292.60	269.19	292.60

TABLE.4. MODAL MASS

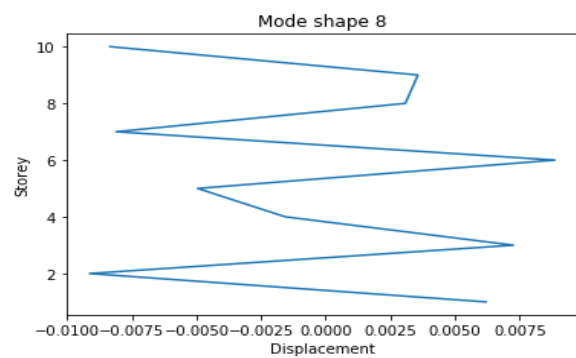
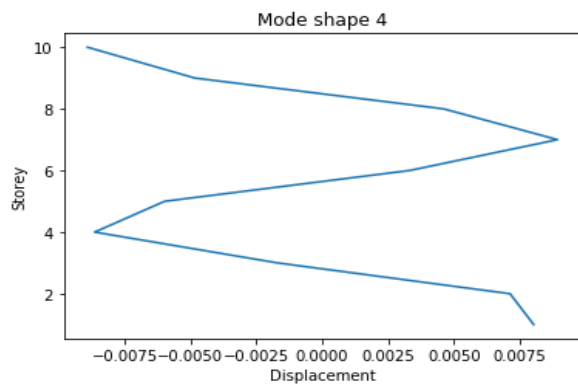
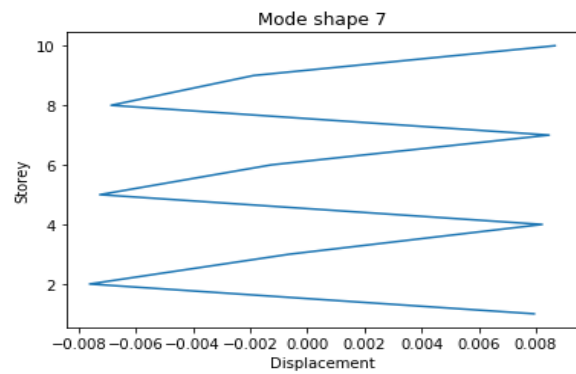
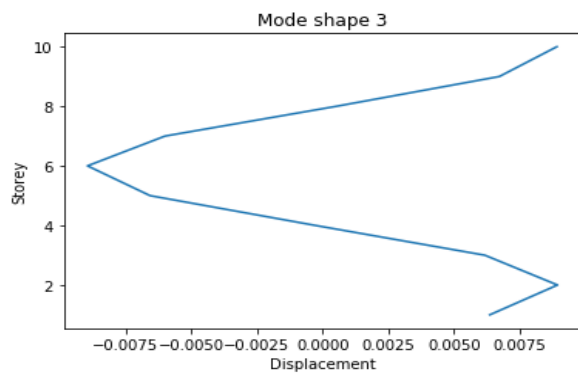
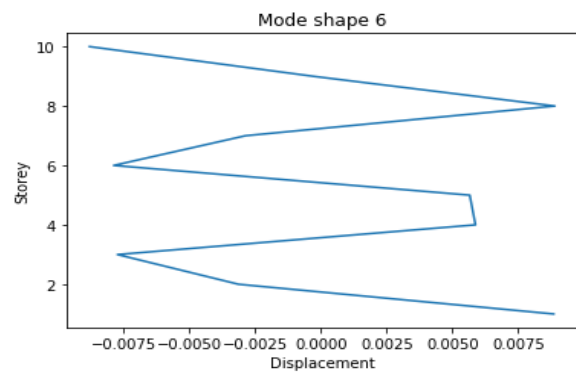
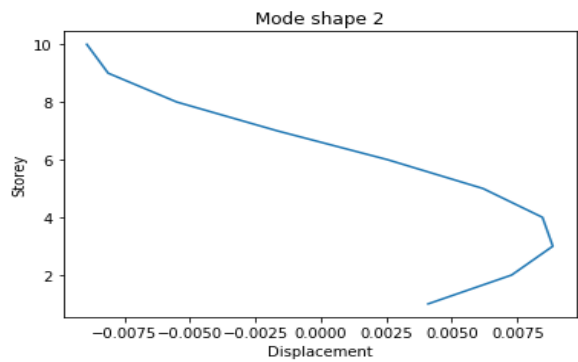
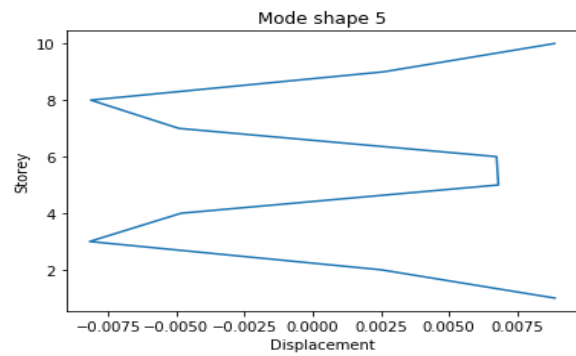
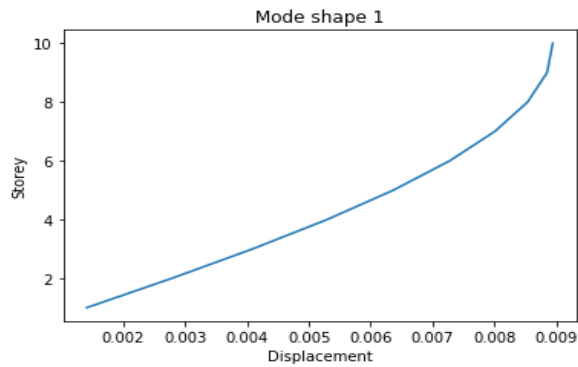
MODE	MODAL MASS		
	PYTHON	ETABS	MANUAL
1	2199.16	2018.23	2199.16
2	100.95	92.87	100.95
3	147.56	135.75	147.56
4	2.26	2.08	2.26
5	62.76	57.73	62.76
6	1.17	1.076	1.17
7	35.38	32.55	35.38
8	5.74	5.28	5.74
9	16.18	14.88	16.18
10	45.22	41.60	45.22

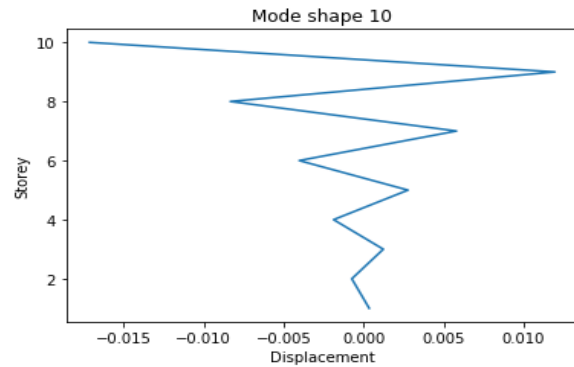
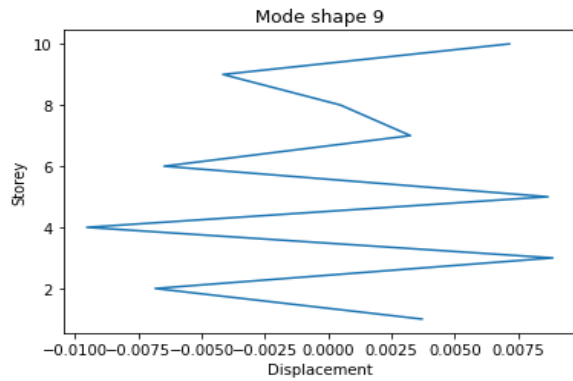
TABLE.6. LATERAL FORCE AT EACH STOREY

STORY	LATERAL FORCE AT EACH STOREY		
	PYTHON	ETABS	MANUAL
1	193.104	177.65	193.104
2	32.94	30.30	32.94
3	21.14	19.44	21.14
4	13.21	12.15	13.21
5	-13.66	12.56	-13.66
6	31.33	28.82	31.33
7	-2.50	-2.32	-2.50
8	-3.80	-3.49	-3.80
9	-6.20	-5.71	-6.20
10	292.60	267.18	292.60

### VIII. GRAPHS OF EACH MODE SHAPE:

For above tabulated results the mode shapes are plotted against displacement versus each storey:





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