24-650 Applied Finite Element Analysis
Assignment 7

submitted by

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Objective

The goal of this assignment is to perform an analysis of a masonry chimney. The results are:

Maximum Displacement: 1368mm

Safety Factor = 0.065783, so it will **collapse** since much less than 1.

Assumptions and Loading Conditions

1) The masonry chimney is made of concrete material: E=30,000 MPa, Poisson's ratio = 0.18, Ultimate Tensile Strength = 5 MPa.
2) Assume the pressure wave impacts exactly 2 surfaces on one side of the chimney.
3) The pressure wave is indicated below:

t (sec)	p (MPa)
0.0	2.00
0.1	1.36
0.2	0.78
0.3	0.32
0.4	0.10
0.5	0.00
0.6	-0.06
0.7	-0.10
0.8	-0.08
0.9	0.00

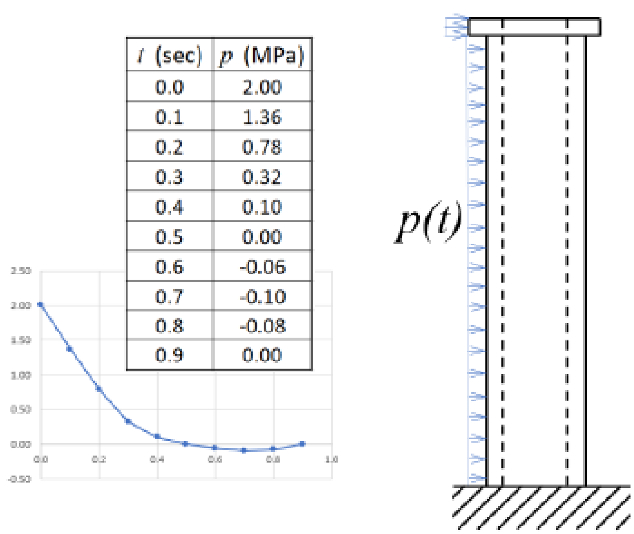
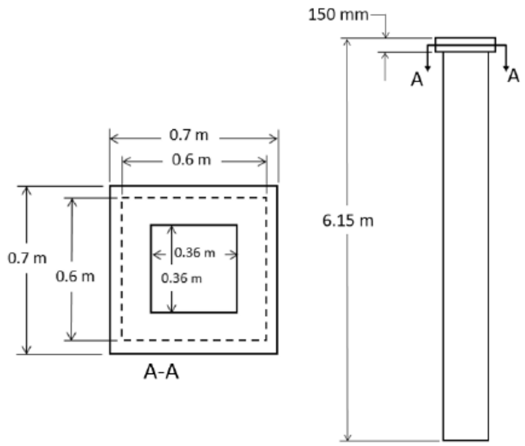


Figure 1. Pressure distribution.

Model



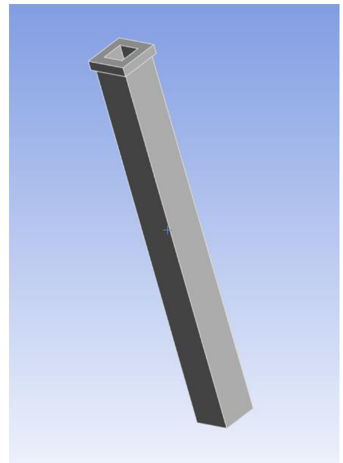


Figure 2. The geometry of the chimney.

Boundary Conditions

The boundary conditions of support on bottom of the pin is indicated below.

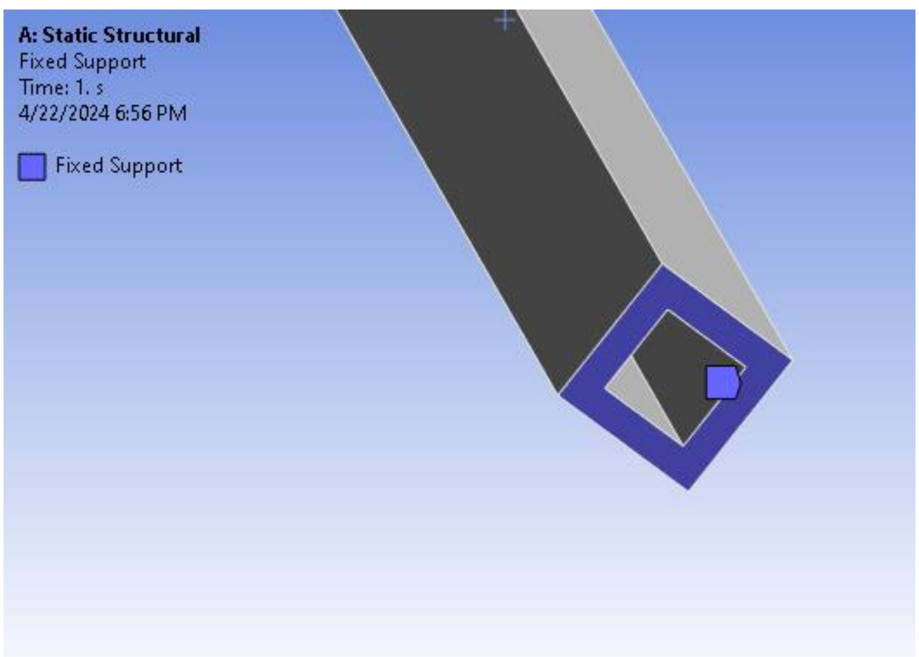


Figure 3. Fixed Support BC

Modal analysis - Analysis Settings

For model analysis, the maximum of modes has been selected to **22**, since mode of 20 can guarantee the ratio of effective mass is above 90%, with some extra safety margin of 2.

Details of "Analysis Settings"

Options	
Max Modes to Find	22
Limit Search to Range	No
On Demand Expansion Option	Program Controlled
-- On Demand Expansion	No
Solver Controls	
Damped	No
Solver Type	Program Controlled
Rotordynamics Controls	
Advanced	
Output Controls	
Analysis Data Management	

20	723.63	6.8214e-008	3.2285e-002	1.2369e-008	2.2216e-004	1.502e-008	2.2183e-004
Sum		0.94706	0.93172	0.94698	0.99937	0.94806	0.99937

Figure 4. Modal analysis settings

(As indicated above, modal of 20 is capable to maintain a ratio with minimum of 93%, so modal of **22** is selected to add some extra margin)

Harmonic analysis - Analysis Settings

For model analysis, the pressure force has been applied (see in figure below):

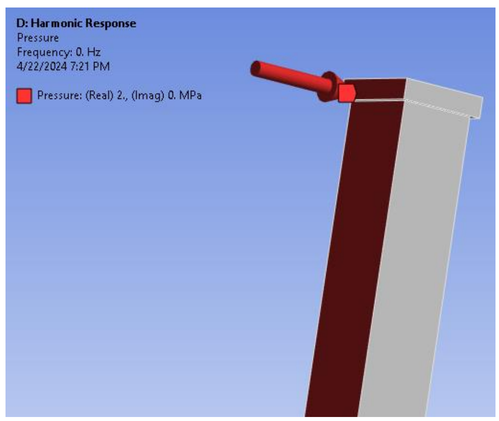


Figure 5. Pressure force.

And the maximum frequency range has set to 300Hz, to include any frequency in the first 10 mode from modal analysis, with the damping set to indicated value (3%):

Details of "Analysis Settings"

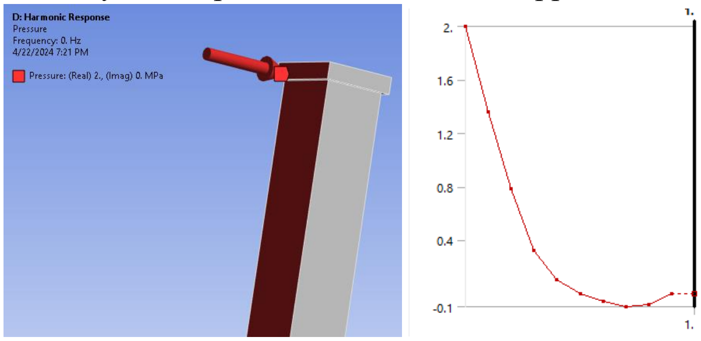
Step Controls	
Multiple Steps	No
Options	
Frequency Spacing	Linear
Range Minimum	0. Hz
Range Maximum	300. Hz
Solution Intervals	200
User Defined Frequencies	Off
Solution Method	Mode Superposition
Include Residual Vector	No
Cluster Results	No
Modal Frequency Range	Program Controlled
On Demand Expansion Option	Program Controlled
-- On Demand Expansion	No
Store Results At All Frequencies	Yes

Output Controls	
Damping Controls	
Eqv. Damping Ratio From Modal	No
Damping Define By	Damping Ratio
Damping Ratio	3.e-002
Stiffness Coefficient Define By	Direct Input
Stiffness Coefficient	0.
Mass Coefficient	0.
Analysis Data Management	

Figure 6. Harmonic analysis settings.

Transient structural analysis - Analysis Settings

For model analysis, the pressure force has been applied, with tabular data (see in figure below):



	Steps	Time [s]	Pressure [MPa]
1	1	0.	2.
2	1	0.1	1.36
3	1	0.2	0.78
4	1	0.3	0.32
5	1	0.4	0.1
6	1	0.5	0.
7	1	0.6	-6.e-002
8	1	0.7	-0.1
9	1	0.8	-8.e-002
10	1	0.9	0.
11	1	1.	= 0.

Figure 7. Pressure force.

Step Controls	
Number Of Steps	1.
Current Step Number	1.
Step End Time	1. s
Auto Time Stepping	Off
Define By	Time
Time Step	1.e-003 s
Time Integration	On

Damping Controls	
Eqv. Damping Ratio From Modal	No
Damping Ratio	0.
Stiffness Coefficient Define By	Damping vs Frequency
-- Frequency	10. Hz
-- Damping Ratio	3.e-002
Stiffness Coefficient	9.5493e-004
Mass Coefficient	0.
Numerical Damping	Program Controlled
Numerical Damping Value	0.005

Figure 8. Transient analysis settings.

For the time step controls, the final value of 1e-3 has been applied after convergence study, the convergence study will be introduced in the results section. As for the damping controls, the damping ratio of **3% @ 10.4Hz** is selected from the first mode in the modal analysis. Also, the safety factor will be investigated, and the configuration is indicated below:

Definition	
Theory	Max Tensile Stress
Stress Limit Type	Tensile Ultimate Per Material

Figure 9. Safety factor configuration.

Mech Settings and Solution Convergence

The mesh setting **stays at default** in this project.

For frequency settings, the default value (**frequency intervels = 300**) gives the curve below, as one can see the curve is not smooth, and after the trading-off between computing time and convergence requirement, the **frequency intervels = 300** gives the most balanced result (converged to 4.52-4.73mm):

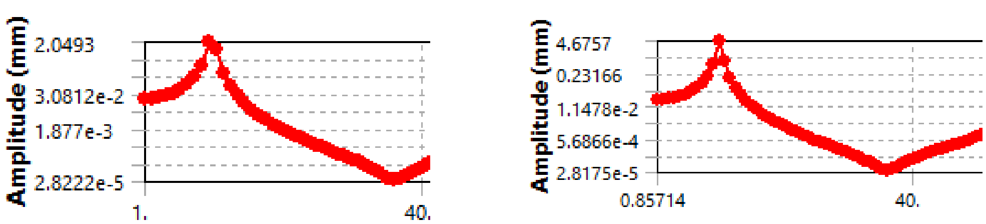


Figure 10. Freq. No. = 300 (left) Freq. No. = 350 (right), x-direction Amp.

For the time step settings, the default value (**time step = 0.1**) gives the curve below, as one can see the curve is not smooth, and after the trading-off between computing time and convergence requirement, the time step of **1e-3** gives the most balanced result (converged to 1375-1395mm):

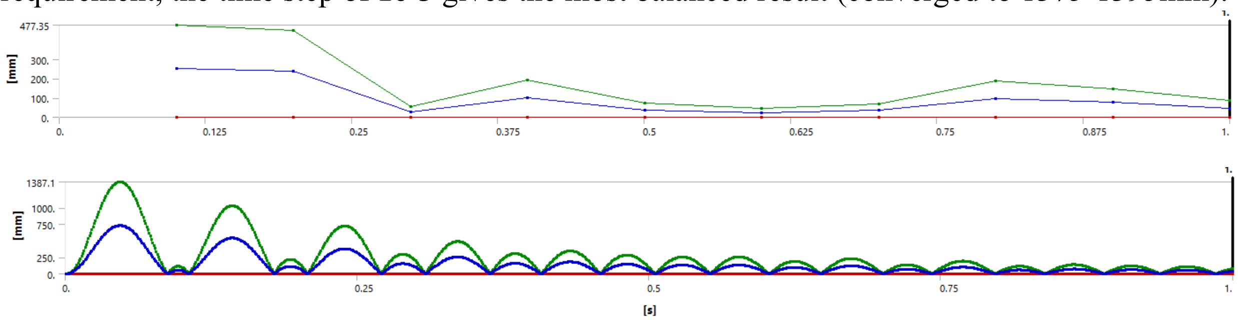
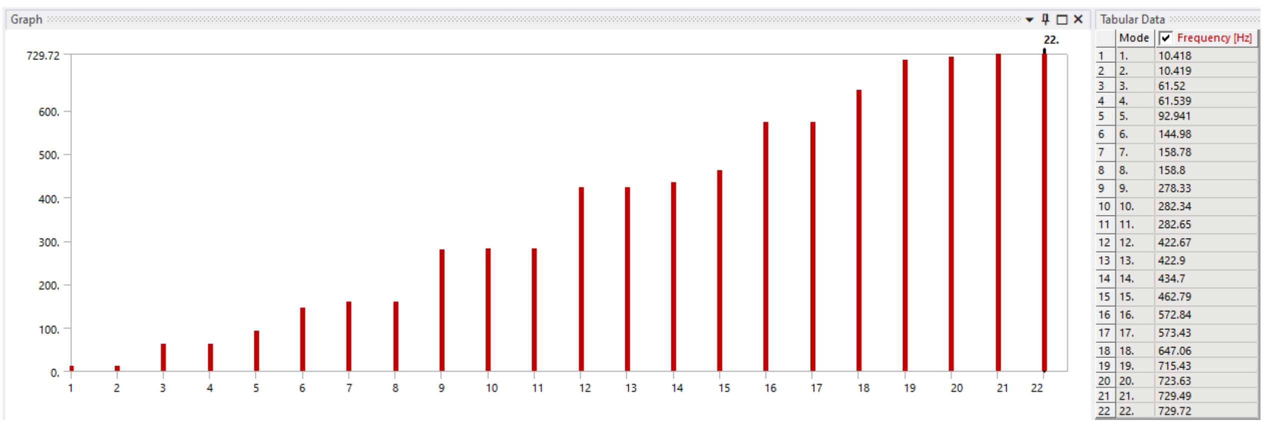


Figure 11. Time step = 0.1s (above) Time step = 1e-3s (below), total deformation.

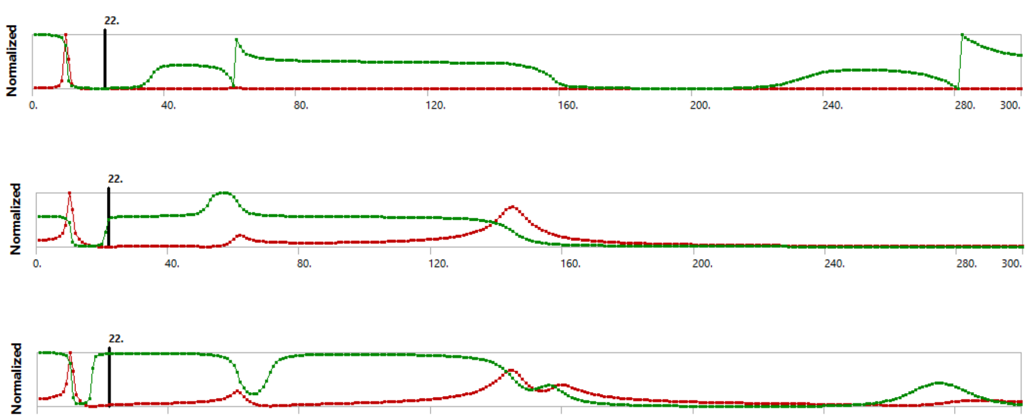
Results (Part A)



	Mode	Frequency [Hz]
1	1.	10.418
2	2.	10.419
3	3.	61.52
4	4.	61.539
5	5.	92.941
6	6.	144.98
7	7.	158.78
8	8.	158.8
9	9.	278.33
10	10.	282.34
11	11.	282.65
12	12.	422.67
13	13.	422.9
14	14.	434.7
15	15.	462.79
16	16.	572.84
17	17.	573.43
18	18.	647.06
19	19.	715.43
20	20.	723.63
21	21.	729.49
22	22.	729.72

Figure 12. Modal analysis result.

Results (Part B)



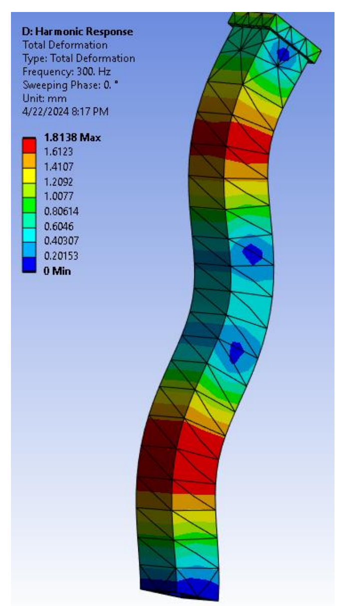


Figure 13. Deformation and normalized frequency response of X, Y, Z axis (top to bottom)

Results (Part C)

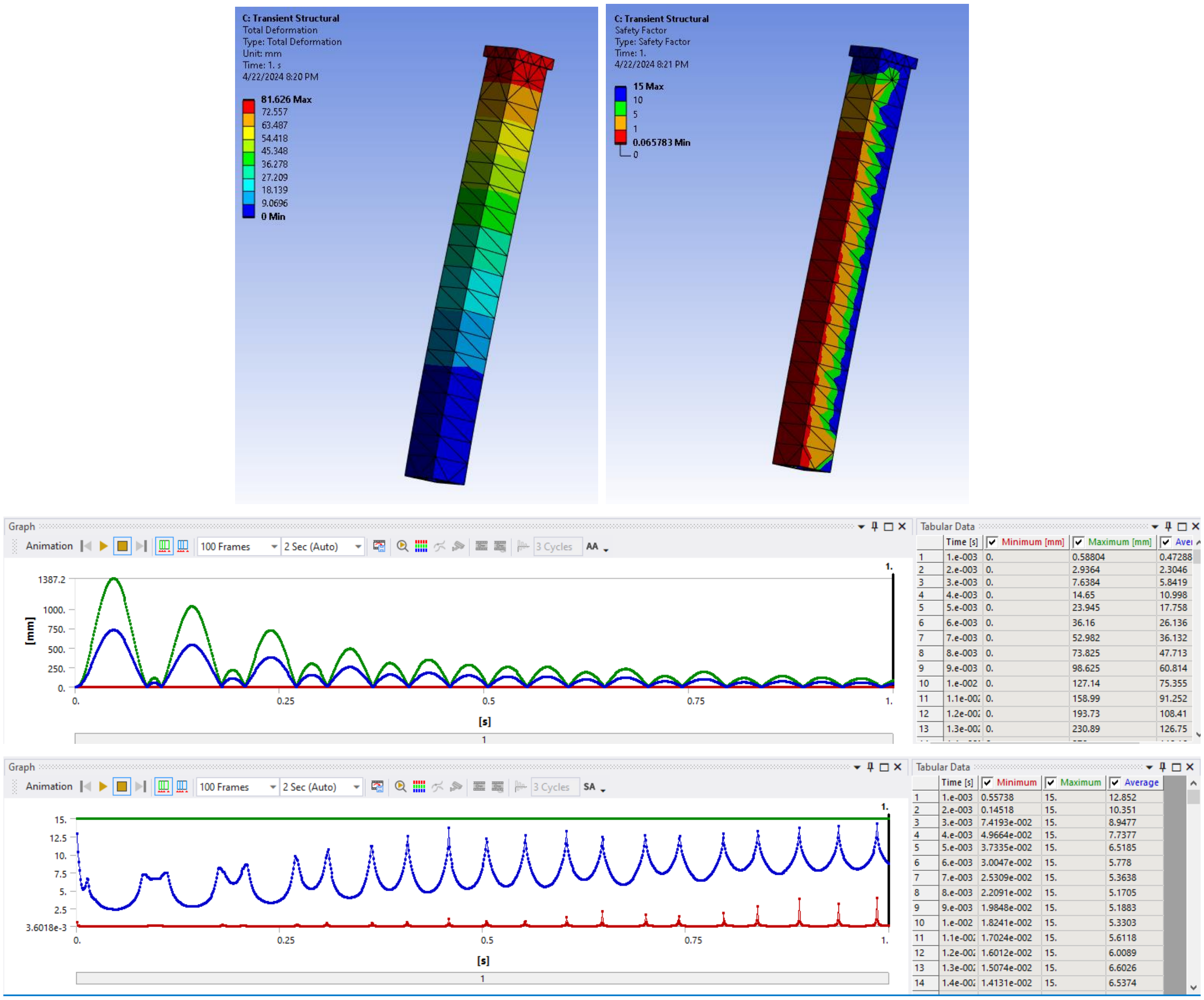


Figure 14. Deformation and safety factor under transient structural analysis

Conclusion

In this project, we conducted modal, harmonic, and transient analyses to comprehensively examine the dynamic behavior of the chimney structure.

These methodologies are crucial as they enable us to simulate and understand a wide array of real-world scenarios, particularly those characterized by transient conditions.

Furthermore, the convergence study, including selection of appropriate time steps and frequencies, along with trading-off computing time and accuracy, plays a significant role in the accuracy and reliability of these analyses.

This detailed approach allows for a more precise assessment of the chimney's response under various operational conditions, thereby ensuring its structural integrity and operational efficiency.