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Seismic Analysis of RC Chimney with Height to Base Diameter Variation with Fixed and Flexible Base Soil Conditions

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ABSTRACT Chimneys are usually designed for loads produced by seismic effect and wind. So, it is inevitable to analyse the dynamic response of chimney due to effect of earthquake and wind loads. On account of changes in geometry of the chimney, structural analysis such as response to earthquake becomes more critical. The seismic performance of reinforced concrete chimney is influenced by various factors, including their height-to-base ratio, base soil conditions of the region. This study focuses on the seismic analysis of reinforced concrete chimneys, considering the effects of height-to-base variation and both fixed and flexible base soil conditions. The prime focus of this study is to conduct the seismic analysis of a reinforced concrete chimney. The analysis begins by selecting representative seismic zones with differing ground motion intensities. Chimney with varying height-to-base ratios are considered, as this parameter significantly affects their dynamic behaviour during seismic events. Two types of base conditions are studied: fixed base, where the chimney is rigidly connected to underlying soil, and flexible base, which accounts for the interaction between the chimney and the soil. The main purpose is to study the effect of various parameters like different soil conditions of the chimney on the seismic performance of the structure and compare parameters such as lateral displacement, Base shear values, time period values. Ultimately, this research aims to enhance the safety and resilience of reinforced concrete chimney with varying height-to-base ratios and different soil conditions.

KEYWORDS: RC chimney, seismic analysis, height-to-diameter ratio, ETABS, flexible base, fixed base, soil conditions.

I. INTRODUCTION

A chimney is an architectural ventilation structure made of masonry, clay or metal that isolates hot toxic exhaust gases or smoke produced by a boiler, stove, furnace, incinerator, or fireplace from human living areas. Chimneys are typically vertical, or as near as possible to vertical, to ensure that the gases flow smoothly, drawing air into the combustion in what is known as the stack, or chimney effect. The space inside a chimney is called the flue. Chimneys are adjacent to large industrial refineries, fossil fuel combustion facilities or part of buildings, steam locomotives and ships. The seismic analysis of reinforced concrete chimney is crucial due to their increasing height and vulnerability to seismic forces. This study examines the impact of varying height-to-base diameter ratios under both fixed and flexible base soil conditions. As industrialization grows, the design of tall RC chimneys must account for seismic loads, which can significantly affect structural integrity. The analysis employs methods like Response Spectrum and Time History to evaluate displacement, base reactions, and moments, ensuring that these structures can withstand dynamic loads effectively. The height of a chimney influences its ability to transfer flue gases to the external environment via stack effect. Additionally, the dispersion of pollutants at higher altitudes can reduce their impact on the immediate surroundings. The dispersion of pollutants over a greater area can reduce their concentrations and facilitate compliance with regulatory limits. Chimneys are typically vertical or as near as possible to vertical, to ensure that the gases flow smoothly, drawing air into the combustion. Chimneys are constructed as tall as possible. The height of a chimney influences its ability to transfer flue gases to the external environment. Industrial chimneys are commonly referred to as flue gas stacks and are generally external structures. They are generally located adjacent to a steam generating boiler or industrial furnace and the gases are carried to them with ductwork. Construction of such tall chimneys needs the better understanding of loads acting on them and of the structural behaviour, so that with the help of modern construction equipment and technique such as slip form, reinforced concrete, the most favoured material for chimney construction, could be used efficiently. The proper design and construction of such chimneys will create self-standing structures to

resist wind load and other forces acting on them. It is a common practice to consider the effects of wind and earthquake separately in the design.

Objective of study:

1. To design of chimney structures studying seismic analysis.
2. To perform seismic analysis using ETABS software.
3. To study the effect of height to base diameter ratio on seismic parameter of chimney.
4. To study the effect of parameter various soil conditions on the seismic performance of the structure.
5. To study the response of RCC chimney subjected to seismic forces with rigid and flexible foundation.

II. METHODOLOGY

Table No: 1 Model Details

| Sr. No. | Design Member | Value | Unit |
|---------|------------------------------|---------------|-------------------|
| 1 | Self-weight of the structure | 20 | kN/m ³ |
| 2 | Height of chimney | 140, 180, 220 | Meter |
| 3 | Diameter at Bottom | 20 | Meter |
| 4 | Thickness of shell at Bottom | 0.5 | Meter |
| 5 | Thickness of shell at Top | 0.5 | Meter |
| 6 | Grade of concrete | M40 | N/mm ² |
| 7 | Grade of steel | FE-550 | N/mm ² |
| 8 | Size of Columns | 600 X 600 | mm ² |
| 9 | Size of Beam | 600 X 600 | mm ² |
| 11 | Foundation Type | RCC PAD | ----- |
| 12 | Poissons ratio | 0.2 | ----- |
| 13 | Modulus of Elasticity | 31622.78 | MPA |
| 14 | Seismic Zone | IV | ----- |
| 15 | Zone factor, Z | 0.24 | ----- |
| 16 | Response modification factor | 2.5 | ----- |
| 17 | Importance factor IP | 1.5 | ----- |
| 18 | Damping | 5 | % |
| 19 | Natural Time period | 2.4 | Sec |
| 20 | Soil Type | Medium, Soft | ----- |

TABLE NO: 2 H/D VARIATION

| MODEL | DETAIL | H/D |
|-----------------------------------|---------------------------|-----|
| Model 1- Fix and Flexible | 140 m Chimney Soft Soil | 7 |
| | 180 m Chimney Soft Soil | 9 |
| | 220 m Chimney Soft Soil | 11 |
| Model 2 - Fix and Flexible | 140 m Chimney Medium Soil | 7 |
| | 180 m Chimney Medium Soil | 9 |
| | 220 m Chimney Medium Soil | 11 |

Software Analysis and design procedure:

- Define Plan Grids and Story Data
- Define Material Properties
- Define Frame Sections
- Define Slab Sections
- Define Load Cases
- Draw Beam Objects (Frame Members)
- Draw Column Objects (Frame Members)
- Assign Slab Sections
- Assign Restraints
- Assign Slab Loads
- View Input Data in Tabular Form
- Run the Analysis
- View Analysis Results Graphically
- Design Concrete Frame Element

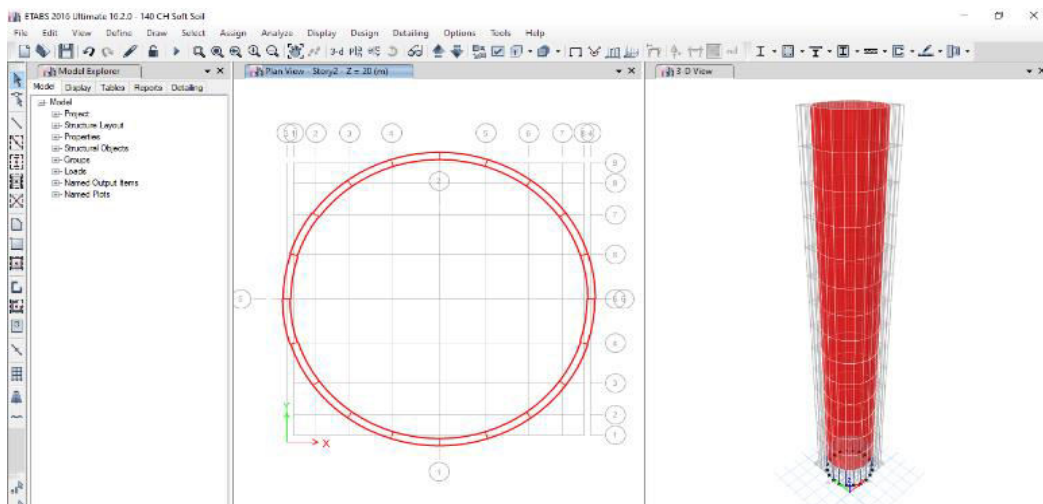


Figure No 1: 140 m Chimney with Fix Base

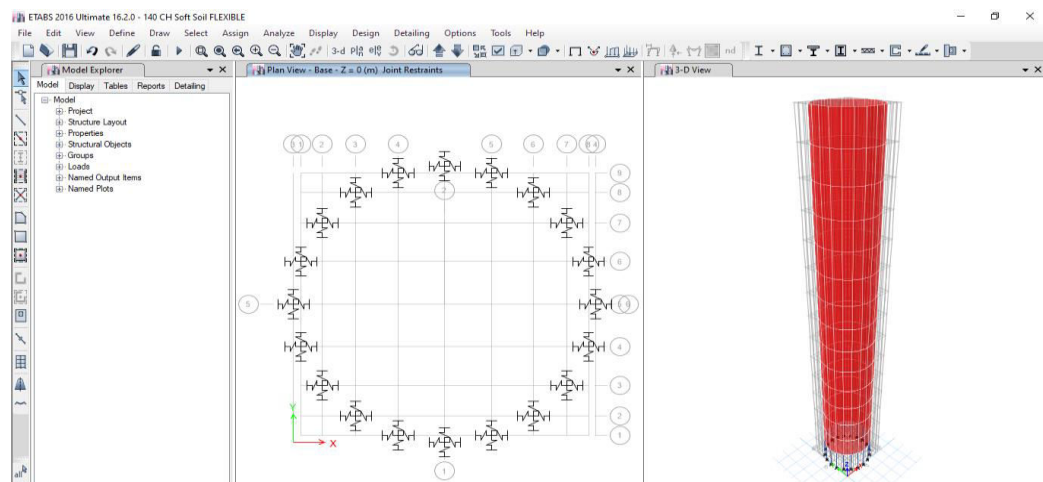


Figure No 2: 140 m Chimney with Flexible Base

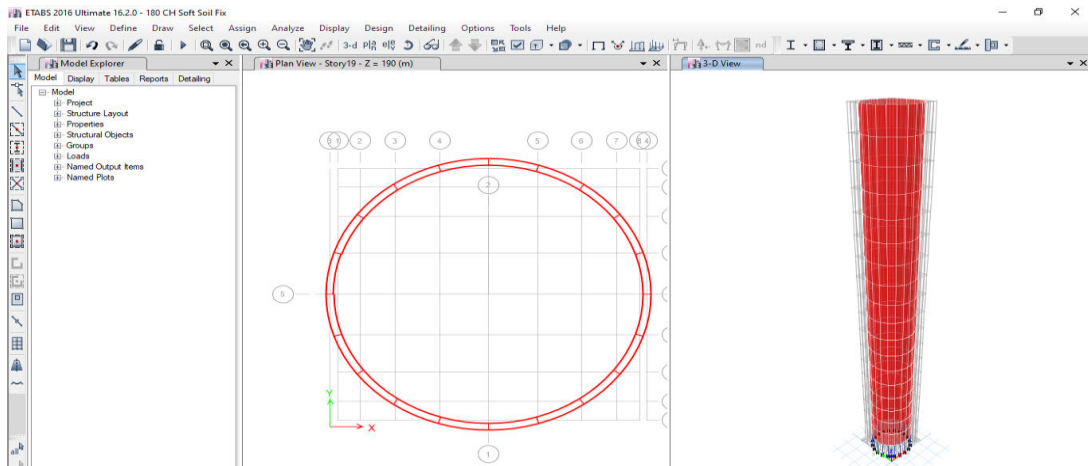


Figure No 3: 180 m Chimney with Fix Base

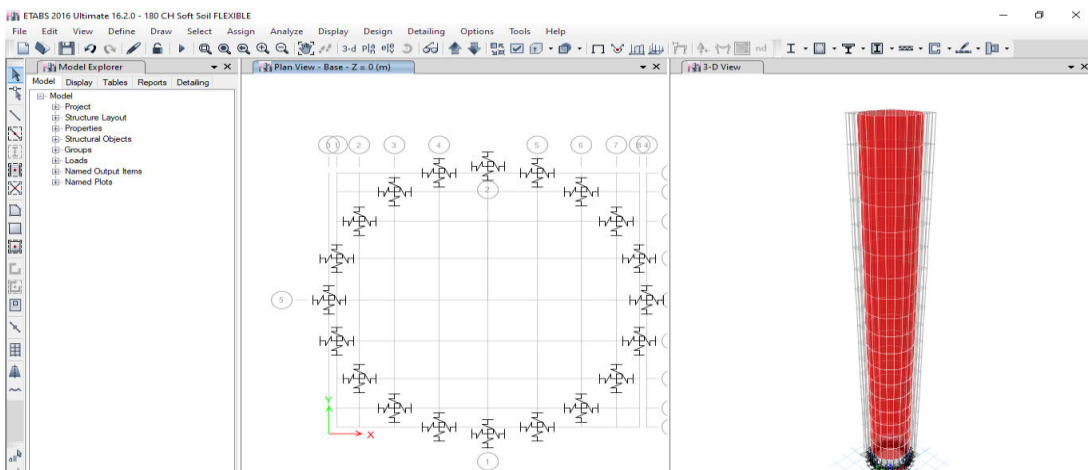


Figure No 4: 180 m Chimney with Flexible Base

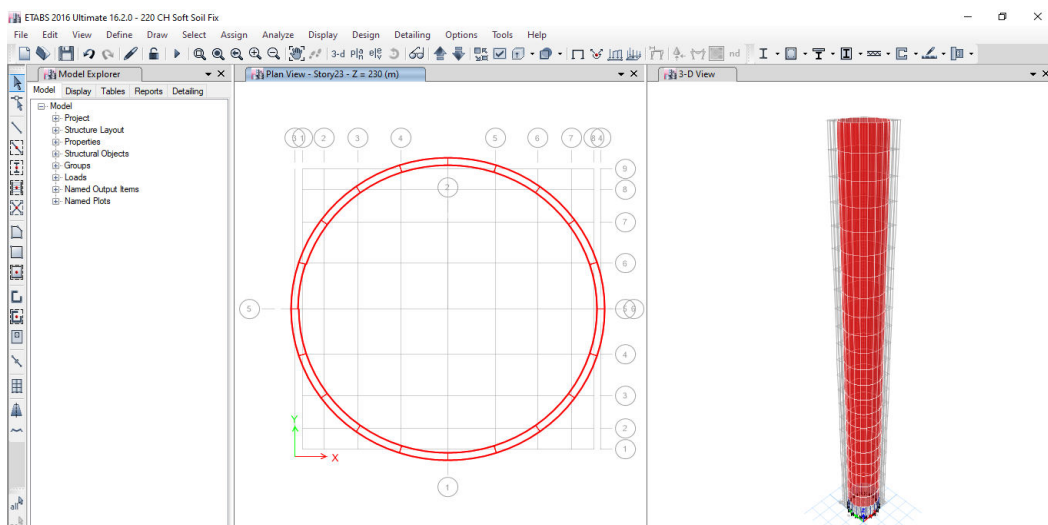


Figure No 5: 220 m Chimney with Fix Base

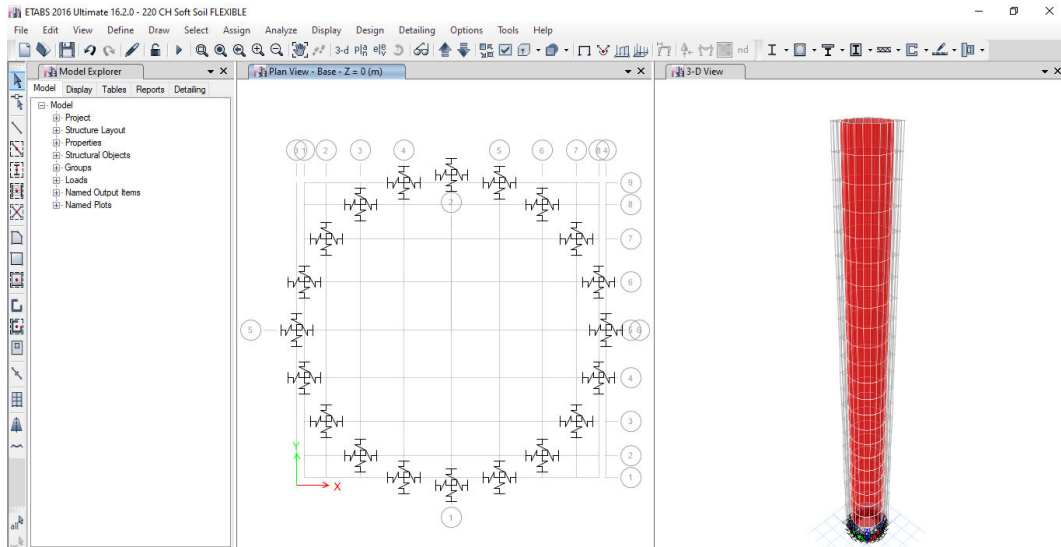


Figure No 6: 220 m Chimney with Flexible Base

III. RESULTS AND DISCUSSION

In the present study a RCC chimney of 140 m, 180 m and 220 m height subjected to the earthquake loads imposed in the seismic zone IV is considered for the analysis. The following are the details of the chimney considered. Seismic analysis is carried out by Response Spectrum analysis as per IS 1893:2002 and fixed and flexible base also analyzed in ETAB the result of all them are disused below with respect to the base shear, lateral deflection and time period.

I. Effect of Soil Condition of Chimney on Displacement (mm)

Table no 3: Effect of Soil Conditions of Chimney on Lateral Displacement (mm)

| SOIL | 140 FIX | 140 FLEXIBLE | 180 FIX | 180 FLEXIBLE | 220 FIX | 220 FLEXIBLE |
|--------|---------|--------------|---------|--------------|---------|--------------|
| SOFT | 616 | 625 | 1155 | 1232 | 2139 | 2448 |
| MEDIUM | 494 | 501 | 929 | 991 | 1726 | 1976 |

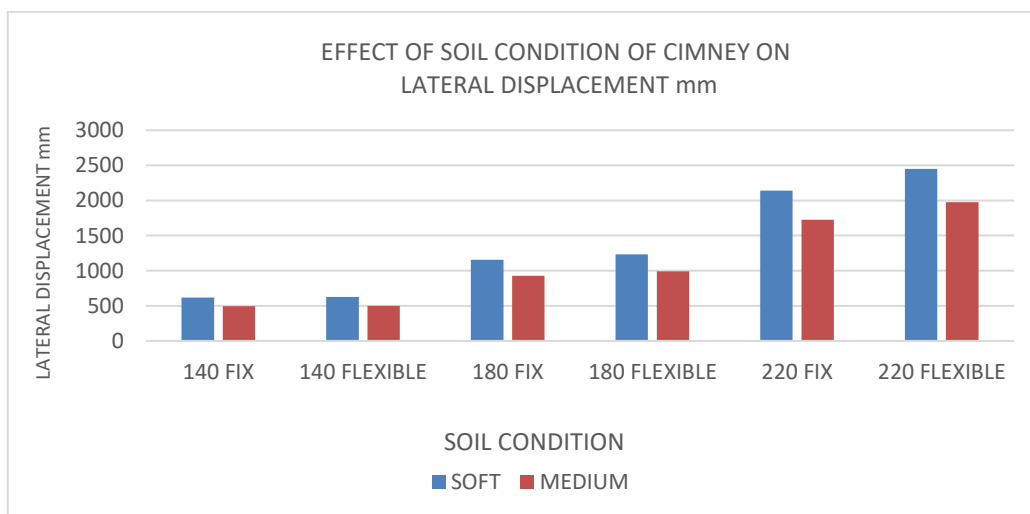


Figure No 7: Graphical representation of Effect of Soil Conditions of Chimney on Lateral Displacement

II. Effect of Soil Condition of Chimney on Time Period (Sec.)

Table No 4: Effect of Soil Conditions of Chimney on Time Period (Sec.)

| SOIL | 140 FIX | 140 FLEXIBLE | 180 FIX | 180 FLEXIBLE | 220 FIX | 220 FLEXIBLE |
|--------|---------|--------------|---------|--------------|---------|--------------|
| SOFT | 8.833 | 8.976 | 13.195 | 13.633 | 18.376 | 19.661 |
| MEDIUM | 8.833 | 8.976 | 13.195 | 13.633 | 18.376 | 19.661 |

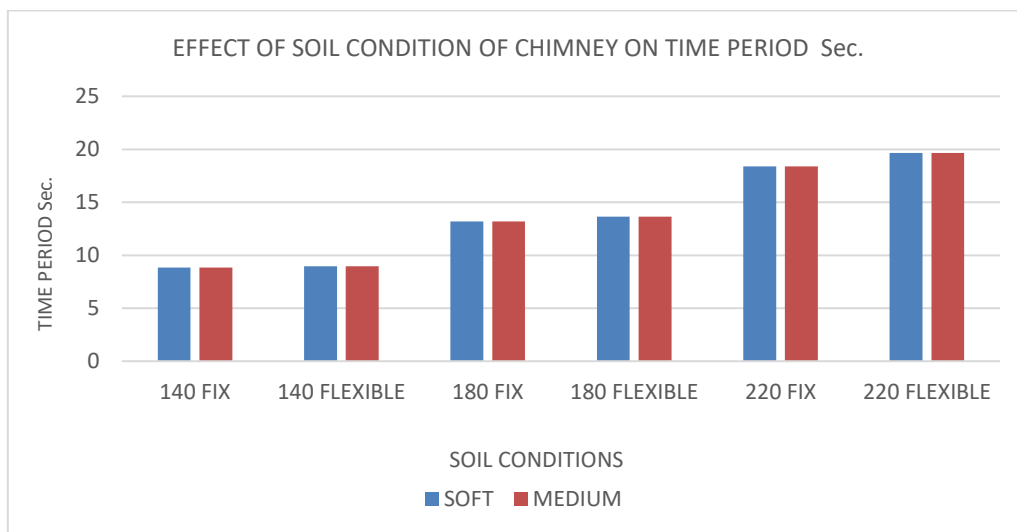


Figure No 8 : Graphical representation of Effect of Soil Conditions of Chimney on Time Period

III. Effect of Soil Condition of Chimney on Base Shear (kN)

Table No5: Effect of Soil Conditions of Chimney on Base Shear (kN)

| SOIL | 140 FIX | 140 FLEXIBLE | 180 FIX | 180 FLEXIBLE | 220 FIX | 220 FLEXIBLE |
|--------|---------|--------------|---------|--------------|---------|--------------|
| SOFT | 1438685 | 1437752 | 1888175 | 1887984 | 2366040 | 2365694 |
| MEDIUM | 1421422 | 1420662 | 1857392 | 1857236 | 2316472 | 2316190 |

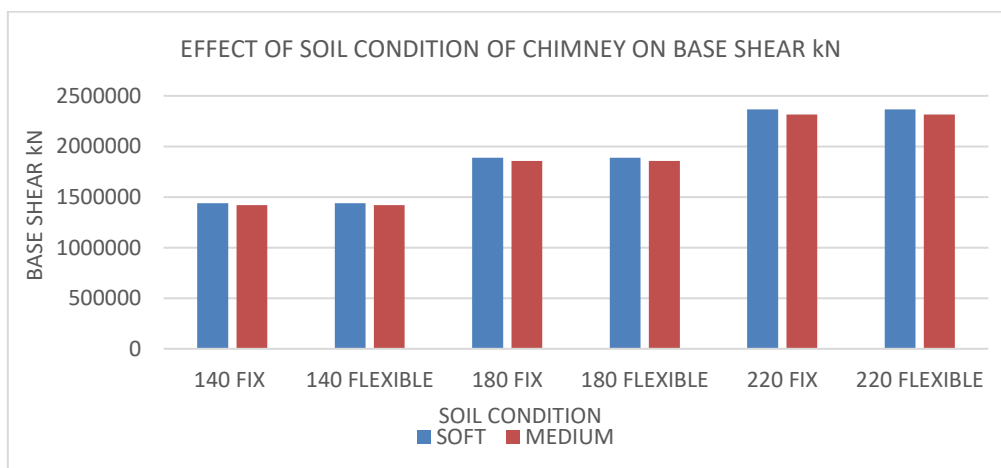


Figure No 9: Graphical representation of Effect of Soil Conditions of Chimney on Base Shear

IV. CONCLUSION

In this analysis Chimneys with fixed and flexible base subjected to seismic forces were analysed under different soil condition like medium and soft soil strata. Seismic response of tall chimneys is influenced greatly by soil supporting its base and nature of earthquake excitation's striking the base. The all results conclude by the following results.

1. For the analysis of the chimney model after applying the 20 m diameter and having 140 m, 180m, 220 m of height changing conditions, Displacements for soft and medium soil condition with having height 140 m,180m gives minimum displacement difference as compare to 220m by the 75-80%. As comparing the results for Time Period for soft and medium soil condition with having height 140 m,180m gives minimum Time Period difference as compare to 220m by the 70-85%. As comparing the results for Base Shear for soft and medium soil condition with having height 140m,180m gives maximum Base Shear difference as compare to 220m by the 50-60%. After analyzing the models it is conclude that models having heights up to 180m gives the economic results than the height of 220m in both soil conditions. The results of model after 180m height increased because of the 20m of diameter. For the analysis of models having height 180m suggest diameter of chimney more than 20m.
2. For the analysis of 140m, 180m, 220m, models after applying the soil changing condition as comparing results for medium and soft soil condition, Displacement values are notably higher on soft soils compared to medium soil due to lower stiffness, Base shear values increased when the types of soil changes from medium to soft, the reason for the changes in results are the increasing stiffness values for soft and medium soil condition.
3. After applying the Response Spectrum analysis on the fix and flexible base footing, Base shear are decreases that means it effects on the lateral force of the of the Flexible base structure, which is good for the design purpose. It also increases the time Periods and displacement of the Flexible base structure due to its spring stiffness. After analysing the all models the research concludes that flexible base is better than the fix base.

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