Analysis and Design of Silo by using STAAD PRO

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ABSTRACT- The concretes of flat bottom circular silos are often deployed to store materials in various industries, such as cement factories, power plants, oil and gas industries, etc. Silos are special designs, exposed to many different non-traditional conditions of loading, leading to unusual modes of failure. The failure of silo can be devastating because it can lead to loss of container, contamination of the material it contains, loss of material, cleansing, replacement of costs, environmental damage, & possible trauma or loss of life. The best designing of silo has helped in safe structure. Concrete can offer the protection of stored materials, requires little maintenance, aesthetically, and are relatively free of certain structural hazards, such as rubbing or because of the. In this work the silo is to be analyzed in the STAAD-PRO software, design of various of parts of the silo shall also be designed so that the economical approach shall be followed. The different parameters shall also be tested in evaluation & designing of silo.

Keywords- Silo, Staad-Pro, Shear force, Bending moment.

I. INTRODUCTION

1.1 INTRODUCTION OF STAAD PRO

Research Engineers International first created the structural designing & analysis software tool STAAD in 1997. Bentley Systems acquired It search Engineers at the end of 2005. In field of structural analysis and design, STAAD Pro ranks among the most popular software packages in the world. There are over 90 different jig codes that it may apply to metals, including steel, concrete, wood, and aluminum. From more conventional static analysis to more cutting-edge techniques like p-delta, geometric non-linear, Pushover, and buckling analyses, it may use a wide range of analytical methodologies. Additionally, it is capable of using a wide range of dynamic analysis methodologies. Both spectra generated by user and spectra specified by international codes are compatible with RSA capability

Automating structural engineers' work using STAAD Pro eliminates the need for time-consuming and laborious manual processes. On these digital platforms, civil engineers may study and plan a wide range of building kinds. Consulting businesses, structural engineering firms, government firms, and other building departments employee. You may get a comprehensive understanding of STAAD Pro, a popular design program, using any number

of online platforms and applications that provide certification in this area. An advanced degree is not required to understand this dynamic program; nevertheless, a Civil Engineering background is required to enroll in this course. It would be wise to read up on the course and see how other students rated it before signing up for this online class.

1.2 INTRODUCTION OF SILOS

- A silo is a tank for storing granular materials that is upright and built on higher ground with an entrance cut into the bottom to allow material to fall through.

- Bunkers and other similar storage structures are ideal for storing a wide variety of goods. The plane gap determines how silos and Hopper are categorized. In one case, a bin is referred to be a bunker if its layout causes the plane of the gap to cross the surface at its highest point; in another, silos are formed when the layout causes the plane of the gap to cross the opposite site of the building. Structures having a higher ceiling and a larger diameter, breathing room, or both are common placements for silos. In order to decrease lateral pressure at high altitude, the height/diameter ratio must be larger than or equal

to two, as stated in Code 4995 (part I): 1974.

- The silo often has a spherical base but may take on other shapes such as squares, rectangles, or polygons. Its roof and bottom might be flat, tapering, or pyramidal.

- It is common practice to use a beam ring to distribute the weight across the silos's columns, the overall structure wall, the hopper floor, and the number of columns. Vertical and horizontal pressure are the primary design considerations while building silos. A non-uniform pressure on the bottom of the hopper, which rises in comparison to the pressure due to gravity cargo, is the outcome of an earthquake study in which an increase in bending moment generates an increase in lateral load.

II. LITERATURE REVIEW

In (2016) Sachidanandam K, Jose B, Ravindra Raj conducted a study on "Behavior of Silos and Bunkers" in this study a practical approach to deciding pattern is required (mass flow or core flow), Measurements needed with powder properties Design models should be utilized, as per material being handled and the operational requirements of any given case 4 pressure sensors were installed in every one of the two ladder racks that made up the measurement system. From the base to top, they were arranged vertically along inside wall of silo. Load sensors, each with a thickness of less than 1 mm, were spaced 1.0 m apart on the rack, with first sensor positioned 0.05 m from base of the silo. F ollowing findings are derived from an extensive literature study conducted in the field. For silos with wall heights higher than 3 meters, the recommended guidelines for bunker and silo wall design likely exaggerate the pressures caused by silage.

They looked at what goes wrong with bunkers and silos and found that it's usually because to mistakes in design, manufacturing, or construction, as well as poor use or lack of maintenance. Concrete storage buildings are more cost-effective in design and construction than steel structures, according to previous study.

In (2016) Cholappanavar P. A conducted a study on "Parametric study of structural analysis, design and optimization of RC bunker through sequential linear programming" in this study C-program has been developed for the optimal design and analysis of Reinforced Concrete (RC) bunker for different capacities and for different bulk materials. The role of optimisation and its savings are highlighted in this paper.

Hence partial or approximate methods proposed by Janssen and Airy are usually adopted. Airy's solution depends on Coulomb's wedge theory of lateral earth pressure. According to this theory, horizontal compression per unit length of periphery and position of plane of rupture can be calculated. In the present paper, the horizontal pressure is estimated by Rankine's method. The bunker design by optimized dimension caused. Average saving on concrete quantity for various capacities of the bunker is 12.70

In (2017) Dharani K and Jayakumar D conducted a study on "Analysis and design of fly ash and bed ash silo for thermal power plant structures" in this study the detailed review on the performance and behavior of bunkers and silos, emphasizing the need for comprehensive understanding of their structural responses under different working and environmental conditions. According to their review, silos and bunkers are subjected to a wide range of loading scenarios, including dead load, live load, and pressures generated by the stored material itself. However, the more critical aspect arises during dynamic situations such as seismic events, where the lateral and vertical components of earthquake forces can significantly alter the stress distribution within the structural system. They highlighted that during filling and discharging of bulk materials, the pressure conditions inside the silo or bunker walls constantly change, and these fluctuating stresses can lead to non-uniform load distribution, localized overstressing, and sometimes progressive failure. The authors stressed that these conditions cannot be ignored, as they play a crucial role in determining the overall stability and safety of the structure.

In addition to loading conditions, Dharani K and Jayakumar D pointed out that failures of bunkers and silos frequently occur due to human and technical factors, such as inadequate design assumptions, fabrication errors, poor erection practices, and insufficient consideration of material flow properties during operation. They observed that improper understanding of material behavior, especially when dealing with ashes, powders, or granular materials, can lead to blockages, arching, and structural distress during discharge. Their review further emphasized that for a silo or bunker to achieve its intended durability and safety, all relevant factors—including seismic actions, wind loads, pressure variations due to material flow, construction quality, and operational requirements—must be carefully considered at the design stage itself. They concluded that only a holistic design and analysis approach that integrates both structural engineering principles and practical operational considerations can ensure the long-term reliability and efficiency of bunkers and silos.

In (2018) Mohammad Umair Salim, Hasan Khurshid conducted a study on "A Simplified Analysis and Design of Reinforced Concrete Circular Silos and Bunkers" Objective of the present investigation is to develop the design techniques from various sources to an integrated approach which can be used for a wider range of reinforced concrete silos. Analysis and design methods are summarized and approximated to ensure practical applicability of the efficient design of reinforced concrete silos.

Comparison of results of tangential forces, hydrostatic pressure, bending moments, shear force and reinforcement ratio in different parts of silo also indicates the fairly good agreement with FEM Model results concluded It encourages the use of the designed procedure for the optimum design of R.C. silos.

III. OBJECTIVES

Objectives of the present study are mentioned below:

- Structural Behavior Analysis: To study the structural behavior of silos under different load conditions such as dead load, live load, wind load, and seismic load.

- Application of STAAD Pro: To utilize STAAD Pro software for accurate structural modeling, analysis, and design of silos.

- Optimization of Design: To determine the most efficient cross-sections, reinforcement, and material usage to ensure economy and safety.

- Assessment of Loading Conditions: To analyze the effect of filling, emptying, and pressure exerted by stored material on silo walls and supporting structures.

- Safety and Stability: To ensure the designed silo structure complies with codal provisions and safety standards against buckling, overturning, and collapse.

- Comparative Study: To compare manual design calculations with STAAD Pro analysis results for accuracy and reliability.

- Earthquake Resistance: To evaluate the seismic performance of silos and ensure they can withstand earthquake-induced forces.

- Practical Applicability: To provide a reliable design methodology that can be practically implemented in thermal power plants, industries, and storage facilities.

IV. METHODOLOGY

The methodology adopted for the analysis and design of silos is systematic and involves multiple stages to ensure accuracy and reliability of results. The first stage is Planning, where the dimensions, material properties, loading conditions, and seismic zone details are identified. This step involves defining the problem clearly and preparing the structural model based on standards and design requirements. Once the planning is completed, the structure is analyzed using STAAD Pro software. In this stage, the silo is modeled, and loads such as self-weight, stored material pressure, wind load, and earthquake forces are applied. The software carries out the analysis to determine nodal displacements, stresses, bending moments, shear forces, and pressure distribution along the silo walls.

The next stage is Design, where the results obtained from the analysis are used for structural design of critical components of the silo such as walls, columns, foundation, and roof slab. The design is carried out in accordance with relevant codes and standards to ensure safety, stability, and serviceability. Finally, the Result stage involves interpretation of the outcomes. This includes comparing the displacement, stress, and force values with permissible limits, and drawing conclusions regarding the performance of the silo under different loading conditions. The methodology therefore provides a structured approach that integrates planning, computer-based analysis, practical design, and validation of results.
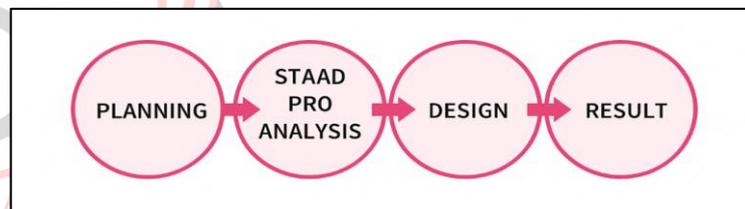

Fig 1: Methodology

V. PLAN, ELEVATION AND COMPONENTS OF RCC SILO
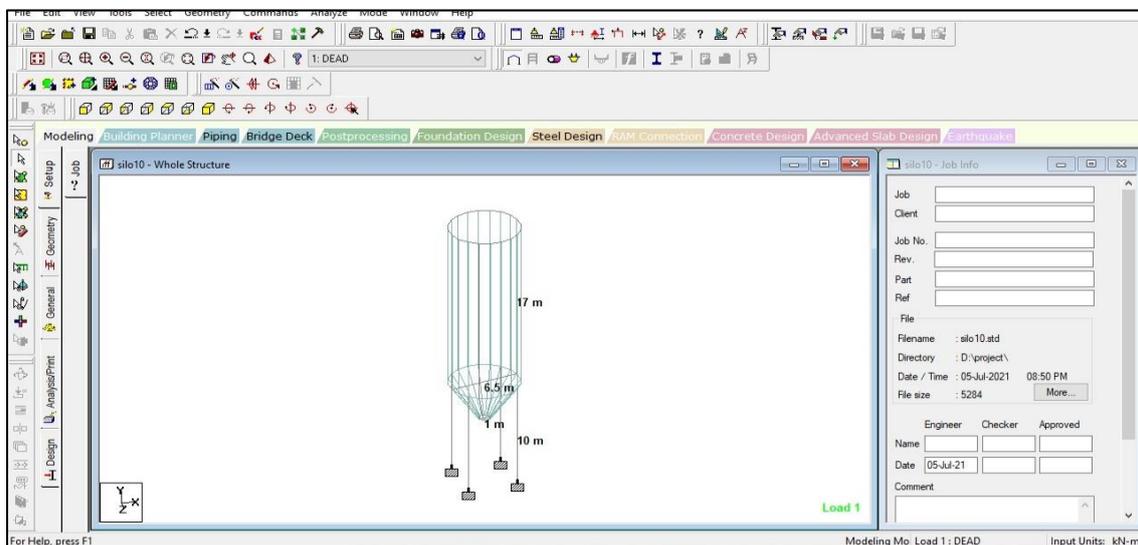
5.1 PLAN AND ELEVATION OF RCC SILO

Fig 2: Plan

Elevation of RCC Silo

Height = 21000mm,

Diameter=6500mm.

5.2 COMPONENTS OF RCC SILO

- Hopper is container or chamber with funnel form that may temporarily hold and transfer loose materials. It is loaded from top and emptied from bottom.

- Column is an upright pillar that supports the silo walls.

- While silos rely on edge beams for stability, they also rely on foundations to anchor the silo to ground and distribute weight evenly.

- Silo walls are made with either RCC or steel material to resist the horizontal pressures in the silos.

5.3 MODELLING

5.3.1 MODELLING
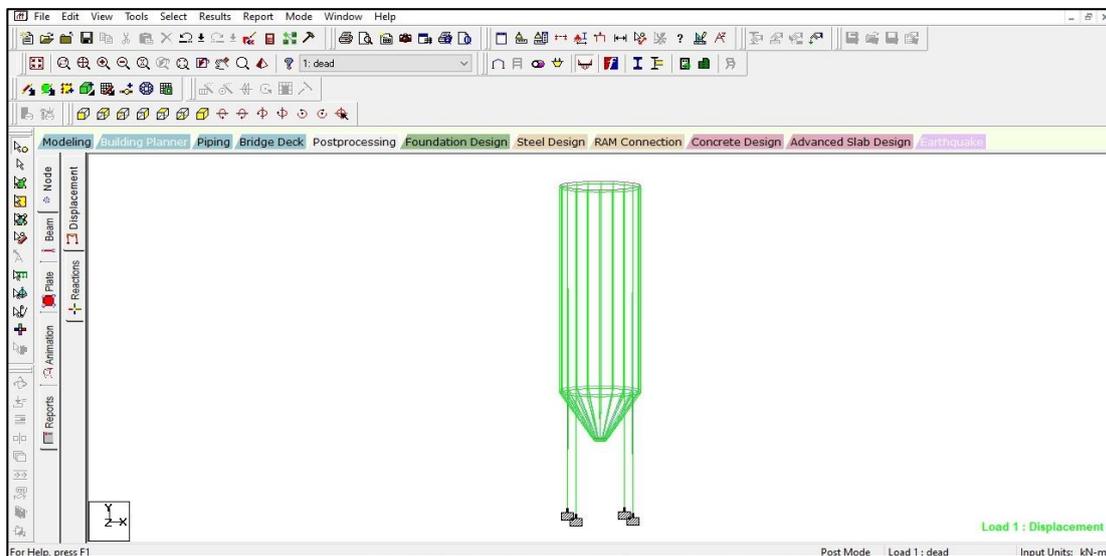
Fig 3: Modelling of Structure
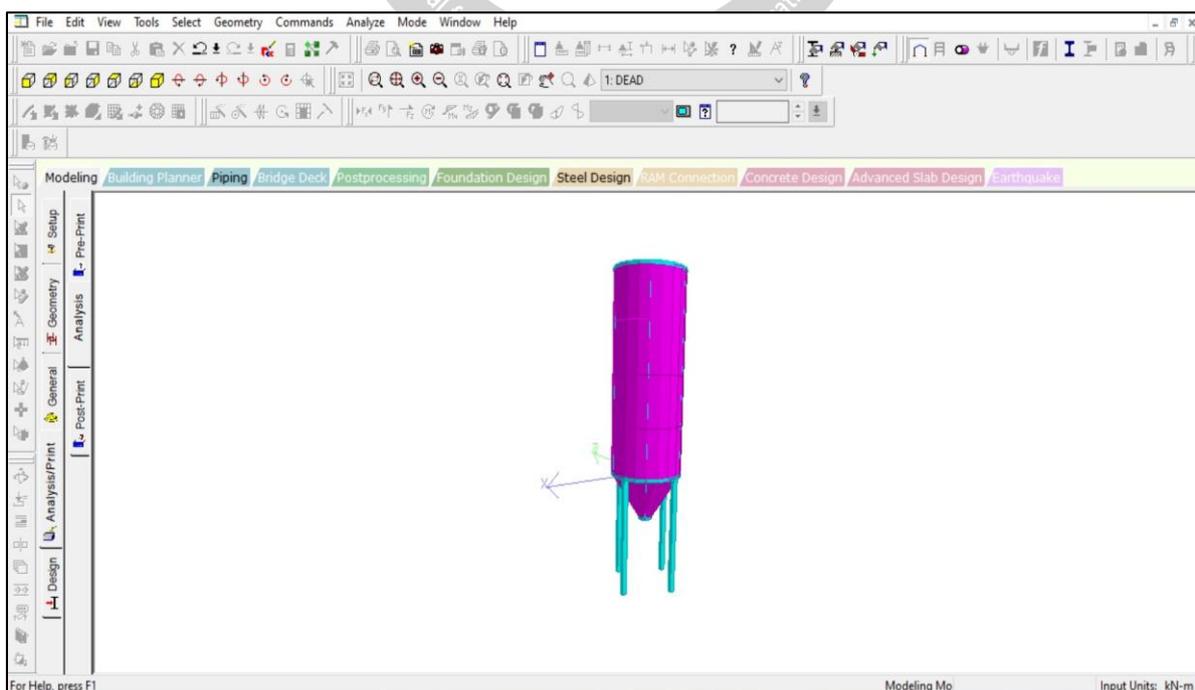
Fig 4: Front View of Silo
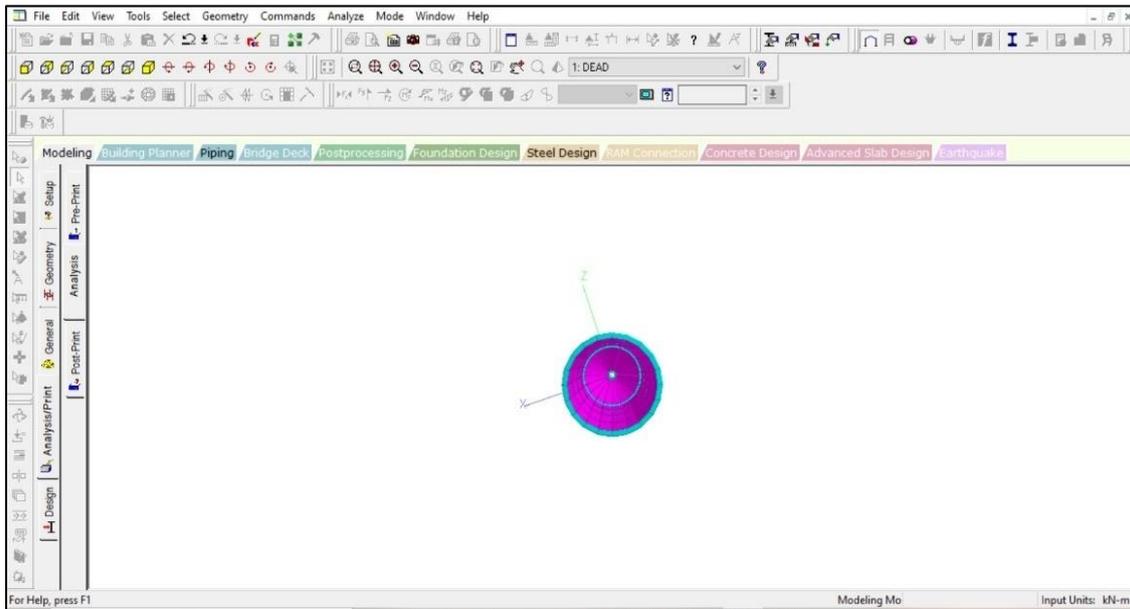
Fig 5: Top View of Silo

5.3.2 DESIGN OF SILO

1. A cylindrical silo has an internal diameter of 6.5 m and 21 m deep (cylindrical portion) with a conical hopper bottom. The material stored is Cement with a density of 14.4kN/m^3. The coefficient of friction between wall and material is 0.444. The ratio of horizontal to vertical pressure intensity is 0.40. Angle of repose = 25^0. Design the reinforcements in the silo walls, Adopt M-15 grade concrete and ribbed for steel. Adopt Janssen's theory for pressure calculations.
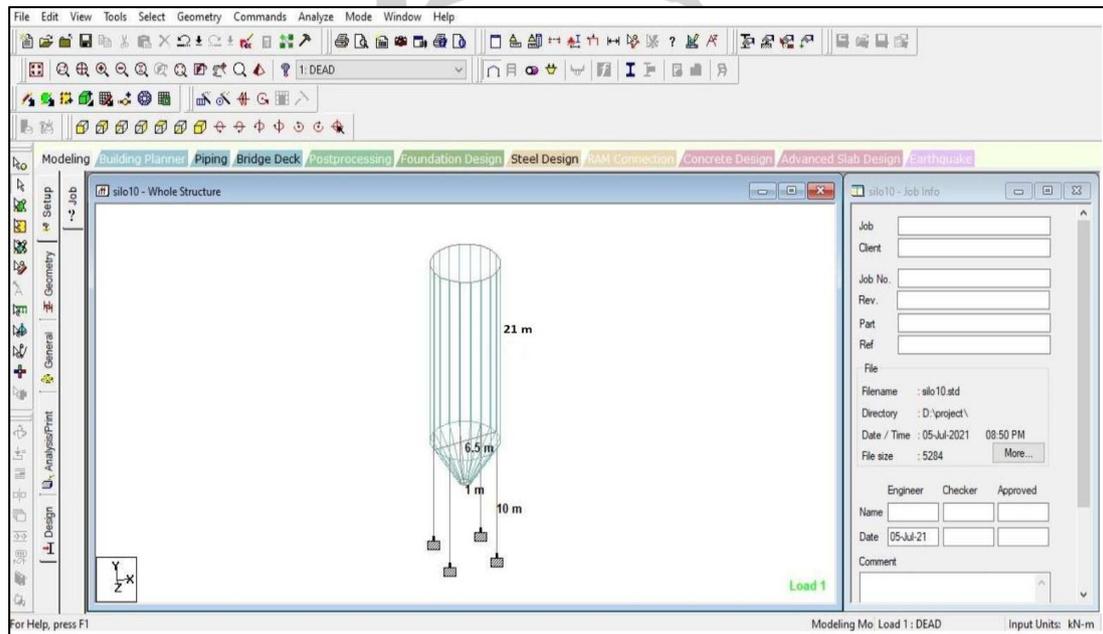
Silo Dimension

1. Data

Diameter of silo = 6.5 m

Depth of cylindrical portion =21 m

Density of Cement = 14.4 KN/m^3

Coefficient of friction between wall and material=0.444

The ratio of horizontal to vertical pressure intensity = 0.40

Angle of repose = 25^0.

2. Allowable Stresses

$\sigma cb = 5$ N/mm^2 $\sigma ct = 2$ N/mm^2 $\sigma st = 230$ N/mm^2 m = 19

3. Dimensions of Silo

Diameter of silo = 6.5 m

Height of cylindrical portion = 21m

Depth of hopper bottom = 4 m

Diameter of opening in hopper bottom = 1 m

5.3.3 DESIGN OF CYLINDRICAL WALLS

Horizontal pressure = $P_h = wR/\mu^1[1 - exp(-\mu^1 nh/R)]$ $n = 1 - sin(25)/1 + sin(25) = 0.40$

$R = D/4 = 1.625$

$P_h = 24.58 kN/m^2$

Is calculated and the value of is compiled in Table 2.4. Appendix 2 gives the values of e-x for different values of x.

Maximum horizontal pressure in the cylindrical portion (21 m from top) =25.13kN/m^2 Hoop tension in cylindrical wall per meter height = $0.5 \times P_h D = 81.67 kN$ area of hoop reinforcement = $A_{st} = 355.08 mm^2$

Adopt 8 mm diameter hoops at 140 mm centers. (A_{st} provided $- 359 mm^2$) Using 150 mm thick cylindrical walls,

tensile stress in concrete = $F_t/(A_c + mA_{st})$

$= 0.53 N/mm^2 > 2N/mm^2$ permissible stress

Table 5.1: Reinforcement details in silo walls

Depth from top (m)	Spacing of 8 mm diameter hoops	Vertical distribution
0 to 12	180 mm	8 mm diameter at 270mm c/c
12 to 16	160 mm	8 mm diameter at 250 mm c/c
16 to 20	140 mm	Throughout the whole depth

Minimum area of steel = 0.12 = $0.0012 \times 150 \times 1000 = 180 mm^2$

At the very top of the silo, install hoops with a diameter of 8 mm and spaced 270 mm apart.

The information on the reinforcements that need to be applied at various depths to the walls of the cylindrical silo is laid out in Table 5.1.
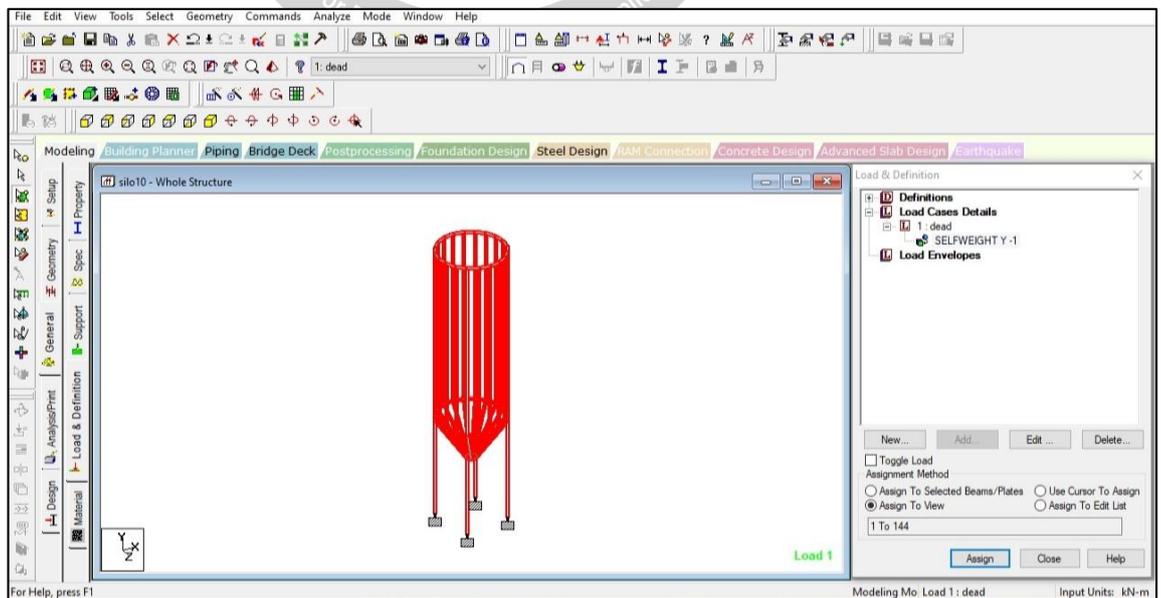
5.4 LOADS AND SUPPORTS
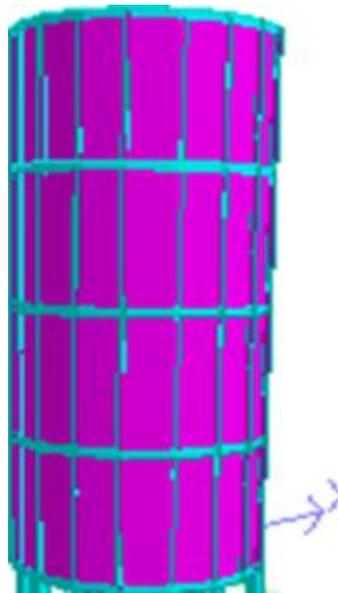

Fig 6: Applying Dead load
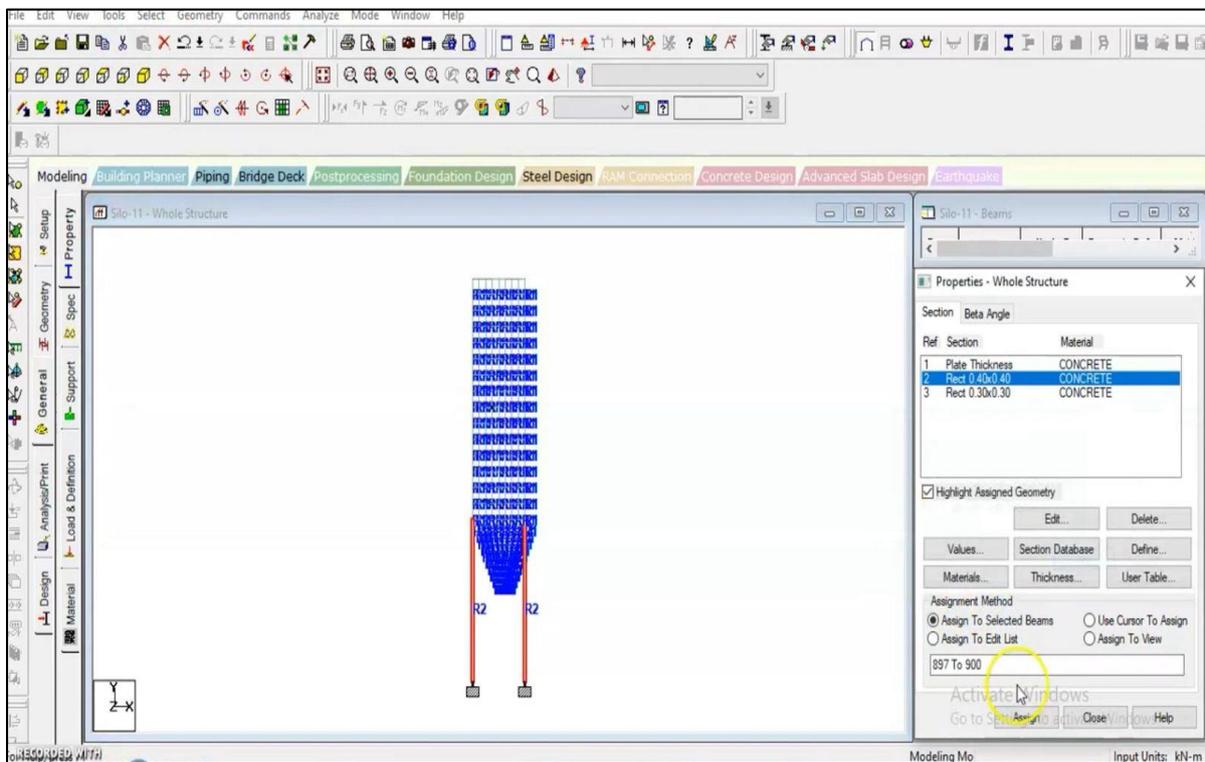
Fig 7: Applying load on plates

Fig 8: Applying properties

5.5 ANALYSIS OF RCC SILO

5.5.1 ANALYSIS OF STRUCTURE:

This section outlines the steps involved in analyzing the structure of an RCC silo, specifically a rectangular silo.

The steps are as follows:

1. Study of the given structure: The analysis begins with a study of the given circular silo to understand its design and configuration.

2. Refraction and BM diagrams: The next step involves creating refraction and Bending Moment (BM) diagrams to visualize the structural behavior of the silo under various loads.

3. Observation of BM and deflection values: After creating the diagrams, the analysis observes the Bending Moment (BM) and deflection values that occur in the silo.

4. Noting down maximal values: The maximal values obtained from the analysis are noted down for further reference.

5.5.2 PROCEDURE FOR ANALYSIS

Modeling process −→ Assign the load property −→ Analysis and print −→ click all −→ add −→ Analise (menu bar) −→ run Analise −→ go to window (by default will shows diagram).

Result (menu bar) −→ view values −→ beam results −→ select maximum of bending and shear and displacement −→ ok.

Click on shear, bending and deflection diagrams

- Although the text is partially cut off, it appears to be discussing the procedure for analyzing the RCC silo. The visible text mentions "Analysis and print," suggesting that the procedure involves performing an analysis and printing the results.

- To elaborate on this content, the analysis of an RCC silo involves a detailed examination of its structural behavior under various loads. The steps outlined in Section 5.1.5 provide a general framework for this analysis. The creation of refraction and BM diagrams helps engineers understand how the silo responds to different loading conditions, such as the weight of the stored material, wind loads, and seismic forces.

- The observation of BM and deflection values is critical in determining the silo's structural integrity and identifying potential areas of concern. By noting down the maximal values obtained from the analysis, engineers can ensure that the silo is designed to withstand the expected loads and stresses.

- The procedure for analysis, as mentioned in Section 5.1.6, likely involves using specialized software or computational tools to perform the necessary calculations and simulations. The results of the analysis are then printed out for further review and interpretation.

- Overall, the analysis of an RCC silo is a complex process that requires careful consideration of various factors, including the silo's design, materials, and loading conditions. By following the steps outlined in this document, engineers can ensure that the silo is safe, efficient, and meets the required design standards.

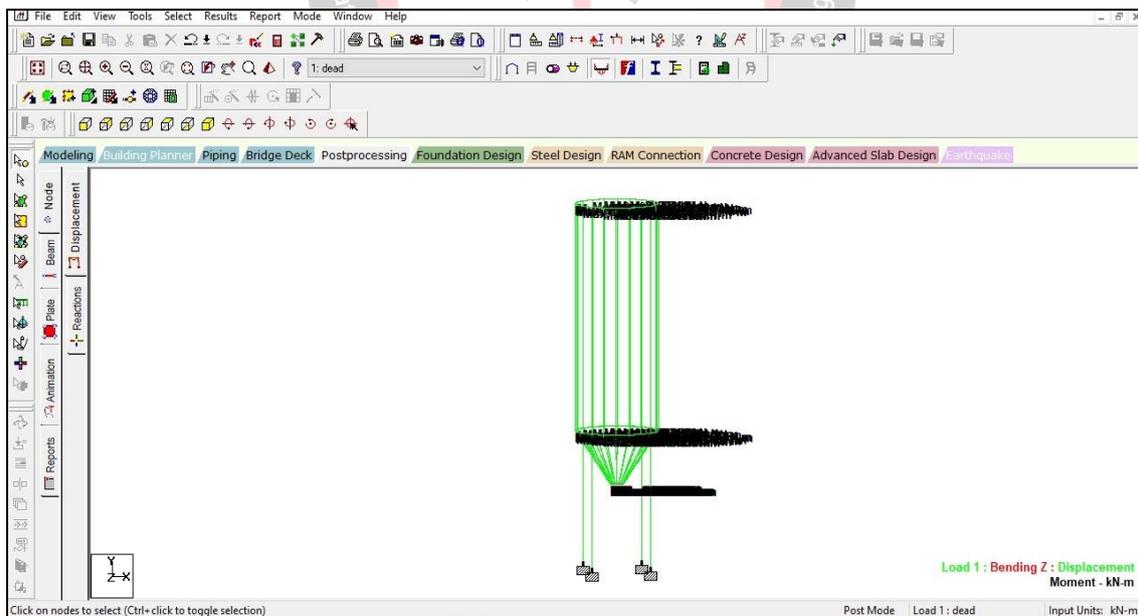### 5.6 ANALYSIS OF STRUCTURE

5.6.1 BENDING MOMENT ILLUSTRATION

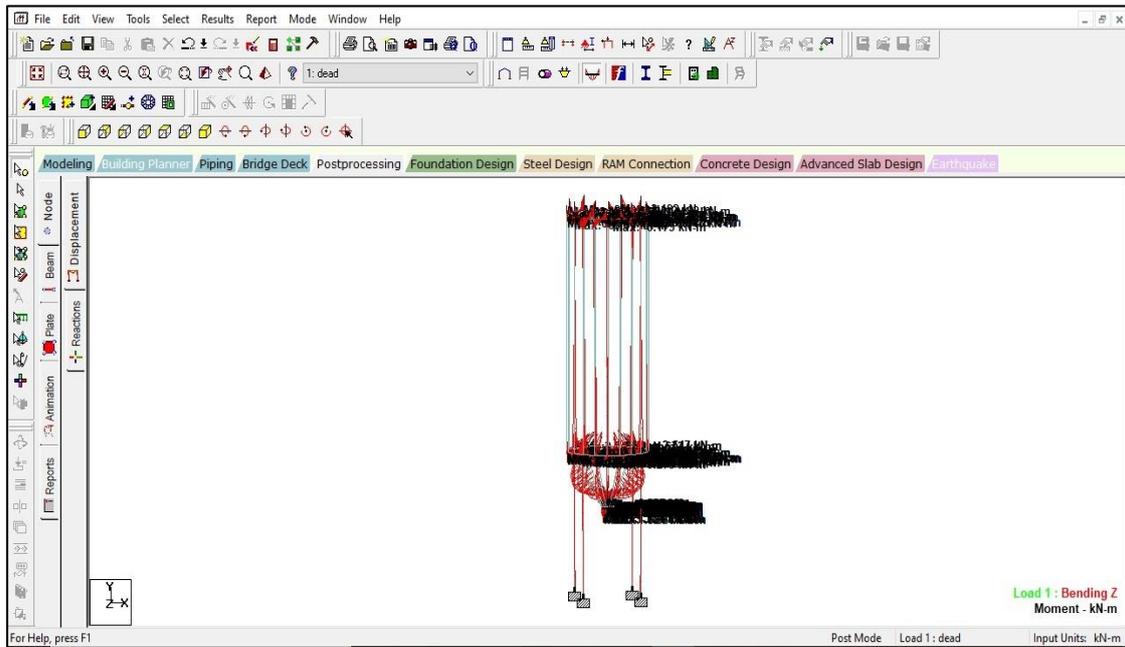**Fig 9: Bending moment**

5.6.2   SHEAR FORCE ILLUSTRATION

Fig 10: Shear force

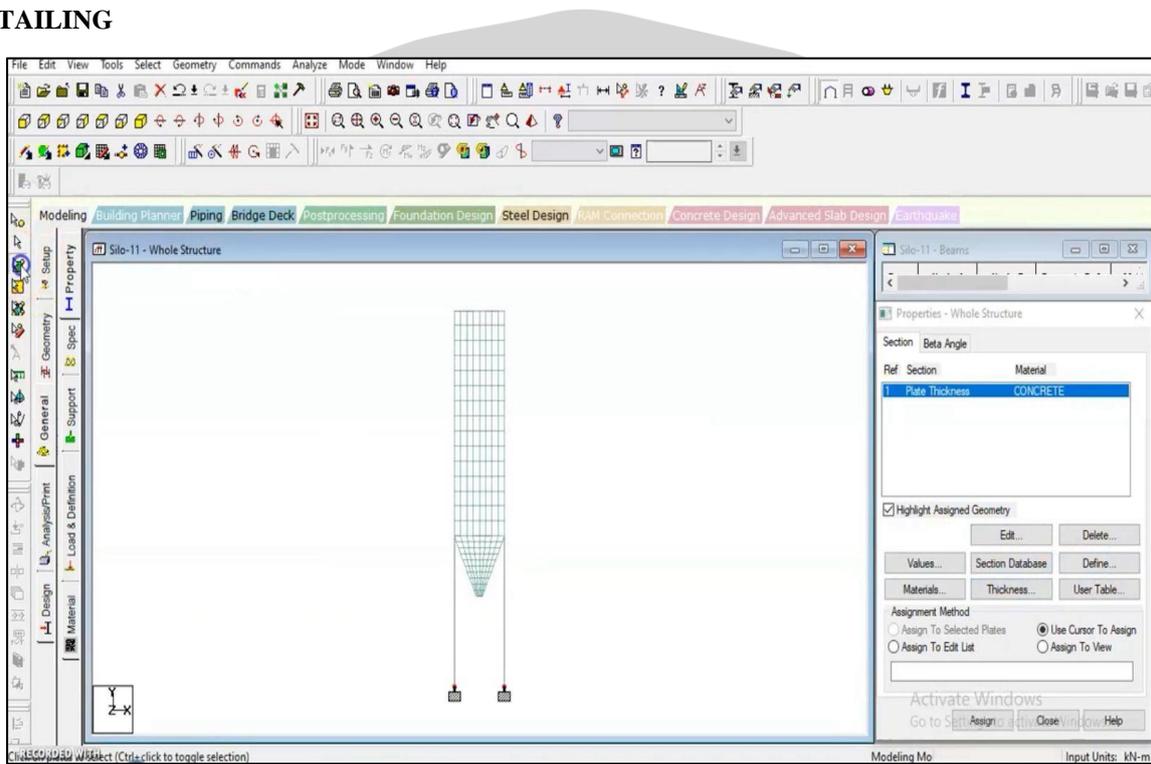### 5.6.3 DETAILING

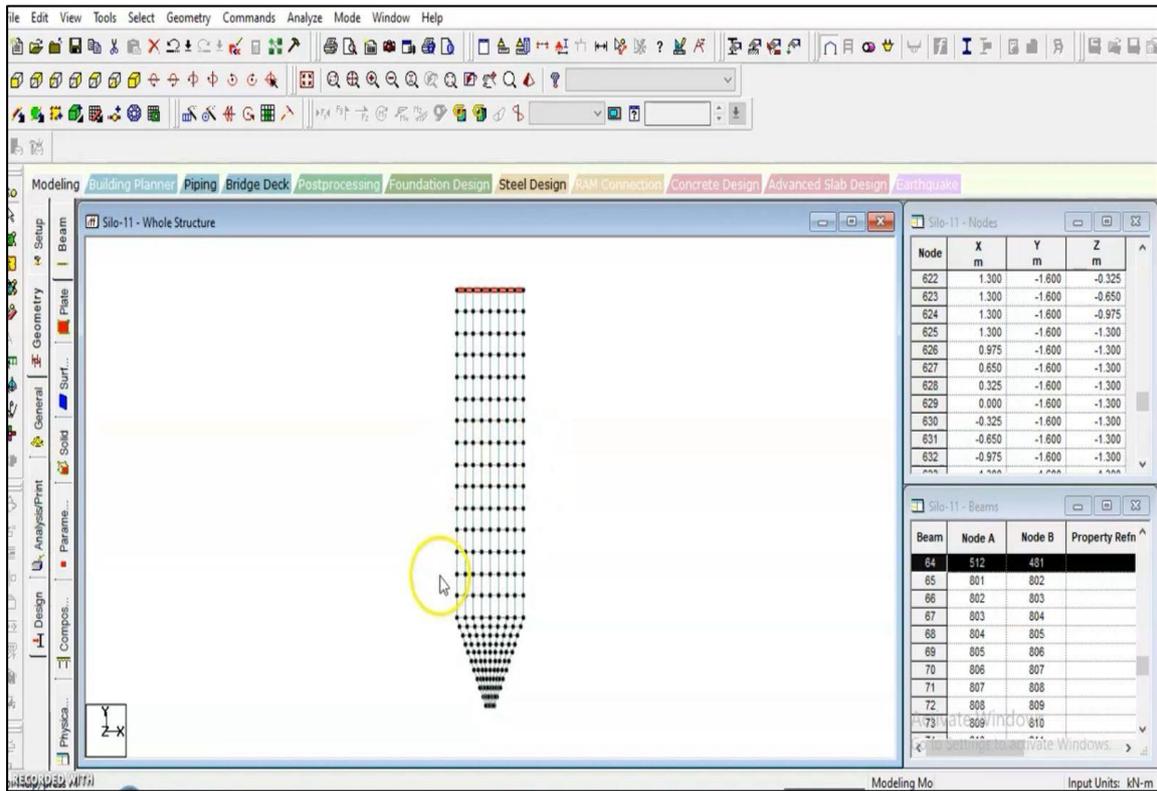**Fig 11: Detailing of Plates**

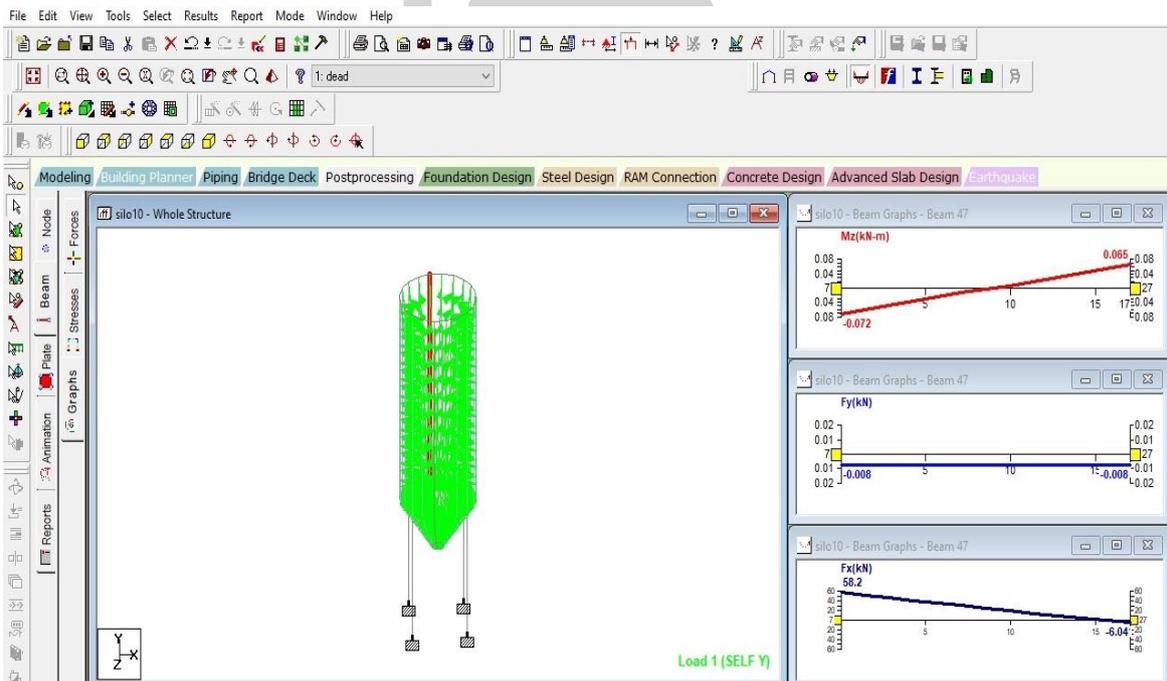**Fig 12 : Detailing of Nodes**

Fig 13: Detailing of Moments

VI. RESULTS & DISCUSSION

6.1 REINFORCEMENT DETAILS OF BEAMS

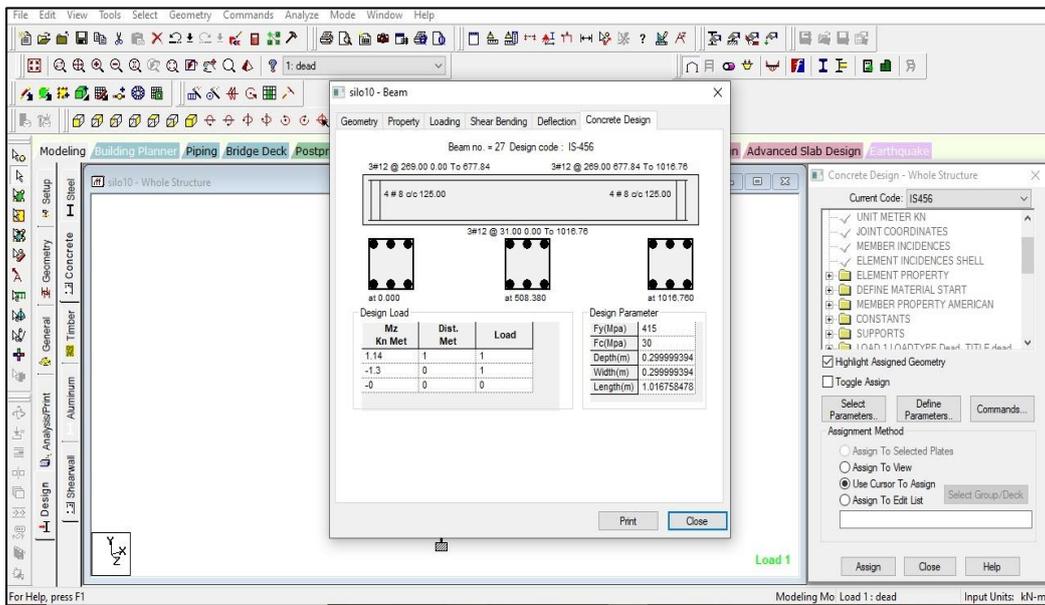**Fig 14: Reinforcement details of beam**

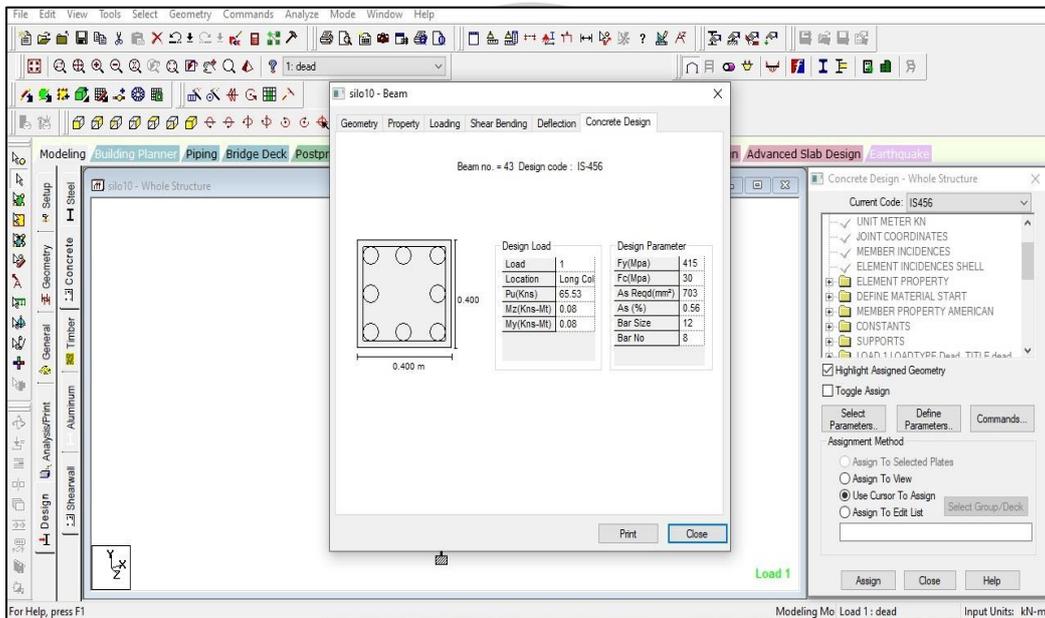## 6.2 REINFORCEMENT DETAILS OF COLUMNS

Fig 15: Reinforcement details of column
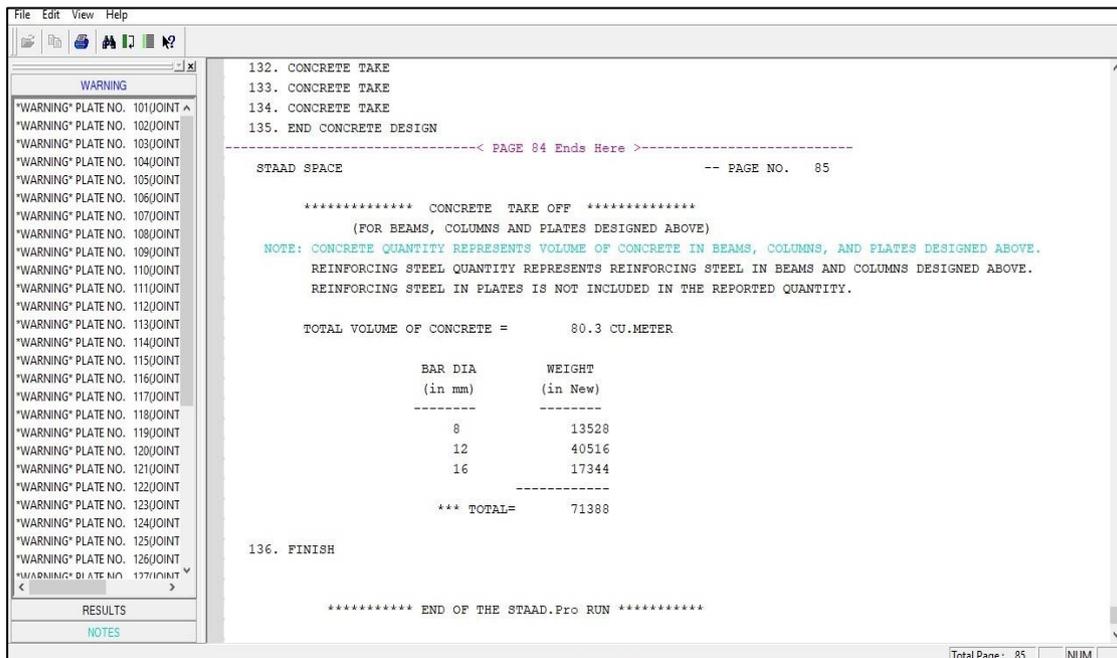
6.3 CONCRETE TAKE OFF

Fig 16: Concrete take off

6.4 CAPACITY OF SILO

- Material Stored = Cement

- Unit Weight of Cement=14.4 KN/m^3

- Capacity of Silo=238KN/m.

VII. CONCLUSION

The following conclusions are drawn from the presents study:

- **Seismic Analysis and Design:**

The first point states that a seismic analysis and design were executed and studied using STAAD Pro. STAAD Pro is popular software used for structural analysis and design, indicating that the project involved assessing the structure's ability to withstand seismic forces.

- **Seismic Analysis in Zone-2:**

The second point specifies that the seismic analysis of silos was carried out in accordance with IS 1893 - 2002 for a Zone-2 location. IS 1893 is an Indian Standard for earthquake resistant design of structures, and Zone-2 refers to a specific seismic zone in India. This suggests that the project is located in a region with moderate seismic activity.

- **Analysis of Bending Moment and Deflection:**

The third point mentions that the analysis examined the bending moment and deflection for various members in the silos. This indicates that the study focused on understanding how the silos would behave under different loads, including seismic forces, and how they would deform or deflect.

- **Calculation of Quantity Material:**

The fourth point states that the analysis was used to calculate the quantity of material in the silos. This suggests that the study not only assessed the structural integrity of the silos but also estimated the amount of material they could hold or store.

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