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Planning Analysis and Design of Pre-Engineering Cement Factory with Silo

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Abstract:- Pre-engineered buildings are made of light gauge metal with light gauge metal wall cladding and standing seam roof panels supported by steel purlins that are suspended between stiff frames. Structures are manufactured in a factory under a strict quality control environment, thereby ensuring superior quality & finish. Preparation of the Layout of a Cement Factory is the preparation of the plan of the factory which aims to improve efficiency by arranging the units according to their function.

Silos are used in cement factories to store bulk products like cement. Silos are used in cement factories to store bulk products like cement. Bulk solids are stored in structures such as bins, bunkers, silos, or tanks. Although there isn't a standard meaning for these names, tall structures holding goods like wheat, cement, and coal are typically referred to as silos, while shallow structures holding coal, crushed stone, gravel, and similar items are called bins or bunkers.

Pre-Engineering Cement Factory planning, analysis, and design are all included in this project's scope. The project's requirements are followed when planning. Planning and analysis are done with tools such as AutoCAD and Staad Pro. Environmental Impacts which is a concern is also considered while having this plan.

Keywords: Pre-engineering, cement factory, silo, design, analysis.

1. Introduction

A pre-engineered building (PEB) is a structure built using pre-designed components that are fabricated off-site and then assembled on-site. These components are manufactured using high-quality materials and are engineered to meet specific design criteria and local building codes.

Buildings are produced in factories with tight quality control procedures, guaranteeing exceptional quality and finish [1]. The process of creating a factory plan to increase efficiency by setting up the units according to their respective functions is known as layout preparation for a cement factory [2].

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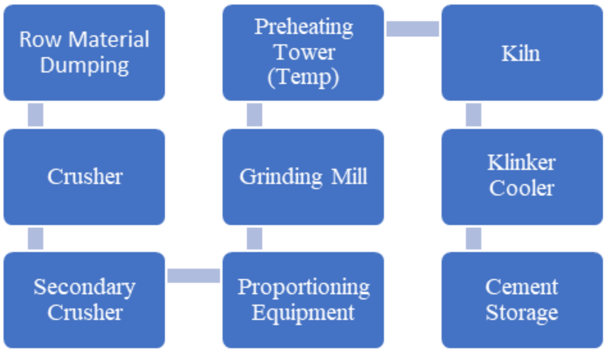
The cement factory's layout is designed with the function point of view in mind. The arrangement displays several parts of cement production [3] (check Figure 4).

BLOCK DIAGRAM



Row Material Dumping- The row material includes aggregates of different sizes with are being dumped in the factory for cement making.

Crusher- The first crusher is used to crush that dump material into a desirable size.

Secondary Crusher- From the primary crusher the material is moved to the secondary which makes the aggregates finer.

Proportioning Equipment- This will mix the required materials into a fixed proportion for further processing.

Grinding Mills- This grind all the mixed materials and brings them into powder [3].

Preheating Tower- A preheater tower in a cement plant is a piece of equipment that preheats raw materials before they enter the rotary kiln for calcining. It's also known as a cyclone preheater or suspension preheater.

Kiln- The main component of cement clinker particles is calcium oxide, which is produced when limestone is broken down in a cement kiln, also known as a rotary kiln [3].

Klinker Cooler- An essential piece of machinery in the manufacturing of cement clinker is a clinker cooler, sometimes referred to as a grate cooler or cement cooler. Clinker is produced in the rotary kiln when cement dries at temperatures as high as 2642°F (1450°C), and it is cooled and moved away from the kiln.

Cement Storage- In the final process the cement is packed and stored in a 50 kg bag.

Mukhopadhyaya et al. (2012) in their work on “An Analytical Study of the Changing Structure in the Cement Industry of India” gave insight into how the deregulation process had affected

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the organization of the Indian cement sector. They said that deregulation increased competition, which prompted consolidation. They believed that the consolidation, entry of multinational companies, and changing cement market had opened the door for the cement industry to perform better.

Kumar et al. (2015) in their article on “Profitability Analysis of Selected Cement Companies in India” identified the profitability position of the cement industry and primarily focused on analyzing the profitability of Indian cement companies between the years 2005 and 2014. Using different techniques like mean, standard deviation, coefficient of variation, and compound annual growth rate. They stated that to achieve positive and beneficial growth and profitability, all cement companies should implement cutting-edge manufacturing methods and different marketing techniques.

Silos are used in cement factories to store bulk products like cement. Annual production of cement is estimated to be in the millions of tonnes. The silos are shaped like circles. The silo's size is determined by a cement factory's output of cement.

The various parts of a silo to be designed such as:

- Vertical Cylindrical walls
- Hopper Bottom
- Edge Beams
- Columns for supporting the silo

Figure 1. Silo

2. Objectives

- To Prepare the layout of a Pre-Engineering Cement Factory.
- To design a cement storing silo for the cement factory.
- To design superior architectural features and excellent aesthetics.

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- To achieve faster completion time - as civil works can be completed parallelly.

3. Scope

- The scope of this project involves the planning, analysis, and design of an engineering Cement Factory [4][5][6].
- Fast erection
- Low cost if choosing the manufacturer's standard package/inventory and no add-on
- Open clear span
- Can be easily expanded to grow with needs [7].
- Environmental Aspects should also be considered during execution [8].

Figure 2. Pre-Engineering Building

4. Software

- AutoCAD 2019 (for Planning)

- Staad.Pro V8i (for Analysis)

5. Methodology

The Methodology steps taken to complete this paper are mentioned below:

- selection of location for cement factory
- survey for the location
- preparation of layout for cement factory

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- collection of data for the design of cement storing silo
- plan, section, elevation, and reinforcement details of silo
- analysis of pre-engineering cement factory by stand.pro
- design of cement factory with silo
- outcomes

6. Planning and Design

Autodesk's AutoCAD is indeed a powerful tool for planning and designing. Whether you're an architect, engineer, or designer, AutoCAD offers a wide range of features to help you create precise and detailed plans.

Proposed building details:

Length- 108 m

Breath- 56 m

Eave Height- 10 m

Plan of warehouse

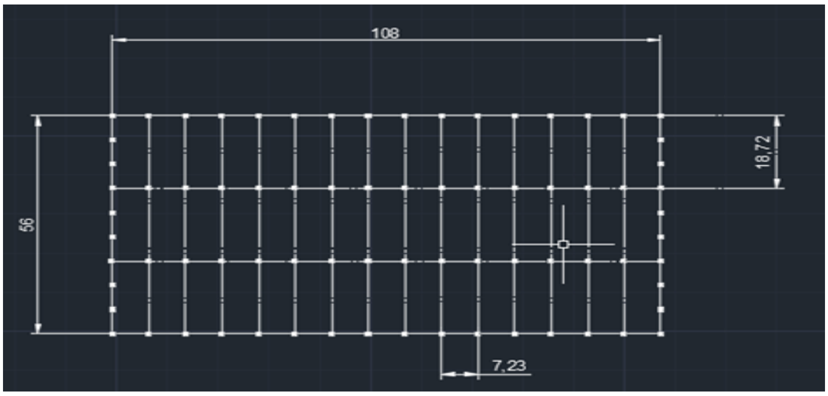

Figure 3. Planning by AutoCad

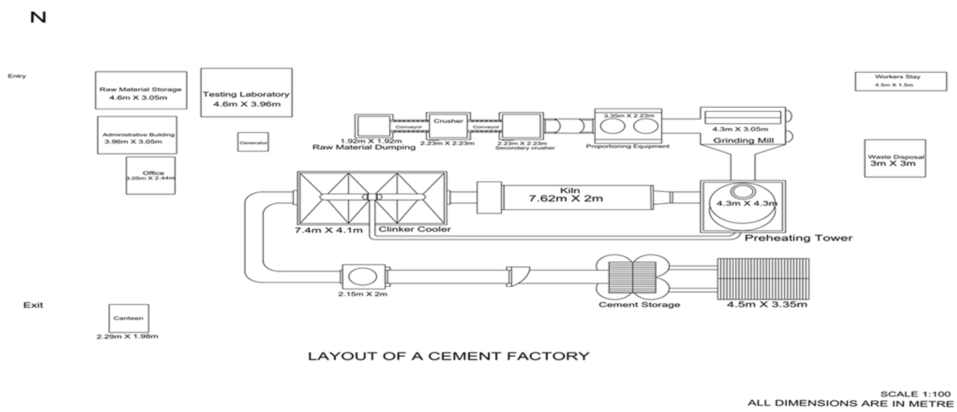

Figure 4. Layout of Cement Factor

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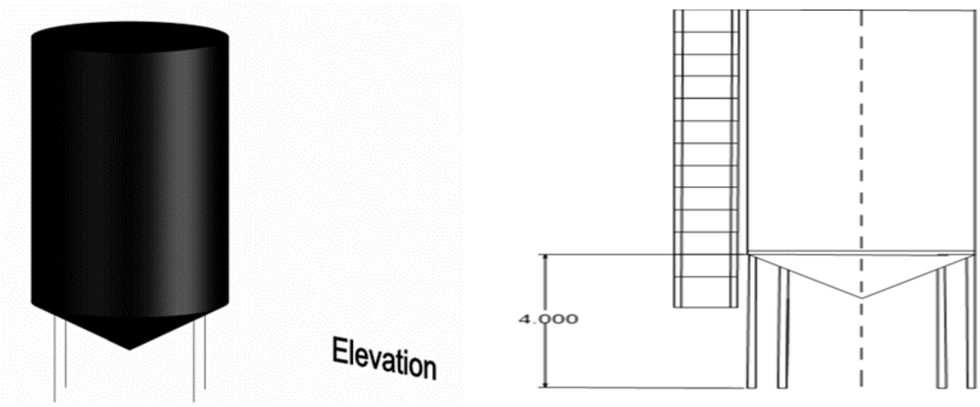

Figure 5. Plan and Front view of Silo

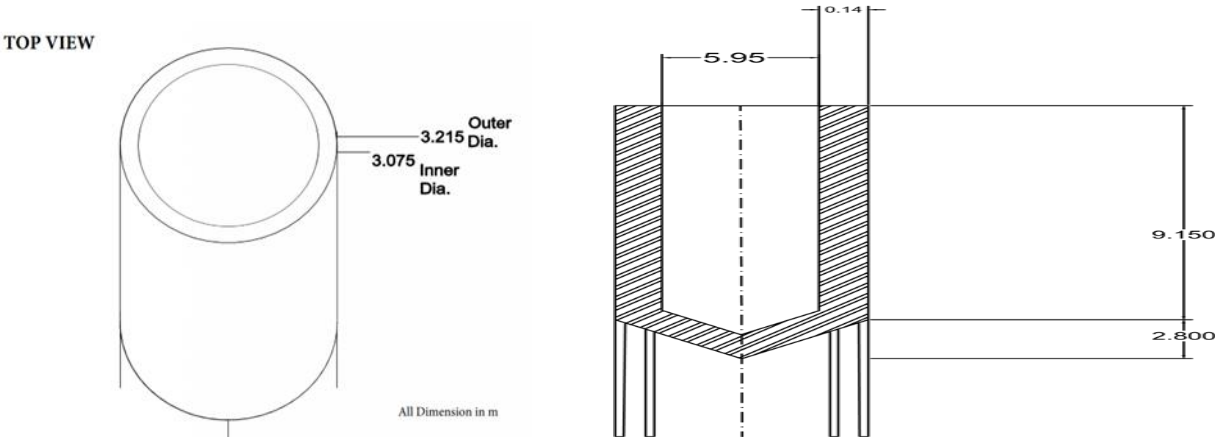

Figure 6. Top and Sectional View of silo

7. **Analysis**

STAAD.Pro is a structural analysis and design software widely used in civil engineering for analyzing and designing structures. It was developed by Bentley Systems and is known for its capabilities in handling complex structural analysis and design tasks.

Analysis of warehouse

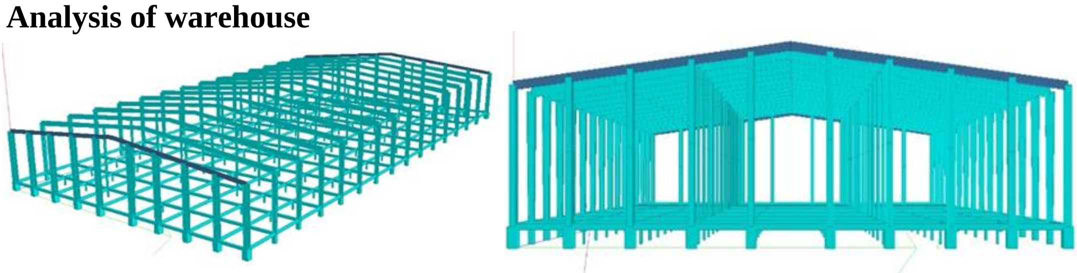

Figure 7. Isometric & Front view of the whole building

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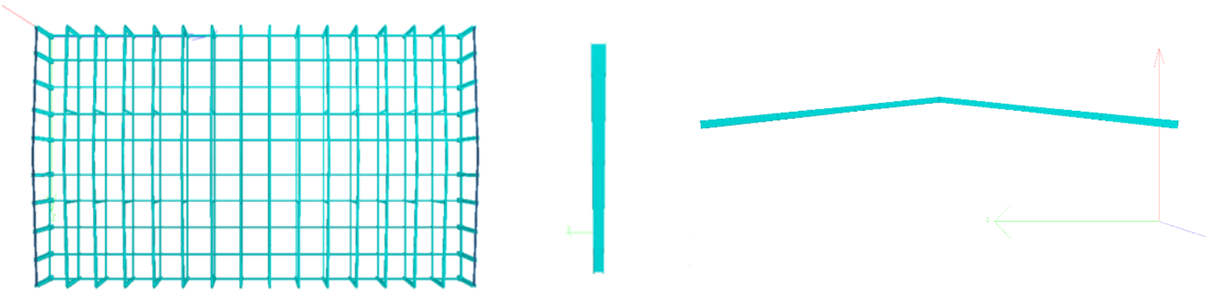

Figure 8. Top view side edge tempered & Tempered Rafters

8. Load Combination

In STAAD.Pro, load combinations are used to evaluate structures under various loading conditions. They allow you to analyze the structure's response to multiple load cases simultaneously, considering different combinations of dead loads, live loads, wind loads, seismic loads, etc. Here's how you typically model load combinations in STAAD.Pro:

- Define Load Cases: First, you define the various load cases that your structure will be subjected to. These could include dead loads, live loads, wind loads, seismic loads, temperature loads, etc. Each load case represents a specific set of loads acting on the structure.

- Specify Load Factors: For each load case, you assign appropriate load factors. Load factors represent the magnitude of each load type relative to its characteristic value. These factors are typically specified by design codes or standards. For example, a load factor of 1.2 might be used for dead loads, while a load factor of 1.6 might be used for live loads.

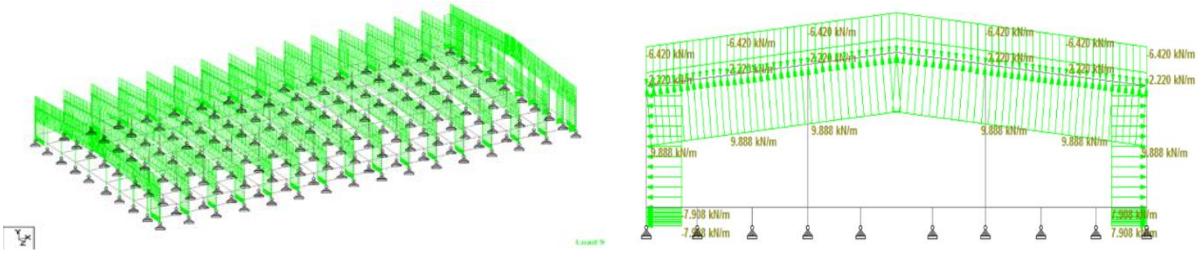

Figure 9. Load Defined by Staad.Pro Software

Axial Force Diagram

An axial force diagram typically represents the variation of axial forces along the length of a structural member, such as a beam or a column. It's commonly used in structural analysis and design to understand how loads are distributed within the member.

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Moment Diagram

A moment diagram, also known as a bending moment diagram, is a graphical representation of the variation of bending moment along the length of a structural element subjected to external loads. It's commonly used in structural engineering to analyze and design beams, columns, and other structural members.

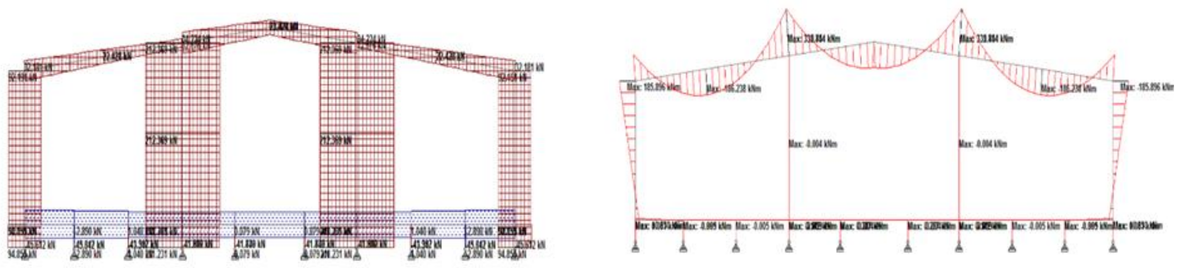

Figure 10. Axial Force & Moment Diagram

9. Results

Design of Silo

Designing a silo to store 10000 cubic feet of cement.

Diameter of Silo = 20 feet = 6.1 m

Height of cylindrical walls of silo = 30 feet = 9.15 m

Depth of Hopper Bottom = 2.8 m

Density of cement = 14.40 kN/m

Coefficient of friction between wall of silo and cement, μ' = 0.70

Angle of repose of cement ϕ = 20°

Ratio of horizontal to vertical pressure intensity n = 0.49

Compressive Strength of concrete fck = 20 $N/mm2$

Yield Strength of steel fy = 415 $N/mm2$

Permissible tensile stress in concrete σct = 2.8 $N/mm2$

σcbc = 7 $N/mm2$

σst = 230 $N/mm2$

modular ratio, m= 280/(3σcbc) = 13.33

Design of cylindrical walls

Hydraulic mean radius, R = (D/4) =1.52 m

Using Janssens's Theory,

Horizontal Pressure, Ph= wR/μ' (1−exp((−μ' nh)/R)) = 27 $KN/m2$

Hoop Tension in cylindrical wall per meter height = 0.5 PhD = 82.3 KN

Area of hoop reinforcement, Ast = ((82.30×103)/230) = 358 $mm2$

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Adopt 8 mm diameter hoops at 130 mm centers.

Table 1. Horizontal Pressure on silo

Depth from Top (h) (m)	Horizontal Pressure (P_h) (KN/m^2)
1	6.20
3	15.11
6	22.80
9	27
11.5	28.44

Using 140 mm thick cylindrical walls,

Tensile stress in concrete = $Ft/(AC + m\ Ast)$

= (82.3 × 103)/((140×103)+(13.33×387))

= 0.56 $N/mm2$ < 2 $N/mm2$

Minimum area of steel = 0.12 %

= (0.12 × 140 ×1000)

= 168 $mm2$

Adopt 8 mm diameter hoops at 290 mm canters towards the top of silo.

Table 2. Spacing of 8mm diameter hoops and Vertical Reinforcement

Depth from top (m)	Spacing of 8 mm diameter hoops (mm)	Vertical Reinforcement
0 - 3	230 mm	8 mm diameter at 270 mm centers throughout the whole depth
3 - 6	160 mm	
6 - 9	130 mm	

Design of Hopper Bottom

Total Thickness= 180 mm = 0.18 m

Surcharge load on hopper bottom / meter = $wh-(4Ph\ \mu')/b$ = 117 KN

Weight of sloping botto= π[[(6·1+1)/2]+√({0.18} 2+{0.18}^2)] (√({0.18}2+{0.18}2))× 25

= 75.90 KN

Total Load = (117 + 75.90) = 193 KN

Mean diameter at center of sloping sla = 3.75 m

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Tension, T = 193/(π×3.75) × cosec 45° = 25 KN

Use 8 mm diameter bars at 200 mm centers in the direction of sloping slab.

Surcharge pressure on hopper bottom= 117/(π ×{6.10}2) = 1 KN/$m2$

Maximum horizontal pressure in hopper bottom, Ph = 28.44 KN/$m2$

Normal pressure intensity, Pn = (1.00 cos2θ+P_h sin2θ) = 14.43 KN/$m2$

Normal component due to self weight of sloping slab = $wd\ cos\theta$ = 3.18 KN/$m2$

Total Normal pressure, P = (Pn + $wd\ cos\theta$) = 17.61 KN/$m2$

Mean diameter of sloping slab = [(6·1+1)/2]+(√({0.18}2+{0.18}2))= 3.75 m

Hoop Tension = (0.5 × 17.61 × 3.75) = 33 KN

Use 8 mm diameter hoops at 200 mm center to center in hopper bottom.

Edge Beam

At junction of cylindrical wall and hopper bottom and at top of cylindrical wall, the edge beams of 300 mm with 4 bars of 12 mm diameter are provided to increase the rigidity of the structure.

Total Load acting on column = Weight of cement + Weight of silo

= 419040 + 95304 = 5044 KN

Design of Column for Supporting for supporting the silo

The Silo comprises of 6 Columns equally spaced on circle of 6.1 m diameter.

Vertical Load on each column = 841 KN

Self Weight of column of height 4m and diameter 0.5m = π/4 × 0.5^2 × 4 × 25 = 19.63 KN

Total Vertical Load on Each column = 860.6 KN

Wind Forces on column

Intensity of Wind Pressure = 1.5 KN/$m2$

Reduction Coefficient for circular shape = 0.70

Total Horizontal Wind force = 78.32 KN

Moment in each column of base = 26.10 KN-m

Using 6 bars of 25 mm Φ & lateral ties of 10 mm Φ at 300 mm centres

Asc = (6 × 491) = 2946 mm^2

Ac = [π/(4) × $(500)^2$ + 1.5 × 13 × 2496]

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= 0.245 ×106 mm

h = (250 – 40 – 12.5) = 197.5 mm

x = h sin 60° = 171 mm

$Ie = \pi/(4) \times (250)^4 + (1.5 \times 13)\ \{4 \times 491 \times (171/\sqrt{2})\ 2\} = 3.626 \times 109\ mm4$

Direct Compressive Stress, σcc' = (860.6×103)/(0.245×106) = 3.51 N / mm²

Bending Stress, σcb' = ((26.10×106×250)/(3.626×109)) = 1.79 N / mm²

Permissible stress in concrete is increased by 33.33%

$((\sigma cc')/\sigma cc + (\sigma cb')/\sigma cb\ ) < 1$

= (3.51/(5×1.33)+1.79/(7×1.33))

= 0.719 < 1.0

Hence, **SAFE**.

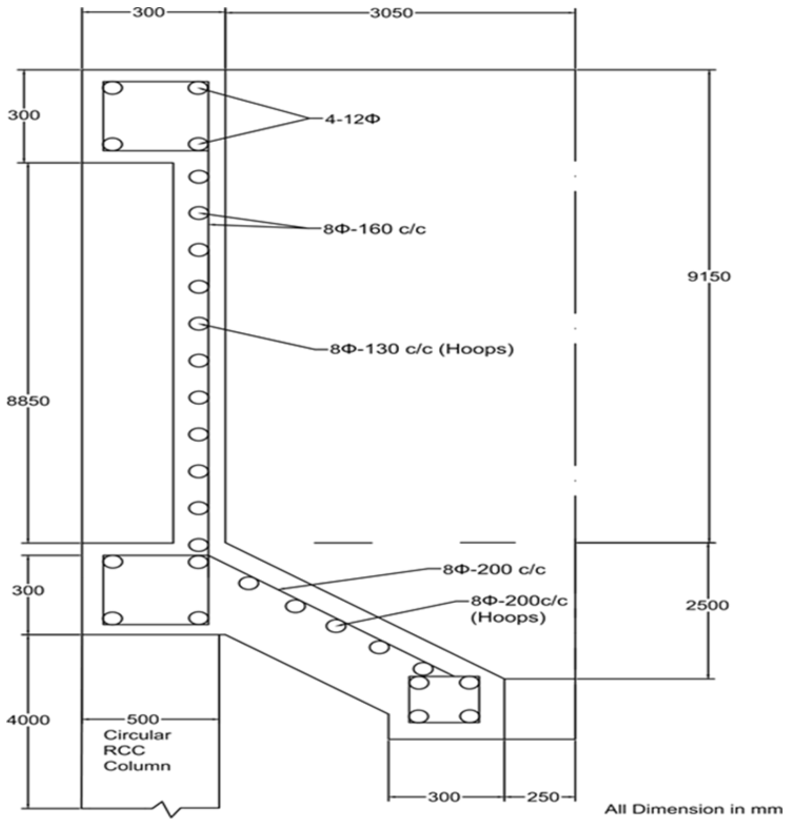

Figure 11: Reinforcement Details in Silo

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10. Discussion

A pre-engineered cement factory refers to a cement manufacturing facility that is designed and constructed using pre-engineered building (PEB) technology. Pre-engineered buildings are structures that are built using standardized components manufactured off-site and then assembled on-site. These components include columns, beams, rafters, and wall panels, among others.

Clear spans up to 93 meters wide and eave heights as high as 30 meters are possible. A building system that offers speed, quality, and value. Ideal for any non-residential low-rise building. The planning of the industrial building by AUTOCAD 2019 gives the exact dimensions of each part of the area. The 3D Analysis of the industrial building is done by STAAD.Pro. The design of this project was done with the help of Indian Standard Codes.

Designing a cement factory with sustainable and environmental outcomes in mind is crucial for mitigating the environmental impact of cement production [8].

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