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ANALYSIS AND DESIGN OF FLY ASH AND BED ASH SILO FOR THERMAL POWER PLANT STRUCTURES

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ABSTRACT

Silos are the commonly used storage structures in production industries such as cement factories, power plant structures etc. When a Silo is used in the Thermal power plant structures it should be capable of storing ashes with high temperature. When compared to the Steel Silos, performances of RC Silos are better due to its easy construction and maintenance. In this thesis design and analysis of Fly ash and Bed ash Silo for thermal power plant structures was carried out with the sequence of preparation of plan, calculation of loads & load combinations, analysis using STAAD PRO and design as per Indian Standards. The height and diameter of two Silos are different and they are connected by a staircase.

KEYWORDS: Silo, STAAD PRO, Wind load, Seismic load, Indian Standards.

INTRODUCTION

Elevated reinforced concrete Silos are playing important role in every production industries because of the demand for production. More particularly power production from thermal power plant structures is increasing day by day and producing huge amount of wastes such as fly ash and bed ash. To store those ashes in power plant we need a good storage container say Silo which should satisfy the basic requirements of the power plant. Silos can be constructed as a single one or as group of two or more. Special care should be taken in design and analysis of Silo since it is a high rise structure with heavy load. In this work Fly ash Silo and Bed ash Silo are spaced at a distance of 6 m(refer elevation) and having overall height of 25 m & 21.76 m, diameter of 9.3 m & 6.3 m (centre to centre), capacity of 750 m^3 & 170 m^3 respectively. Location of Thermal power plant structure was taken as Zone II for seismic consideration. Load considerations were based on IS: 875-1987-Part 1 for dead load, Part 2 for live load, Part 3 for wind load and IS:1893(Part 1)-2002 for Seismic load. Analysis was carried out in STAAD PRO by stiffness matrix method. Reinforced concrete design was carried out based on IS: 456-2000 and SP-16.

LITERATURE REVIEW

Afsal Ansari, Kashif Armaghan and Sachin S. Kulkarni concentrated on the study of RCC silos which are mostly used for granular materials storage. In their study they stated that concrete storage units are somewhat economical in design and cost. Also it can offer protection to the stored materials needs little maintenance and free of hazards such as buckling or denting to some extent. For the analysis of most economical configuration of silos for volume of 125m^3 they have been designed twenty eight samples by changing the ratio of height to diameter and finally found out the most economical size. Their designs have been based on the recommendations of IS 4995-1974 (part 1-2) “criteria for design of reinforced concrete bins for the storage of granular and powdery materials” and IS 456-2000 codes. Finally they concluded that by increasing the height by diameter ratio, the total cost of construction will also increase. In detail they concluded that increasing diameter results in high cost & vice versa and increasing height results in reduced cost of construction. [3]

Indrajit Chowdhury and Raj Tilak suggested a procedure to incorporate the dynamic pressure due to earthquake in the analysis of circular silos. They carried out this analysis using conventional Jansen’s method with some modifications and they did parametric study about dynamic pressure on wall of silo with different structural configuration. They proposed new mathematical model to apply within a design office frame work which did

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not need an elaborate FEM analysis and could well adapted in a spreadsheet or mathcad shell. They insisted that usual ignorance of vertical component of earthquake in structural design would encourage the lateral dynamic pressure and should not be ignored particularly for the huge capacity silo. Finally they concluded that ignorance of seismic effect would considerably under design the silo wall design procedure. [3]

A.Mueller, P.Knoedel and B.Koelle investigated the critical filling level of silos and bunkers with respect to seismic design. For the seismic design they have considered the lowest natural frequency, response spectra, acceleration function, masses and stiffness. They used response spectra method as per Euro code 8 for the design of coal bunkers in which vibration periods are larger which describes the shape of acceleration function that results in smaller acceleration and base shear. They made different assessment of the column's bases which are pinned or clamped, might produce model errors but those errors remain moderate due to diagonal bracing. In the response spectrum when the oscillation period is larger than control period, it is assumed that the seismic load will decrease, since the accelerations decrease. They concluded that the base shear cannot be decreased, if the frequencies of the structure are altered by increased mass, which is due to the reduction of acceleration with increasing period does not balance additional mass. [3]

Suvarna Dilip Deshmukh and Rathod S.T. made a comparative study on the design and seismic behaviour of RCC silo. They have studied about the unusual failure modes and their causes. They have analyzed and designed as per IS 4995, Euro code (EN 1998-4:1999 and EN 1991-4:2006) and ACI code. For the design they have considered static and dynamic pressure exerted by stored materials & seismic loads. Based on their study they have been concluded that while designing silo wall, pressure due to seismic action must be considered. In their analysis they found out that varying reinforcement along depth of wall & more on the middle portion of wall could perform well. [3]

K.Sachidanandam and B.Jose Ravindra Raj studied the causes for failure of bunkers and silos and illustrated them as, due to design, fabrication & erection error, improper usage and maintenance. They have studied about the powder flow and used that gathering in design of silos and bunkers which can discharge the material free from hang-up. Based on their study and learning from many projects, they listed some practical approach to the upcoming researchers. They are, a) requirement of flow pattern, b) measurement of powder properties, c) Based on the material to be handled and operational requirements, design models should be utilized. Also they evaluated the problems in silage juice level which means fermented green forage fodder stored in a silo, loading problems and measurement techniques for effective design. [3]

METHODOLOGY

The following 5 step by step sequence was followed for the analysis of Silo.

STEP 1: PREPARATION OF PLAN

To create a model for the analysis plan and elevation is necessary for the given requirements. Using Auto Cad software plan and elevation of Fly ash and Bed ash Silo was drawn based on the power plant requirements. Elevation took important place in the model creation which is shown in Fig-1.

STEP 2: LOAD CALCULATIONS AND LOAD COMBINATIONS

Load calculations are carried out based on various Indian Standards such as IS: 875(Part – 1)-1987 for Dead loads (Unit weight of Building materials and Stored materials), IS: 875(Part –2)-1987 for Imposed loads, IS: 875(Part – 3)-1987 for Wind loads and IS: 1893(Part 1)-2002 for Seismic loads. Horizontal pressure acting on Silo wall at various depths and forces due to horizontal pressure are calculated based on IS: 4995(Part I)-1974. Temperature stresses and Hoop steel required to resist those stresses are calculated based on IS: 4995(Part II)-1974. Loads mentioned above are considered to be Primary load cases. Further Load combinations are considered based on IS: 456-2000 for the limit state design under two conditions such as limit state of collapse and limit state of serviceability. Following are the load combinations considered in the Silo analysis. 1) Dead load + Live load 2) Dead load + Live load + Ash load 3) Dead load + Live load + Ash Load + Wind load (+,- x & +,- z) 4) Dead load + Wind load (+,- x & +,- z) 5) Dead load + Live load + Seismic load (+,- x & +,- z) 6)Dead load + Live load + Ash load + Seismic load (+,- x & +,- z) and 7)Dead load + Seismic load (+,- x & +,- z). The above combinations are taken for the partial safety factor values of 1.5 and 1.2 with the reference of IS: 456-2000.

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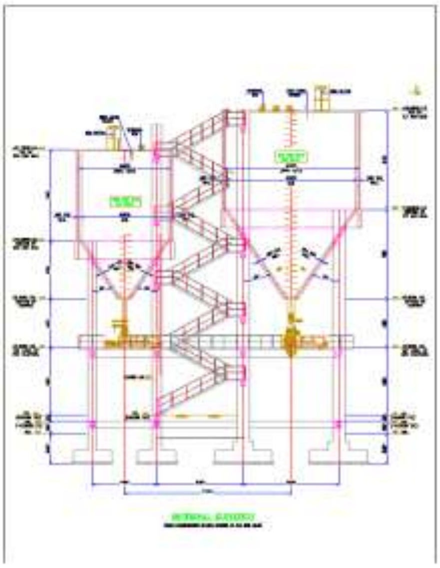

Fig-1 Elevation of Fly ash and Bed ash silo

STEP 3: CREATION OF MODEL IN STAAD PRO

With the reference of prepared plan model of Silos can be created for the analysis. The created model with its nodes, model with property assigned view and rendered view are shown in Fig-2.

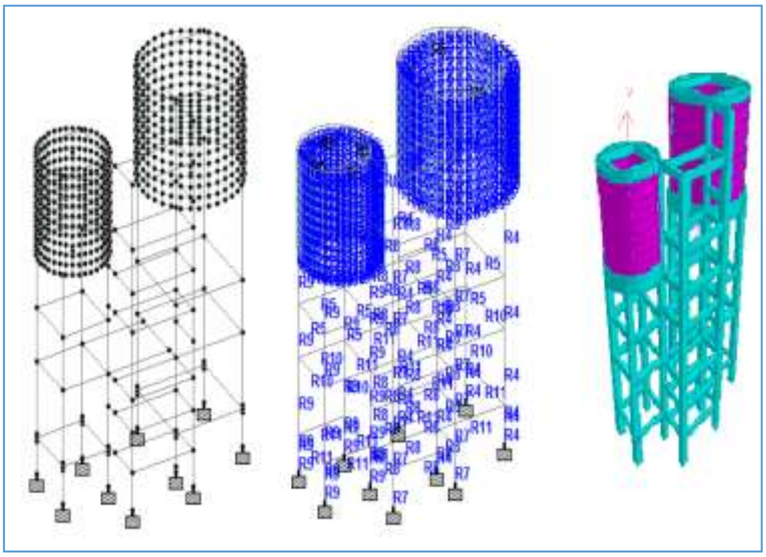

Fig-2 Model with Nodes, properties and rendered view

STEP 4: ANALYSIS USING STAAD PRO

The created model in the STAAD has to be analyzed after the assignment of properties of members. Load cases details and definition of loads should be defined carefully based on the calculation of loads and IS codes. Load cases details were in the order of Dead load, Live load, Ash load, Wind +x & -x, Wind +z & -z, Seismic +x & +z and other load combinations for the analysis. Assigned loads on the members can be viewed separately to understand the location of loading on the Silo. Various load assignment on members are shown in Figure 3, 4 and 5. Finally model should be analyzed by run analysis menu to get the output. The output file was consolidated with the results of Eigen solutions, response spectrum load, peak storey shear, modal base actions, participation factors and concrete design. Based on the output achieved further design can be performed.

STEP 5: DESIGN AS PER INDIAN STANDARDS

Design of RC Silos was based on the values obtained from analysis where design can be performed manually or using Microsoft Excel. IS:456 -2000 and SP 16 were used for the design procedure and for various checks.

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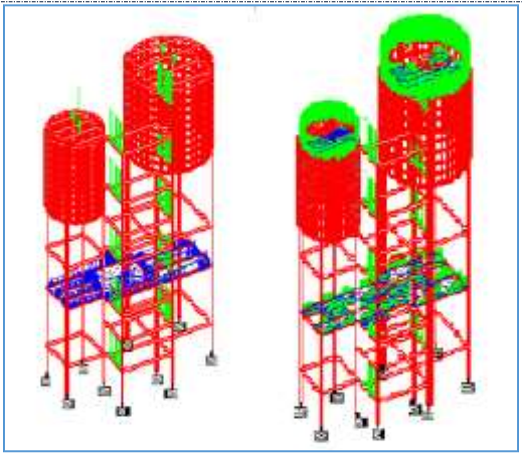

Fig-3 Silos with Dead load and Live load

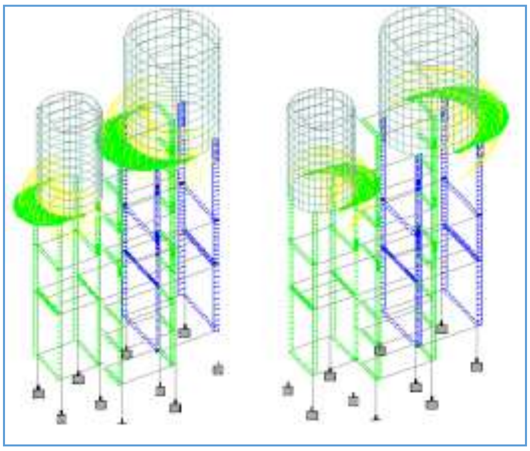

Fig-4 Silos with Wind load (+x and –x direction)

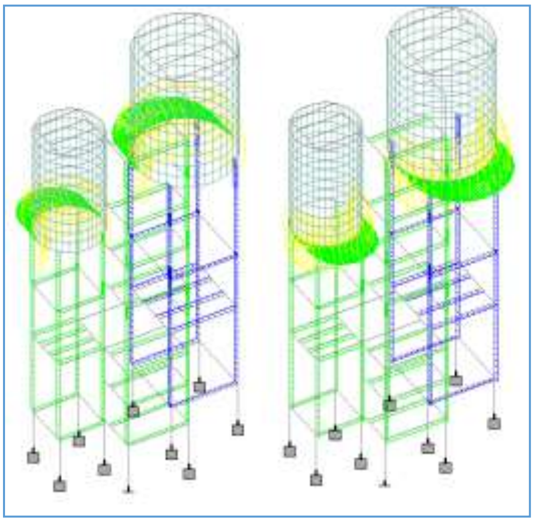

Fig-5 Silos with Wind load (+z and –z direction)

RESULTS AND DISCUSSION

When a elevated Silo is subjected to various loading conditions that will undergo deformations such as bending, deflection etc., Those behavior of a Silo can be viewed prior to the occurrence by using STAAD analysis. Silo under the Shear, Bending and Dynamic forces are analyzed and shown in Fig 6 and 7.

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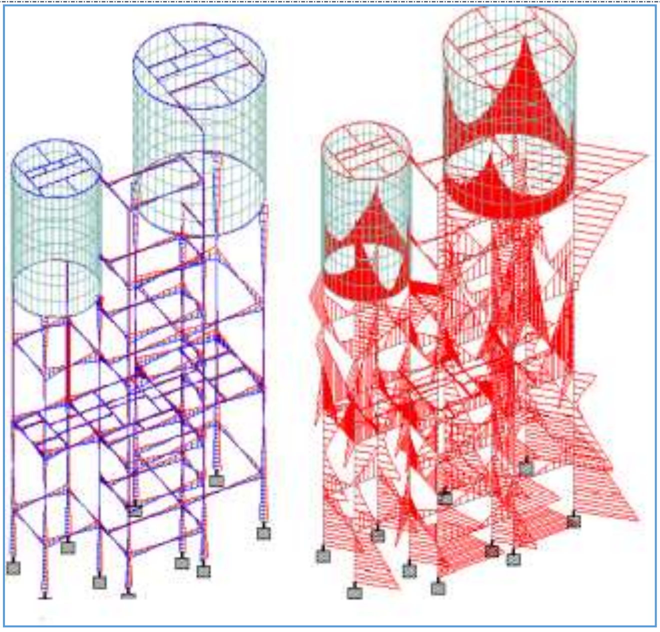

Fig-6 Beam stresses and Bending forces

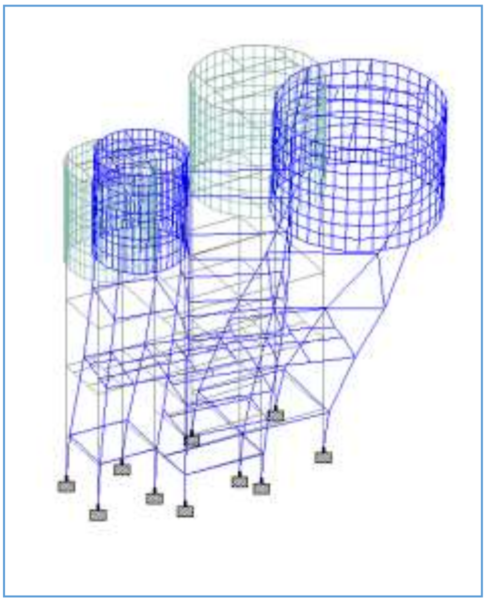

Fig-7 Dynamic action on Silos

Formulae:

The following formulae are important in the design of Silo (as per Indian Standards)

Horizontal pressure, P_h at depth Z = P_h max $\{1-e^{-Z/Z0}\}$

ΔT(temperature difference in bin) = (t / Cc) x { (Ti-To) / (1/K) }

1/K = (1/Ca) + (t/Cc) + (1/Cs)

μΔT(moment due to temperature) = (E_t ΔT E_c I)/t

Design Wind pressure(Pz) = 0.6 $(Vz)^2$

Design Wind speed (Vz) = V_b x k_1 x k_2 x k_3

Wind force = 0.7 x D x H x P_z

Horizontal Seismic Coefficient(A_h) = Z I S_a / 2 R g

Tables:

Silo is a one type of storage bin which needs special calculations for the analysis which are based on the Indian Standard code books IS: 4995 (Part I & II) – 1974. Important part of calculation results are described in the following tables.

Table 1. Vertical pressure at various depths due to fly ash

S.no	R	Z	Ph (KN/m^2)	Pw = Ph x μ(KN/m^2)	Pv = Ph / ʎ (KN/m^2)
1	0	0	0	0	0
2	2.25	2	18.82	10.86	26.89
3	2.25	4	31.96	18.44	45.66
4	2.25	6	41.14	23.73	58.77
5	2.25	8.14	47.92	27.65	68.46
6	1.18	11.82	32.15	18.55	45.92
7	0.125	15.5	3.47	2.0	4.96

Table 2. Vertical pressure at various depths due to bed ash

S.no	R	Z	Ph (KN/m^2)	Pw = Ph x μ(KN/m^2)	Pv = Ph / ʎ (KN/m^2)
1	0	0	0	0	0
2	1.5	2	17.32	9.99	24.74
3	1.5	4	27.42	15.82	39.2
4	1.5	6	33.32	19.23	47.6
5	1.5	7.5	36.07	20.81	51.53
6	0.81	9.88	22.29	12.86	31.84
7	0.125	12.26	3.47	2	4.96

Table 3. Hoop steel required at various depths due to temperature stresses in fly ash silo

S.No	Y	Ph	Ast @ outer face	Spacing and bars
1	0	0	0	0
2	2	18.82	1647.49	Y 20 / 191
3	4	31.96	1757.02	Y 20 /179
4	6	41.14	1833.52	Y 20 / 171
5	8.14	47.92	1890.02	Y 20 / 166.2

Table 4. Hoop steel required at various depths due to temperature stresses in bed ash silo

S.No	Y	Ph	Ast @ outer face	Spacing and bars
1	0	0	0	0
2	2	17.32	1586.9	Y 20 / 198
3	4	27.42	1643	Y 20 /191
4	6	33.32	1675.8	Y 20 / 187
5	7.5	36.07	1691	Y 20 / 185

Table 5. Wind forces at various heights for fly ash and bed ash silo

Height	V_b	k_1	k_2	K_3	V_z	P_z
10	39	1.06	0.98	1	40.56	0.99
15	39	1.06	1.02	1	42.17	1.07
20	39	1.06	1.05	1	43.41	1.13
25	39	1.06	1.075	1	44.44	1.183
30	39	1.06	1.1	1	45.47	1.24

Apart from these calculations the standard values of live load, floor finishes, ash load based on its unit weight, dead load based on its self weight, equipment load and finally seismic load based on Zone factor, response reduction factor & importance factor are referred and incorporated in the definition and load cases details status bar in STAAD for the analysis. After analysis output was arrived and checked for all their stability in order to achieve the effective design of Silo. To avoid the error in output care should be taken in the model creation. After the completion of the model duplicate nodes, members and plates can be checked by using 'check duplicate nodes, beams and plates' in the tools menu.

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CONCLUSION

Design of Silo for Thermal Power Plant structures requires detailed knowledge about the behavior of elevated silo during wind and seismic action because of its heavy volume storage capacity and height. In this thesis analysis was made on two adjacent silos with different height and diameter in STAAD PRO software which is a very advanced kit for bulk analysis of structures. Knowledge of analysis was completely based on the Indian standards suggestions. Design based on output may be performed with the guidance of IS: 456-2000 or MS Excel. Improper analysis before designing may lead to severe problem in the erection, operation or durability. So in order to avoid failure of silos proper analysis has to be carried out. In this thesis various considerations regarding load calculations and load combinations were studied and applied for the analysis of Silo when two Silos are placed adjacent to each other and connected by means of staircase structure.

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