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THE FAILURE STUDY OF BED ASH SILO A CASE STUDY

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Abstract- **Silo collapses is common in the industry. It also gets deformed or distorted during use. A conical RCC hopper of the bed ash silo of 2X62.5MW failed prematurely without occupational hazard. In this case, failure occurred as the RCC hopper got separated from RCC ring beam. The failure was analyzed considering design, construction workmanship, material used, operation, and maintenance. This is a suspended cone hopper. However in the recent designs the cone hopper is supported from below by a reinforced concrete ring slab and sides are filled with concrete. During erection and construction of RCC, fault occurred in and around ring beam and suspended hopper joint. In joint area porous concrete was seen and it caused cracks in concrete. It is due to lack of approach and poor compaction. The ingress of air and moisture into the concrete face corroded reinforcement bars. Incorrect steel rod binding and improper development length results in insufficient concrete cover. The bars were placed out of position or in the wrong position. In this case the reinforcement bars got sheared and yielded at the junction of the hopper and ring beam causing collapse when the RCC hopper is even partially loaded.**
Keywords – Silo, RCC failure, Silo construction, Bed Ash silo operation, Conical RCC hopper

I. INTRODUCTION

On 17th April 2016 night around 10.30 PM the RCC hopper of Bed Ash Silo of 2X62.5MW power plant suddenly collapsed. The plant was in operation since January 2016. The RCC hopper got separated from RCC ring beam at +EL 14.50 and fell on the working floor 10 meters below.

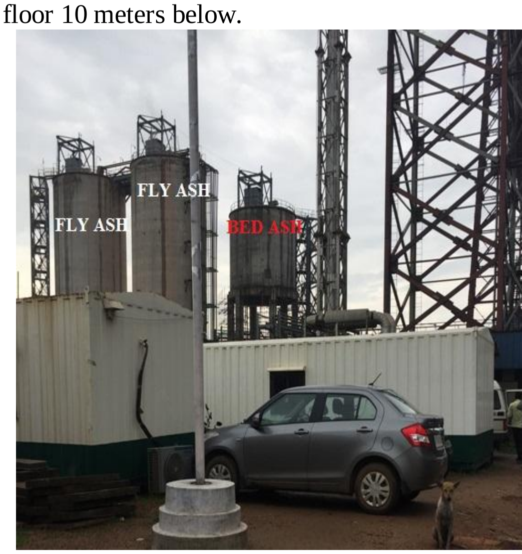

Figure 1: Location of Silo

Figure 2: Ring Support

The details of Silo are:
Capacity : 1000MT
Inner Diameter : 9.800m
Silo Height : 26.735m
Support columns : 6 (six)

2. THE FAILURE

M/S Bhubaneswar Power Private Limited BPPL -2X 67.5MW is a captive power plant for TATA Alloys. It supplies power on demand. The bed ash silo construction was completed in September 2015 and was in operation since January 2016. The failure was on 17.04.2016.

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Both the units (**2X 67.5MW**) were in operation at the time of incidence and ash was being conveyed to the bed ash silo as per the regular practice and operational requirement. On 17.04.16 at about 10.30 p.m. the hopper portion of silo sheared off from the ring beam and got detached. The detached concrete chute fell down on the operating platform damaging equipments on the working floor.

"The failure is noticed to have occurred at the junction of the hopper and the ring beam. With the observation of separation plane and the pattern of the separated bars it is primarily understood that the shearing must have initiated towards west side joint of the hopper due to which the hopper tilted and shearing continued and the hopper is separated from the ring beam and collapsed on the operating platform at EL +4.35m and puncturing the same and damage of few of its floor beams."

The silo and bin failures are very common in industrial scenario, though the complete collapses of structures are rare. The distortion or deformation is observed in many sites. As per internal report "The hopper reinforcement bars seem to get sheared and yielded at the junction of the hopper and ring beam, due to entrapped air in the concrete developing into hair line cracks in the west side location ,further extended and gave way at time of loading."

The major causes of silo failures can be categorized [1] in four points:

1. DESIGN,
2. CONSTRUCTION WORKMANSHIP AND MATERIAL USED
3. USAGES DURING OPERATION
4. MAINTENANCE

3. THE DESIGN

Design Details:
Total height 25.65m
Cylindrical Shell inner diameter-9.8 m
Thickness -250 mm
Hopper Shell Height -9.625m,
Maximum inner diameter-9.8m

This concrete silo has a suspended cone hopper. In the recent design the cone hopper is supported from below, by a reinforced concrete ring slab and filled with concrete. [2]

Wind Load:

The effect of wind on the structure as a whole is determined by the combined action of external and internal pressures acting upon it. In all cases, the calculated wind loads act normal to the surface to which they apply.

The silo is having inner diameter 9.8m & the height is 26.735m from FFL. The capacity of the silo is 1000 M Tons. The code of practice for design loads IS: 875 Part3 for wind load was referred. The wind speed given is between 2-180Kmph with annual mean of 12 Km per Hour. The mention in the code based on 50 years return data specifies 50m/sec for coastal zone of Odisha. However with the consideration of design wind speed of 180Kmph the wind speed multiplication factor K1=1.08, K2=2 and K3=1.0 is taken for calculation of wind force on structure.

Earthquake force:

As the area is in Zone-III seismic zone As per IS: 1893, importance factor 1.75 is taken to design the structure to withstand lateral seismic forces.

Thermal loads:

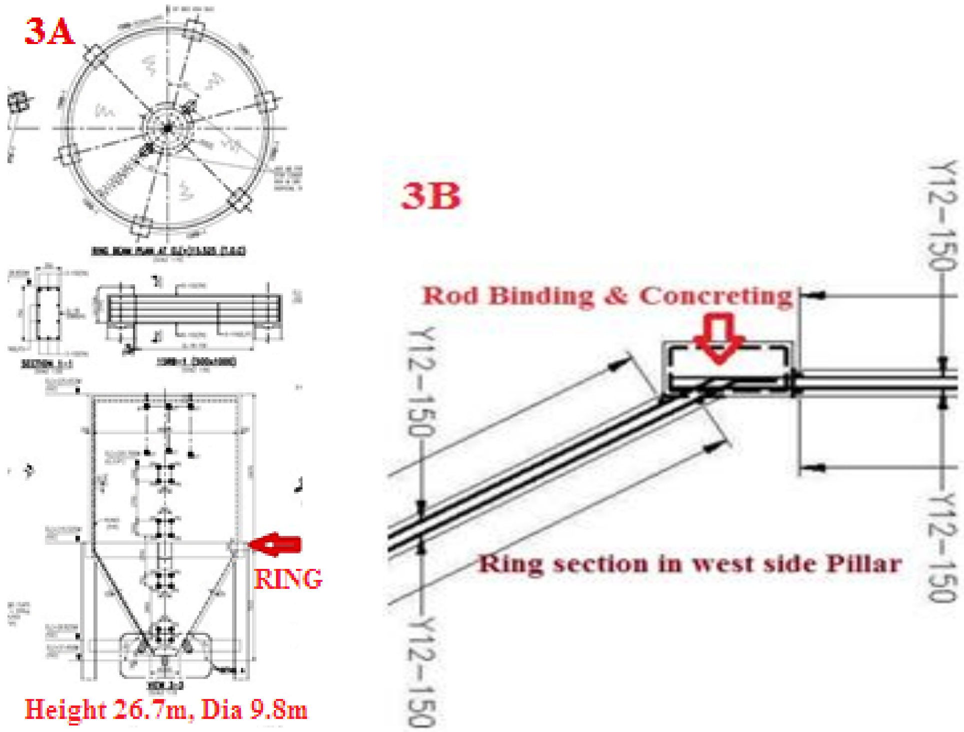
The thermal effect of hot stored materials is considered to avoid thermal bending. It's OK as per the design given in the ACI standards. As per the ACI Standards Wall thickness of suspended reinforced concrete hoppers shall not be less than 125 mm. And here 250 mm taken. [3]

Soil is rocky type so soil load bearing capacity is good. The members & sections of drawing is as per standard with reference to both static load and dynamic load. So strength design of the bed ash silo is noted to be adequate to store 1000 metric tons of bed ash in the silo. The total ash holding capacity is 1000MT, at the time of the incident the silo was filled with 50% capacity. Hence overloading is ruled out.

4. CONSTRUCTION WORKMANSHIP AND MATERIAL USED

In the RCC construction phase more common problem is workmanship. Poor site erection or construction methods and workmanship is responsible for the failure of structure. The most common construction mistake is inadequate supervision at construction site as per quality control plan.

"In this case the failure is noticed at the junction of the hopper and the ring beam With the observation of separation plane and the pattern of the separated bars it is primarily understood that the shearing must have initiated towards west side joint of the hopper due to which the hopper tilted and shearing continued and the hopper is separated from the ring beam and collapsed to the operating floor."



In the figure-3A arrow mark shows the joint at which the RCC hopper is suspended and connected to straight potion of silo. The figure-3B shows the rod binding and concreting area. The workmanship needs to be perfect here with standard quality checks. The hopper is suspended from ring beam. It has no support at bottom FIGURE-3A. During erection and construction of RCC, main fault has occurred in and around joints. In joint area if concrete is not properly compacted by ramming or vibration and the result is a portion of porous honeycomb concrete. This sort of defect is caused by lack of approach, hence poor compaction while erecting or onsite joining. Complete compaction is essential to give a dense, impermeable concrete at the joint marked with arrow.

Figure 3a B C: Junction Of The Hopper And The Ring Beam

figure 3B Poor joint allowed ingress of moisture to the concrete causing corrosion in steel. The corroded reinforcement bars has sheared and yielded at the junction of the hopper and ring beam. This short of defect causes cracks in steel. The faulty concreting is due to lack of approach and poor compaction while erecting or onsite joining.

Incorrect steel rod binding can result in insufficient cover FIGURE-3C. If the bars are placed out of position or in the wrong position or proper development length for rod is not given, collapse can occur when the element is even partially loaded. The cracking of the concrete is common in the joints. Through these thin cracks ingress of moisture, gases and other substances

caused corrosion of the reinforcement bars. The corroded and thinned reinforcement bars got sheared when it is partially loaded.
This is a suspended cone hopper. However in the recent design the cone hopper is supported from below, by a reinforced concrete ring slab and concrete filling.

4.1 Material Used:
Sample material for bed ash, reinforcement bar and RCC were collected & tested in XRF Spectrometer Model: Epsilon 1. The results given below are acceptable.

Table-1 Bed Ash Composition

SiO_2	Al_2O_3	Fe_2O_3	TiO_2
59.7%	25.6%	6.7%	2.6%

Table-2 MS Reinforcement rod 12mm

C	Mn	Si	S	P
-	0.802%	0.289	0.048%	0.114%

Table-3 Concrete Analysis

SiO2	CaO	Al2O3	Fe2O3	K2O
36.82%	32.04%	12.51%	11.74%	3 %

5. USAGES DURING OPERATION:
A properly designed and properly constructed silo should have a long life. Problems can arise when flow properties of stored material change and wear occurs in the inner surface of silo.
In this case flow is by gravity. The standardized mesh size is + 4.75 to - 25 mm and only 17% is of higher size in the bed zone. It was told by the plant engineers that clinker or un-burnt mass is absent. Any explosion is not possible as the ash is non inflammable though the specified ash temperature is 150 to 350^{0}C.
The plant is quite new and was in operation for 3 months (January to April 2016) only. The damage or collapse due to operational problem is unlikely.

6. MAINTENANCE:
The plant is quite new and was in operation for only 3 months. The visual inspection was done for any spalling, surface cracks or hole during operation. After the failure some cracks were noticed in the columns. There was no significant maintenance requirement to cause failure.

7. CONCLUSIONS:
1. The design, materials, operation and maintenance are as per the specification and normal practice. The concrete silo has a suspended cone hopper without support from below, is a risky design.
2. The bed ash silo collapsed due to **shearing of reinforcement bars** at the west side junction of ring-beam and hopper of silo at a level of +EL 14.5m.
3. The steel reinforcement bars were out of position at the hopper and ring beam junction. Proper anchoring got affected due to faulty positioning and development length of reinforcement bars during erection.
4. The reinforcement bars joints did not fit together properly; joint area concrete is not properly compacted causing porous concrete. The porous concrete due to entrapment of moist air developed corrosion and hair line cracks in steel and further extended gave way at time of loading.
5. Inadequate cover of reinforcement has permitted ingress of moisture, gases and other substances causing corrosion of the reinforcement bars and shearing. The shearing of reinforcement bars caused collapse of silo as shown in FIGURE- 3C.

8. REFERENCES
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