Hopper Failures in Steel Coal Storage Bunkers
A Case Study

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Abstract

Bunkers made of steel are used to store coal in coal-fired power plants. These bunkers generally store up to sixteen hours of the boiler’s daily coal requirement and are huge in size. Bunkers are circular or rectangular in plan. Circular bunkers are more economical, lighter, easier and faster to erect and hence generally adopted these days. Of late, some bunker failures have been reported. This paper studies the possible reasons for one such bunker failure and the rectification procedure suggested for strengthening the existing bunkers of the plant that had not failed, but were suspected to be in a critical condition.

Introduction

A coal-fired power plant having circular coal storage bunkers had a catastrophic failure in one of the coal bunkers of one unit. The bunker cone or hopper got detached from bunker cylinder and the entire cone along with stored coal had come down resulting in plant outage. The design of the bunker was rechecked and was found to be in order.

A detailed study was carried out to understand the reason for the failure. The study revealed that the most possible reason for the failure was faulty erection procedure adopted by the contractor. There was apprehension of more such failures occurring as all the bunkers in the project were erected using the same faulty procedure. A rectification scheme was developed by giving alternative support to the hoppers so as to prevent hopper detachment.

Layout And Geometry of Coal Bunkers and Mill & Bunker Bay

The circular steel bunkers of the plant were all housed in the mill and bunker bay or mill and bunker building. The steel bunkers had a top cylindrical portion and a bottom conical portion called hopper. The cylindrical top had an internal diameter of 8000mm with an approximate height of 10000mm, and was fabricated with 12mm thick MS plates. The cylindrical portion of the bunker was between EL 38.50m and EL 28.50m.

The bottom portion of the bunker or the conical portion was 10000mm high with an internal diameter varying between 8000mm at top to 9000mm at bottom. The conical portion was provided between EL 28.50m and EL 18.50m. The conical portion was fabricated using 8mm thick plates- SS409M.

The mill and bunker building (Figure 2) which houses the bunkers is a structural steel building 12000mm wide, 47500mm high and 57000mm long. This building has portal frames in the transverse direction. Each portal frame has two columns along grids C and D at 12000mm centers. All the columns along grids C and D are vertically braced. The building has two major RCC floors and a RCC roof. The RCC floors and roof are cast on structural steel floor beams. The floor at EL 12.700m is the feeder floor which supports the gravimetric feeders. Coal stored in the bunkers above this floor is taken to the mills below through the gravimetric feeders.

At EL 39.95m is the Tripper floor. Coal is dropped into the bunkers placed below the tripper floor with the help of coal trippers that move on this floor. The roof for this building is at EL 47.50m. The Mill and bunker building also has structural steel floor framing beams at EL 25.750m which is the bunker supporting floor.

Figure 1: Picture showing the bunkers in Mill and Bunker Building

Bunker Supporting Arrangement

General arrangement of the bunker is shown in Figure 3. The cylindrical portion of the bunker was fabricated with 12mm plates; however the bottom 2m height of cylindrical shell was fabricated from 20mm thick MS plates. A horizontal flange of 400mm width and 32mm thickness was welded to the 20mm cylindrical shell bottom. The 20mm cylindrical web and the 32mm flange form a skirt girder. The circular flange plate of the skirt girder rests on 6 stub columns which rise from the mill and bunker building framing beams at EL 25.750m. These stub columns transfer the entire bunker vertical loads due to self-weight and stored coal weight to the Mill and bunker building through the framing beams. The top cylindrical portion of the bunkers is connected to the...
building framing at three elevations with plan bracings to transfer horizontal wind and seismic loads.

**Hopper Supporting Mechanism**

The conical bottom portion of the bunker is welded to the 20mm cylindrical shell internally. As the bunker is around 20m in height and 8m in diameter, single piece erection of the bunker would be difficult. The bunker was to be erected in two pieces- Cylindrical shell first and hopper portion next. To help with the site erection of the bottom hopper portion, a circular sloping 16mm thick plate which is 750mm wide and whose slope matches the slope of the hopper is shop welded to the inside bottom portion of the cylindrical shell. This sloping annular plate acts as a seating bracket for the hopper shell, after it is lowered from top through the cylindrical shell till the hopper can be site butt welded to the top cylindrical portion of the bunker. This bracket plate has erection holes for counter sunk bolts. These erection holes in the bracket plate have matching holes in the conical shell for fitting and matching and to help with easy/ correct erection of the conical shell. The topmost piece of the SS conical hopper shell which is around 160mm wide, 8mm thick is shop welded to the cylindrical shell just above the bracket plate. This is done so that the top diameter of the loose conical shell piece which has to be site erected by lowering through the top cylindrical shell can be less than the diameter of the cylindrical shell, so that the hopper can be easily lowered through the cylindrical shell. The conical shell piece is site butt welded to this top 160mm wide piece of the conical shell plate. The bracket plate will also act as a backing strip for this weld. This weld is a very important weld and needs to be carried out carefully and has to be radio graphically tested to ensure its strength, as the entire hopper load gets transferred to the skirt girder through this weld. In other words the hopper actually hangs from the skirt girder through this weld.

**Erection Procedure**

The erection procedure that should have been followed is explained below:

1. The Mill building framing should be completed and six stub columns for transferring the bunker load to the building structure should be erected on the mill building beams at EL 25.750m.
2. The top cylindrical bunker portion with seating bracket plate and top 160mm wide SS conical shell plate welded at shop internally to the cylindrical shell should be placed on the six stub columns.
3. The conical shell should be lowered from top through the cylindrical shell and placed on the bracket plate and matching of erection holes finished.
4. The gap between the 160mm SS shop welded plate and the conical shell plate should be welded at site with square butt weld. The bracket plate should act as backing strip for this weld.
   - For this, continuous contact of conical shell with bracket plate should be checked and ensured. This site square butt weld should be radiographically tested.
5. The plan bracings between bunker cylindrical shell and building should be completed.
Reasons For Failure

During site visit after the failure following were observed:-

1. Conical hopper portion of the bunker was found detached from the top cylindrical portion of the bunker at the location of the square groove field butt weld that was carried out between the two SS 8mm hopper plates.

2. The 16mm thick bracket plate and the top 160mm wide SS 8mm thick plate were found intact and welded to the cylindrical portion of the bunker after the failure.

3. The top portion of the conical hopper had vertical cut marks that were found welded. After discussion with the site engineers it was established that the contractor had erected the conical hopper portion from bottom and not from top.

As the hopper was erected from bottom and not lowered from top through the cylindrical shell, it was difficult to push in the larger diameter of the conical shell to the smaller diameter of the bracket plate that had been shop welded to the inside of the cylindrical portion of the bunker. Hence the contractor had vertically cut the top of the conical hopper at a few locations and crimped the conical shell at top so as to push the conical shell inside the annular bracket plate. Later the conical shell was opened. This resulted in the conical shell not sitting properly on the bracket plates and thereby not properly aligning to the top 160mm wide SS plate. The bunker conical piece was held in position from below and then the square butt weld between the two unaligned shell pieces was carried out. There would have been gaps between the bracket plate and the conical shell. This was also observed at site for the other bunkers that had not failed during the site visit. Due to this faulty welding, the weld had given way and the conical portion got detached from the cylindrical portion.

Rectification Scheme

All the hoppers of the plant were erected from bottom as mentioned above. Gaps between the seating plate and the hopper plate for bunkers that had not failed were observed at site during site visit. There was an apprehension that all the hoppers were not welded properly to the cylindrical portion. Hence a rectification scheme was developed to provide alternate supports to the bunker hoppers that had not failed. The rectification work had to be carried out at site without disturbing the erected bunkers and without stopping plant operations, hence alternate supports were provided to the hopper and no attempt was made to rectify the faulty weld.

As per the original design the entire hopper was to be hanging from the web of the skirt girder and all hopper loads were to be transferred to the skirt girder through the butt weld between the web of skirt girder and the hopper skin plate. As this weld was suspect, it was necessary to shift the support location of the hopper from web of skirt girder. To achieve this following structural arrangement was provided (Figure 4):-
(I) 16mm thick annular pad marked “4” was welded to the outside of the bunker hopper skin plate at the level of the skirt girder flange. As the bunker hopper plate had bulged and was not at the proper location and did not have proper alignment, it was necessary to make site measurements and custom fabricate the pad to fit the conical shell so that the pad plate can be welded to the conical shell.

(ii) 16mm thick annular plates marked “2” and “3” were then welded to the bottom of the flange of the skirt girder and was butt welded at the other end to the above provided annular pad marked “4”. By doing this an additional support was provided to the hopper from the bottom flange of skirt girder.

In this arrangement due to large distance between hopper support point and center line of skirt girder, torsion gets induced in the skirt girder. Detailed analysis was carried out to check adequacy of the suggested modification against torsion.

(iii) To take care of this torsion, a 16mm thick plate 400mm long marked “1” was welded vertically to the flange of the skirt girder, thus creating a horizontal ring beam along with item “4”, item “2” and existing skirt girder flange.

(iv) To take care of torsion in the above mentioned ring beam, stiffeners 16mm thick marked “7” were welded to the bottom of ring beam. Additional 16mm thick stiffeners marked “6” were also welded vertically to the skirt girder.

(v) At locations of the six load transferring stub columns, 2-MC150 box bracings marked “5” were introduced to form six brackets to additionally support the hopper at six points. By providing these additional supports there was fear that the bunker plate would get stressed and would probably deform excessively. Detailed analysis was carried out to check stresses and deformations at the six supports.