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DETERIORATION AND REPAIR OF CONCRETE STRUCTURES IN THERMAL POWER PLANTS

S.R. Karade, A.K. Mittal, P.C. Thapliyal and S.P. Agrawal

Central Building Research Institute
(A Constituent Establishment of CSIR),
Roorkee-247667
srkarade@cbri.in

Abstract

In India more than half of the electric power is generated in coal based thermal power plants. In addition, new thermal power plants are also being constructed to meet the growing demand of electrical energy. Concrete structures in these thermal power plants are exposed to a wide range of aggressive conditions causing deterioration. To minimise interruptions in power generation and to maintain the efficiency of the power plants, it is important to protect the structures and maintain them properly. In this paper the type of concrete structures in coal fired thermal power stations and the causes of their deterioration are discussed. The work done by CBRI for the health assessment and repair & protection of these concrete structures is also reported.

INTRODUCTION

The present installed capacity of power generating units in India is about 1,45,588 MW. The share of state sectors in power generation is about 53%, while central sectors have 34% and private sectors have 14% (Ministry of Power, 2008). Out of total electric power generation in the country, share of thermal power is around 64.6%. Coal based thermal power plants alone are sharing around 80% of this thermal power generation. In the Eleventh Five Year Plan addition of 78,000 MW is planned, which include 52905 MW power would be generated from coal based thermal power plants (NTPC, 2007). Presently, there are about 120 coal based thermal power plants in India. With further addition of new power plants the maintenance of the infrastructures will be a huge task in future. The performance of the structures is affected by various factors such as temperature, humidity, water and airborne pollutants, and mechanical damages. In coal based power plants the burning of coal produces a very corrosive atmosphere. The exposures conditions vary from acidic to alkaline. Concrete structures of the existing thermal power plants are deteriorating at an alarming rate due to these exposures. Different types of repair materials and protective coatings are required for their repair and maintenance. Currently, suitable combinations of materials like cement, fibres, latexes, alkyds, epoxies, urethanes, and others are being used, depending on the power plant type, its specific location and exposure environment.

Large number of structures/structural elements are made of concrete in coal based thermal power plants, which include chimneys, cooling towers, water treatment plants, coal handling unit (CHP), buildings and machine foundations. The characteristics of these structures and causes of deterioration are discussed in this paper.

COAL HANDLING PLANT (CHP) STRUCTURES

Coal handling plant is an important part of a coal fired thermal power plant. Generally CHP receives coal by four modes: railway, roadway, airway (by ropeway direct from coal mines) and ship transport. The coal is unloaded at various unloading station as per receiving mode and transported by conveyors to crushing and screening plant via transfer house. After crushing, the required quantity of coal is transported to bunker and the remaining coal is stored in stockyard. From the bunker the coal goes to coal mills and then to boiler furnace.

In CHP the design of coal unloading system depends on the location of the coal source and mode of transportation. Railway is the dominant mode for the plants far away from the coal mines. Generally there are two types of coal unloading systems in use: Merry-Go-Round (MGR) and Wagon Tippler. In MGR system the coal is unloaded from wagons with bottom doors, which are pneumatically operated. Coal from the wagons is unloaded in the underground track hoppers and then sent to crusher house with the help of conveyors. In wagon tippler type system (Fig. 1) coal is unloaded by tilting the wagons with help of wagon tippler into the wagon tippler hopper and then fed to the crusher house with the help of inclined belt conveyors.

The structures in a CHP include unloading hoppers, reclaim hoppers, inclined belt conveyors, transfer towers, vibrating screens, magnetic separators, crushers, weighing machine, silos and dust collecting system. Crusher house (Fig. 2) is a building, which houses roller screens and coal crushers. Thus, it is subjected to mechanical vibrations and exposure to coal dust. Most of the conveyor belt support structures are made of steel with the columns standing on concrete foundations. The concrete is damaged mechanically mostly by impact of various objects and vibrations. In general, CHP structures are exposed to dusty, dirty and often wet conditions. They are also sometimes exposed to accidental fire in the coal. The signs of deterioration observed in these structures are structural cracking, concrete spalling and reinforcement corrosion.

WATER SYSTEM STRUCTURES

The water system in thermal power plants includes the pre-treatment and clarification plant, demineralisation (DM) plant, cooling towers and effluent treatment system. DM plant is used for supplying clean and soft water to boilers for steam production. The water produced contains negligible impurities and ensures a longer life and better efficiency of the boilers and their components. This plant uses ion-exchange processes for water treatment. In this process, for the regeneration of the ion exchange beds carried out using strong acids and bases. These chemicals are very aggressive to the linings and other construction materials (Fig. 3). A concrete column exposed to such condition is shown in Fig 4.

The role of cooling towers is to extract heat from the circulating water coming from the boilers and emitting it to the atmosphere. Cooling towers can be classified in two main categories: natural draft and mechanical draft. In cooling towers the water falls downward over finned surfaces increasing the contact time between the water and the air, which leads to maximum heat transfer efficiency of the cooling tower.

The hot and humid condition in cooling towers deteriorate concrete elements leading to cracking, delamination and spalling (Fig. 5 & 6). The vapours provide moisture for the corrosion of the embedded steel reinforcement particularly in higher and outer parts of concrete shells in the cooling towers.

CHIMNEY

Chimneys in the coal-fired power plants generally have an outer shell made of reinforced concrete and an internal fire resistant lining system, which protects the inner surface of concrete shell from high temperature and protect it from chemical attack by acidic components of flue gases. Imperfect and damaged lining of the chimney allows the inner surface of the concrete shell to expose to flue gases, high temperature, humidity fluctuations, and eventual moisture condensation. The corrosion in the concrete in such environment is mainly due to chemical reactions of carbon dioxide, sulphur dioxide and trioxide, nitrogen oxides and vapour with the products of cement hydration producing calcium carbonate and sulphur-bearing compounds (Pavlik et al., 2007). The deterioration in concrete shell increases with the height (Fig 7). Some of the commonly observed symptoms of deterioration are stains, cracking and spalling of concrete. This enhances the exposure of concrete shell and further deterioration takes place. The platforms at different heights are also damaged and finally dropped due to misplacement and/or corrosion of reinforcement (Fig. 8).

WORK DONE AT CBRI

Central Building Research Institute (CBRI), Roorkee, has taken a number of projects on health assessment and repair of thermal power plant structures throughout the country e.g. NTPC, Badapur and Kanti Bijlee Utpadan Nigam Ltd., Muzzaffarpur. The health assessment is done using various non-destructive testing

(NDT) methods. Besides these, the institute has developed various patching materials, reinforcement coatings and grouting materials, repair mortar and coatings for steel and concrete structures over the years (Aggarwal, 1996; Aggarwal et al. 2007a & b; Asthana et al. 1999; Karade and Agrawal, 2007; Karade et al., 2005 & 2006). The coatings developed by CBRI are epoxy-cardanol system for concrete and steel structures and for reinforcing bars used in RCC and an acrylic based for concrete structures. An epoxy latex is also developed to use as a bonding agent and for repair mortar for concrete structures. The institute has facilities available for testing of different materials like grouts, sealants, coatings, mortars, concrete and composites.

The repair materials i.e. bonding agent, polymer modified mortar and coatings developed by CBRI have been used in the field for the repair and protection of concrete structures in thermal power plants like NTPC, Badarpur (Fig. 9) and in Kutch (Gujrat). The properties of cardanol epoxy coating used in chimney in NTPC Badarpur have been compared with those of epoxy based coating in Table 2 (Aggarwal et al. 2007c). The coatings developed by CBRI have been applied on some important commercial buildings, flyovers and railway bridges including the MTP Railway Bridge in Chennai. Besides these, corrosion resistant coatings developed by CBRI have been used to coat reinforcement steel in number of structures throughout India.

Various projects have been undertaken by CBRI to study the deterioration of structures in the thermal power plants and to suggest preventive and strengthening measures. The repair schemes in these plant structures generally use the materials developed by CBRI and include the following steps:

1. Removal of the disintegrated/ loose concrete and cleaning of the concrete surface and exposed reinforcing bars.
2. Application of a corrosion inhibiting coat, which may be comprised of a corrosion inhibitor or migrating corrosion inhibitor and coating on reinforcement.
3. Bond coat of a polymer modified cementitious material or an epoxy-cardanol coating.
4. Application of patching materials made of polymer modified cementitious mortar based on epoxy latex/acrylic or epoxy mortar.
5. Surface protective coatings using one of the coating systems like those based on epoxy- cardanol resin.

So far the field performance of these repair materials is satisfactory. Further study towards development of repair materials with resistance to high temperatures is in progress. Efforts have also been made to develop protective coatings with superior chemical and corrosion resistance properties.

CONCLUSIONS

The number of deteriorating concrete structures in coal based thermal power stations is increasing day by day. These structures are deteriorated mostly by acidic coal dust and flue gases. Studies have been undertaken by CBRI to assess the extent and causes in some of the concrete structures in the power stations. The performance of the repair materials developed by CBRI and used in these structures is satisfactory so far.

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Table 1 Installed capacity of power generating units in India*

Fuel	Capacity in MW	%
Total thermal	93,114.64	64.6
Coal	77,198.88	53.3
Gas	14,716.01	10.5
Oil	1,199.75	0.9
Hydro	36,158.76	24.7
Nuclear	4,120.00	2.9
Renewable	12194.57	7.7
Total	**1,45,587.97**	**100.0**

* Source: Ministry of Power as on 30 July 2008

Table 2 Properties of epoxy based coating systems

Coating	Epoxy	Epoxy-cardanol
Tensile Strength, N/mm^2	16.8	18.2
Elongation, %	18.6	15.4
Water Vapour Transmission, $mg/cm^2/mm/24h$	0.19	0.14
Bond Strength, MPa	5.6	4.4

Figure 1 A wagon tippler used for unloading coal from the wagons.

Figure 2 A crusher house building

Figure 3 Erosion of plaster in effluent drains

Figure 4 A column showing extreme deterioration due to corrosion in a DM Plant

Figure 5 A deteriorated wall of cooling tower.

Figure 6 Another view of the cooling tower.

Figure 7 Deterioration of outer surface of concrete chimney

Figure 8 Damaged platforms of the chimney

Figure 9 A chimney after repair and coating