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Disaster Management for Cooling Tower- Case Study.

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ABSTRACT
Cooling towers are prone to numerous disasters that can arise naturally or through human intervention. The safety of cooling towers becomes utmost importance for the plants to function properly. The study focused on identification of various disasters and the risks associated with them. The disasters can be earthquake, volcanoes, storm, extreme temperature, fire incident, terror attack, hazardous material leakage etc. The impact and vulnerability analysis of these disasters is conducted to find the associated risks properly. Mitigating risks is as important as identifying them. The two most important risks identified are Design Risk and Bacterial Risk. The preparedness to these risks helps in mitigating them. A probabilistic catastrophic risk model has been identified which performs a cost benefit analysis for mitigating the risks.
Keywords: *Disaster management, Cooling tower, Natural Disaster, Manmade Disaster, Disaster risk reduction.*

I. INTRODUCTION

Cooling towers are heat rejection device, which extracts waste heat to the atmosphere though the cooling of a water stream to a minimum temperature. The type of heat rejection in a cooling tower is termed "evaporative" in that it allows a rest of that water stream, some portion of the water being cooled to evaporate into a moving air stream to significant cooling is provided to the rest of that water stream. Heat from the water stream transferred to air stream raises the air's temperature and its relative humidity to 100%, this air discharged to the atmosphere. Evaporative heat rejection devices commonly used as cooling towers to provide lower water temperatures than achievable with "air cooled" or "dry" heat rejection devices, as like car radiator, thereby achieving most cost-effective and energy efficient operation of systems in need of cooling.

Disasters are too much old as human history but the dramatic increase and the damage caused by them in the recent past was becomes cause of national and international concern. Over the past decade, the number of natural disasters and man made disasters has climbed enormously. Disaster now is considered as the main obstacle in the security and sustainability of the country it causes huge loss to life, material and environment.

II. TYPES OF DISASTERES THAT AFFECTS COOLING TOWERS

A. Natural Disaster

- **Earthquake** – Reinforced concrete (RC) cooling towers, which comprise of a thin concrete shell of revolution, are common place in civil engineering structure that is concerned with the generation of electric power. Size and the catastrophic ramifications are cause of their collapse, it is imperative to consider all possible conditions of loading in design for RC cooling towers, and in many nations earthquake loading is the most critical loading factor. Power plants are required to provide post disaster functions and so cooling towers in these situations must remain viable and robust infrastructural components to following a strong earthquake. Vigorous industrialization over the last few years has seen the construction of a number of large RC cooling towers, and severe catastrophic earthquakes that have bedeviled the nation and its neighbors recently owing to its location within the Alp-Himalaya fault zone are widely known. Because of this, research into seismic behavior has a national priority in structural engineering, and in particular studies of the behavior of RC cooling towers under the earthquake excitation are undertaken by several researchers. Despite the importance of research into the structural response of cooling towers, are thin shell structures and which therefore possess the well-known and often poorly predicted attributes for imperfection-sensitivity and like, the research on their response to extreme loading of wind and earthquake excitation reported in the archival literature has not been overly comprehensive. The main reason of this relative dearth of research undoubtedly lies in the difficulty of modeling cooling towers numerically, in particular the difficulties of analyzing cooling towers utilizing many shell elements in a finite element framework which often renders a multi degree of freedom problem intractable because of the interactions of geometric and material non linearity, and in particular with the difficulties that are associated with concrete as a material when cracks, thermal effects, creep, shrinkage and tension stiffening need to be addressed in the analysis. Earthquake-related studies of Reinforced Concrete cooling towers are still quite restrictive in the literature, despite their importance and relevance to engineering practice and to recent global seismic events. The key damage that may occur to cooling towers during an earthquake is the impact on column elements in a cooling tower in maintaining an integral structure under earthquake excitation. Finite element modelling is the one used in designing RC cooling tower structure, with particular focus only on columns in the structure.

- **Volcano:** The volcanoes can impact the structure of cooling towers which can result in collapse of the cooling tower.
- **Rock fall / Landslide:** The landslide can impact the structure of cooling towers which can result in collapse of the cooling tower.
- **Storm (Tropical Cyclone, Extra-tropical Cyclone and local Storm):** The towers can lose their structural integrity and could no longer hold their shape under impact of storm this will lead to collapse of cooling tower.
- **Flood:** Although the impact of flood on cooling towers is minimal, we cannot eliminate it as disaster as floods can impact the functioning of cooling tower in short term and in long term can lead to corrosion inside the inclined columns and ring beams.
- **Legionella in cooling towers:** Biggest risk of Legionella infection occurs when people breathe in minuscule droplets of infected water. Evaporative cooling towers spray minuscule droplets on their fill for maximum heat transfer and by doing so possible create a health risk. To prevent cooling towers from becoming this public health risk, good manufacturers chose a two way path preventing Legionella spreading: Preventing droplets from leaving the cooling tower and preventing Legionella accumulation in the system. To prevent droplets from leaving the tower, cooling tower manufacturers employ drift eliminators. As long as these are well designed, intact and properly maintained, Legionella shouldn't be a big risk, even is the tower is badly infected. Naturally, Wacon International's Central Deck drift eliminators are well designed and tested many times and fit even the highest quality standards. We will provide ample documentation on checking and maintaining the drift eliminators to be included in the normal maintenance routine of your plant. It is a common misconception that plumes could be Legionella infected. A plume condenses above the cooling tower from air and is pure H2O. Preventing Legionella accumulation in water systems is a little trickier. Wacon International's cooling towers are, of course, designed to prevent still water and to minimize the growth of Legionella. However, it is still possible they accumulate Legionella bacteria when badly maintained, not cleaned or when they are connected to an infected water system. We will provide ample documentation on checking, maintaining and cleaning the cooling towers to be included in the normal maintenance of your plant.

B. Man Made Disasters

- **Fire due to human fault:** The accidental fire at cooling towers can result in big disasters. If some hot job is going on near cooling tower then the hydrocarbons being released through cooling towers can catch fire which can lead to series of incidents such as motors not working properly, sensors getting damaged, nearby facilities catching fire and shutdown of plant itself. Fire can spread to cooling towers from nearby buildings also, if some nearby vicinity catches fire it can spread to cooling tower leading to its shut down. Hence, proper measures for making cooling towers fire resistant are necessary.
- **Explosion and Terror Attack:** Cooling towers are thin-walled structures. It can be expected that the height of a super-large cooling tower in a nuclear power plant will be more than 200 m in the near future. Along with the increase of the height of cooling towers, the damage probability of super-large cooling towers subjected to accidental loads will also increase. However, previous designing experiences for towers that are at most 165 m high are not enough for new super-large towers. Once these super-large cooling towers collapse, the safety of the nearby buildings and structures, especially the relevant nuclear facilities around the cooling towers can be threatened. Some of the prominent terror threats to the cooling towers are explosion at the bottom of the tower and the missile attack. Explosive attack can also cause a cloud of dust which will travel in the direction of the wind, which can change at any time.
- **Vehicle and Airplane Attack:** Similar to explosion and terror attack, the vehicle and airplane attack can damage the structure and can induce the collapse of cooling towers which consequently increases the risk for nearby

buildings and structures. Although the world has not seen any airplane attack post World trade centre but the risk of Airplane attack or for that matter Vehicle attack cannot be underestimated. So it's become very important to take into account these accidental loads when we carry out the design phase of the cooling towers. The importance of cooling tower in power plants and the modern society dependency on power makes it extremely imperative for cooling towers to be resistant to these manmade attacks.

- **Chemical Threat:** The accidental leakage of chemicals in the cooling tower system can trigger the process of fouling and corrosion.
  In refrigerant to water condensers, heat is rejected from the refrigerant side to the water side, which often circulates in cooling tower loops. Since large amount of inversely-soluble minerals, such as calcium and magnesium contained in the water loop, due to the evaporation process, water became concentrated. When the concentrated water is heated up by the refrigerant inside condensers, the solubility of the minerals decrease and precipitation occurs. Aside from precipitation, other fouling mechanisms are particulate fouling, biological fouling and corrosion fouling. Cooling tower water is often pre-treated with biological and corrosion inhibitors, so the last two types of fouling mechanisms might be controlled. Minerals concentration, especially calcium concentration was reported to be a main driving force of fouling in heat exchangers.

Figure 1: Fouling in Cooling Tower

Cooling towers are expose materials to a uniquely environment where corrosion poses exceptional challenges. Each cooling tower endures the combined corrosive effects of uncertain water chemistry, high temperatures, and continuous natural aeration. In addition, many towers must also contend with potentially harmful agents in their circulating water and variety of airborne pollutants such as sulphur oxides (SOx) and acid rain. Careful selection of materials significantly retards or prevents the detrimental effects of corrosion. Effective maintenance and treatment can help to increase the life of any cooling tower. Corrosion is defined as the chemical reaction of free elements, ions amd compounds (either airborne or in aqueous solution) with base materials of construction, causing either loss material weight or physical properties. By this very general definition, rust on steel components and chemical reactions on poorly selected polymers are considered forms of corrosion. In the most general terms, corrosion is likely to occur base material is exposed to a chemically or electrolytic ally incompatible substance which must be present in sufficient concentration to initiate reaction, over a sufficient time for the reaction to proceed appreciably, and at conditions where the reaction will occur spontaneously—that is, without the addition of an external catalyst or an external heat source. Proper material selection involves a careful review of the specific corrosive agents likely to be present in a given tower, the conditions occurring in the tower, and the chemical and physical properties of the materials being considered.

Cost Saving Intention: The cooling towers are huge devices with sizes. The structures are made of reinforced concrete or wood. In most of the refineries and fertilizer plants in India wooden cooling towers are being used due to lowest capita cost.

Figure 2: Wooden Cooling Towers

Cooling towers are most critical utility elements as the complete process cooling water requirement depends on them. Wooden cooling towers can be attributed to collapse for following major factors:

- Failure of wooden support structure: The sheer weight of the huge distributor pipe (Approx.80 meters in length, Diameter ranging from 52" to 24") running over the deck with the mass of water in it can lead to collapse in case of failure of the wooden support structure.
- Failure of vertical riser pipe/joint due to corrosion: The corrosion can weaken the vertical riser pipe leading to the collapse of cooling tower.

2.3 Risk Associated with Disasters

The study of disasters on the cooling towers has led us to identify the risks. The two prime risks associated with any of the disasters be it Natural or Man Made are Design Risk and Bacterial Risk.

Design Risk: The design include the functioning and operation of cooling tower. The design part covers all the area ranging from structural design to proper functioning of key components such as Sensors, Fan and Fan motors, Water Basin, Drift Eliminators etc. The most important of all these is the Structural Design of the cooling tower. The design should be such that it should be able to mitigate the collapsing and malfunctioning risks arising from the disasters such as Earthquake, Storm and Explosion etc.

Bacterial Risk: Due to release of Hazardous material from cooling tower**,** Legionella infections caused, become one of the prime concerns as Design failure can lead to closure of plant and has financial impact whereas the bacterial risk leads to a greater social unrest with its effect on the community residing in the vicinity of plant. Thus the proper study towards this risk becomes very important before commissioning of the cooling tower.

III. CASE STUDY

A. Ferrybridge Cooling Tower Collapse

On November 1, 1965 at the Ferrybridge power station near Pontefract, England three of the largest natural draft cooling towers in the world collapsed during a gale force wind. The cooling towers at Ferrybridge, operated by Britain's Central Electricity Generating Board, were structurally complete but not in operation. The wind stretched the reinforced concrete membranes of the towers beyond their structural capacity, causing the concrete to vibrate at a high – pitch and ripple into waves. The upper rim and the side sections ultimately buckled into the centre of the towers.

Cooling towers play a critical role in power generation by providing low temperature water for use as a coolant within the power plant. The eight towers at Ferrybridge power station were "natural draft" towers, which cool water by spraying it through cooler air into large concrete tubes. The hourglass shape of natural draft towers and the warming of the air by the water draw the air up through the concrete tube without the aid of fans, like smoke up a chimney. Differences in water and air temperature and heat losses during evaporation cool the water. The cooled water then pools at the base of the tower and is re-circulated to the power generating station.

The cooling tower at Ferrybridge rose 375 feet above the collection pools, spanned 290 feet in diameter at the base, and weighed total 8,000 tons. They were "thin shell" towers, with concrete structural membranes only five inches thick. In contrast, the shell of an egg as large as Ferrybridge tower would be 25 inches thick. The eight towers at Ferrybridge were grouped into two rows of four, staggered into a checkerboard pattern. They were spaced closer together than towers in previous designs to take advantage of a "pillar of support", a localised area of superior foundation material.

Britain's central electricity generating board, an acknowledged leader in thin shell concrete cooling towers, did not venture into innovative design or construction with the Ferrybridge towers. Although these cooling towers were the largest to date, the increased size represented only a minor extrapolation from similar towers constructed two year before. The board had contracted the design and construction of Ferrybridge towers to film cooling towers ltd. at an estimated cost of $700,000 to $840,000 each. Film cooling towers concrete ltd. had subcontracted the design to the consulting firm of Messrs. C. S. Allott and Son. The series of design and construction contracts left some ambiguity as to which parties were ultimately responsible for the design of the towers.

Details of the Collapse:

A strong wind blew against the cooling towers at the Ferrybridge power station on November 1, 1965 creating a windward and a leeward row of towers. This wind was later estimated to have travelled at 76 to 84 miles per hour at 33 feet above the ground, and at 93 to 104 miles per hour at the upper rim of the towers. As the wind pushed past the towers in the windward row, it was funnelled through the spacing between them onto the windward faces of the second row of towers.

Figure 3: FerryBridge Cooling Tower Collapse

This pressure caused the leeward towers to lean away from the windward towers, stretching their windward sides in the way that leaning from the waist stretches muscles on one end. At the same time, updraft through the towers created a force that tended to lift the towers off their foundations. This lifting action reduced the effective weight of the towers and increased the stretching of the concrete shells. The resulting vibration of the enormous concrete towers produced a high pitched whine that was reported by observers to resemble “someone rubbing a finger round the rim of wineglass.”

The wind eventually stretched the windward sides of three of the second row cooling towers beyond the strength of the steel reinforcing in the concrete shells. The towers lost their structural integrity and could no longer hold their shape. Initially, the upper rims of the three cooling towers buckled into the tower centres. The windward sides collapsed into the tower centres in turn, dragging in the adjacent side sections of the structures.

Three leeward towers collapsed in the fashion. Although the failures were sudden, they were not simultaneous. The first tower failure occurred at 10:30 A.M, the second about 10 minutes later and the third at about 11:30 A.M. A spectacular photograph was taken from the windward side of one of the towers during collapse, showing the overstretched windward side of the tower dragging and twisting the adjoining sections inward.

IV. CONCLUSION

Cooling towers are devices used o cool industrial processes and applications to ensure that the correct temperature of the environment and the process are maintained during manufacturing or large industrial processes. The need for cooling towers is when heavy industrial machinery overheating during the production / manufacturing process leading to unnecessary maintenance costs. Industrial cooling towers have come a long way since then. With the faster growth of industrialization in India, these towers are used in a wide variety of companies and industries across the country. A number of towers are used depends on the machines used in industries. Cooling Towers are able to give an absolute resolution for industrial cooling requirements. Cooling towers plays an important part in different industrial sectors - from energy and power generating plants to cement, pharmaceutical, pulp and paper, petrochemical, and other industrial developing services.

These cooling towers are exposed to numerous disasters either natural or manmade. The disasters range from earthquake, landslide, storm, volcano to terror attack such as explosion and airplane attack. The hazardous material released in air by the cooling towers also poses a serious threat to health of society. The two prime risks identified to be associated with these disasters are design risk and bacterial risk. While both risks are fatal but the impact of both of these is different. The destruction due to design risk poses a more financial side implication whereas the destruction due to hazardous material poses a threat of mass killing by affecting the people living in vicinity. As disasters are uncontrollable we need to mitigate these risks via adopting the process of preparedness. To mitigate the hazardous material risks control strategies has been formulated for stagnant water risk, Nutrient growth risk and poor water quality risk, Deficiencies in the cooling water tower risk and location & access risk. The mitigation has to be done only if the cost benefit analysis for the particular hazard comes to be positive. The probabilistic catastrophic risk model is used for cost benefit analysis and it adds more value than deterministic approach.

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