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Case Study

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STRUCTURAL UPGRADE OF A DEFICIENT STEEL STRUCTURE USING AN INTEGRATED RELIABILITY-BASED APPROACH

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1 Project Overview and Innovation

Aside from member-by-member utilization checks for code compliance, the current North American design codes and standards lack guidance for evaluating the actual global state of deficiency of steel structures when subjected to excessive environmental loads. Amec Foster Wheeler developed a unique approach to quantify the overall condition of a Coker tower (Figure 1 (a)) subjected to service and design wind loads. The novel approach allowed the required repairs to be performed in phases, with an increased safety limit at the completion of each phase.

2 Methodology

The adopted iterative approach is illustrated in Figure 1 (b). Field assessment was conducted to identify the damaged members and to qualify the extent of corrosion. Nonlinear pushover analysis was then conducted to determine the actual capacity of the structure. The capacity of the structure and the magnitude of the applied wind load were input to an in-house reliability assessment algorithm to determine the reliability index of the overall Coker tower, and compared against the target value. Where the calculated reliability index is less than the target value, a structural upgrade was designed to enhance the structural capacity. An iterative procedure was followed to achieve the target reliability index of 3.0.

2.1 Field Assessment

The initial assessment of the structure included a field review of all visually accessible primary members and connections followed by traditional structural analysis. The primary members and their connections were inspected for indications of mechanical and corrosive damage. The reduction in member thickness due to corrosion was projected for the end of the design life. Those areas of the structure where relatively high corrosion were evident were tested by ultrasonic methods. Findings were incorporated into the structural analysis model with reduced sections due to corrosion included and mechanically damaged members rendered inactive.

2.2 Pushover Analysis

The pushover analysis was utilized to determine the overall capacity of the structure under applied wind load. The pushover analysis was conducted using SAP2000. The structure was subjected to a monotonic wind load which increased iteratively, through a displacement-controlled mode, to indicate a range of elastic and inelastic performance. Axial plastic hinges were assigned to each end of all members in the Coker towers. All braces in the towers were designed to fail by shearing off the bolts at approximately 75% of the member strength. The plastic hinge property in compression was selected to reflect the brittleness and uncertainty in the member response upon buckling. The program default flexural plastic hinge characteristic was assigned to the mid-span of all members in the towers.

2.3 Reliability-Based Assessment

The results of the Pushover analysis was utilized in conducting a structural reliability assessment with the purpose of determining the reliability index, and compare it with acceptable levels defined by the structural codes and literature. A target Reliability Index of 3.0 satisfies the fundamental safety requirements of the design codes. An in-house Reliability-Based algorithm was utilized for the calculation of the Reliability Index of the Coker structure with the current repairs. The input parameters for the wind load coefficient of variation are based on the work by Bartlett et al. (2003), which formed the basis for the calibration of the wind load factors for the ABC 2014.

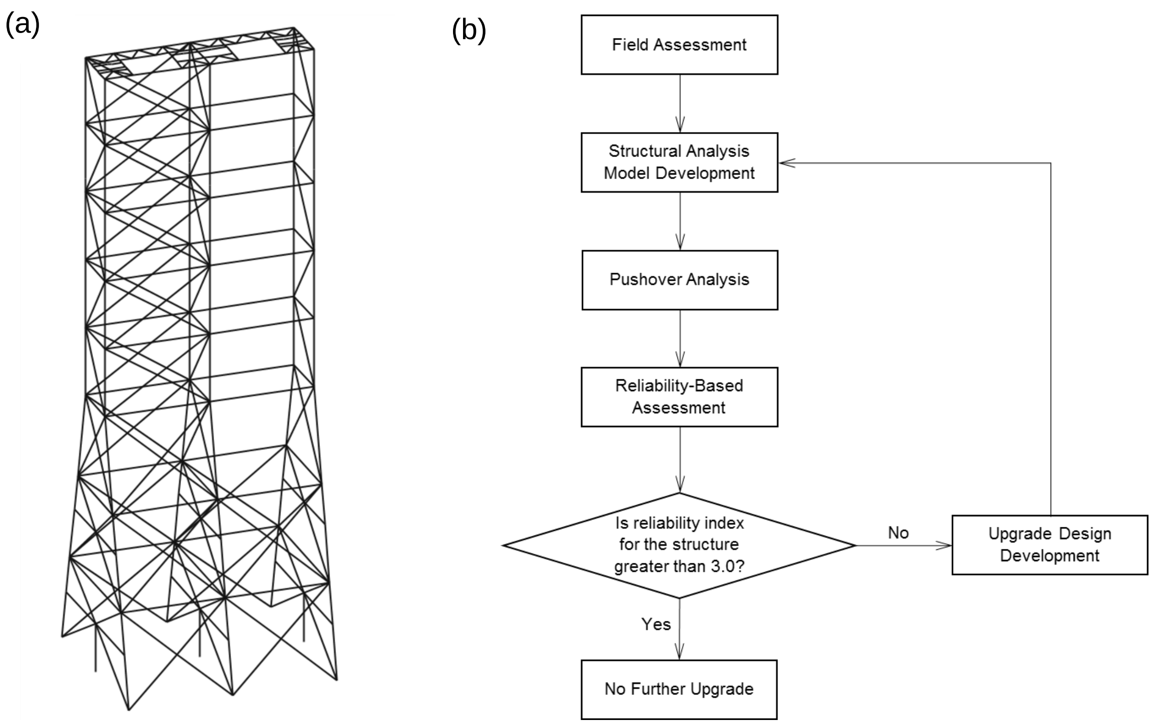

Figure 1. (a) Coker tower (b) Adopted methodology

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