Engineering Failure Analysis 83 (2018) 125–130

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Metallurgical analysis of the collapse of a telecommunication tower: Service life versus capital costs tradeoffs

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ARTICLE INFO

Keywords:
Communication tower
Material selection
Service life
Cost

ABSTRACT

Introduction: Despite knowledge and expertise nowadays, minimizing capital costs may continue to be the remote cause of failure of many engineering structures. Failure analysis of a telecommunication tower, which collapsed during a thunderstorm recently in a public institution, was carried out in this work.

Method: The service history was obtained, and the design, fabrication and the material selection were scrutinized along with standard specification for such structure and microstructural examinations were done.

Results and discussion: The material choice, joint design and weld fabrication allowed differential aeration cells and heat affected zone stress induced corrosion at the welded endplate joints on the structural members. External painting was of no use because while the structure was intact outside, the pipe had the option of corroding from inside due to differential aeration cells. Galvanizing also is sacrificial and consumed interior coating cannot be replaced in-situ. As materials degraded, stresses concentrated. Under wind current, the structure gave up where stress concentrated most. The tower came down after nine years of service, crushing nearby roof and walls. Comparison shows costs factor weighted heavily in the material selection and design, trading off service life.

Conclusion: Remote cause of failure - cost minimization. This reality features in many designs in today's world of ever tighter capital budgets. It appears an index of service life trade-offs for costs is now needed in designs.

1. Introduction

Quality compromise versus assurance is of global dimension, and any institution, community or nation, developing and ignoring emphases on quality, trading it off for whatever reason, overt or covert, does so at its own risk and major losses. Substandard engineering products, production and practices have been a plague in recent times in the society. Ranging from air craft disaster to collapse of private, government and synagogue buildings [17,18,25], and very short service lives of household appliances such as pressing iron, electric clippers and plumbing parts, the root cause is traceable to compromises in procedural and material standard [1,14,20].

Identifying substandard alloys or materials for a particular application is beyond examination with naked eyes. It is a core task of competent professionals. It is not all that glitters that are gold. When a substandard alloy is used in constructions, such as in reinforcement bars in concrete structures, a disaster waiting to happen is being erected. The present case of interest here is about the

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http://dx.doi.org/10.1016/j.engfailanal.2017.09.018
Received 28 September 2016; Received in revised form 26 September 2017; Accepted 29 September 2017
Available online 01 October 2017
1350-6307/

Table 1
Standard regulations for a typical mast and what was done in the failed mast.

Parts	Standard regulation	Failed mast
Brazing	Steel angle cross bracing, Bolted joints	Rolled ribbed rod, Arc welded joints
Masts section	Sections should be made from hollow, heavy duty, thick steel tubes, flanged steel tubes or low-alloy, high-strength steel.	Thin steel tubes, plain low carbon steel pipes
Pipe diameter	Pipe diameter should decrease from bottom to top	Pipes are of the same diameter
Painting	Hot dip galvanizing	Epoxy paints
Base plate joints	Four 20 mm diameter holes drilled to accommodate four 18 mm bolts, nuts and washers.	Three diameter holes without washers
Location	Towers in excess of 25 m in height are permitted, they should be placed at a minimum setback of 5 m distance to the nearest demised property, excluding the fence.	Placed within a quadrangle of building containing offices
Basement	Concrete placement shall be continuous	No continuous concrete basement

collapse of a telecommunication tower in a public institution. In this brief, the standard material specifications for a communication tower are first reviewed, followed by a documentary on the collapsed tower, to present the glaring contrasts. Cost implication of the damage, ethical and professional lapses that the incident is pointing to, are then discussed, to drive home the point for professionals involvement in infrastructure developments.

2. Construction standards for communication towers

Towers and mast have been in use since the beginning of radio communications and broadcasting early last century. Towers are normally self-standing self-supported while masts are guyed by cables fastened to the ground. Towers can be constructed of steels, ceramics and even wood. The Gliwice Radio tower in Poland is a wooden structure erected in 1935 and it is still in use until today (Structurae.net) [23]. Construction and installation specifications have been developed over the years, and applicable and readily accessible reference materials in this regard include the Indian standard tower bolt specification IS 204:199; American Institute of Steel Construction (AISC) specification for structural joints ASTM A325 or A490 Bolts; and the NCC's (Nigerian Communications Commission) technical specification for installation of telecommunication towers and masts [16], covering material specifications, expected service life, painting, obstruction lighting, substructure, earthling, lightning protection, antennae mounting frames, detail superstructures for various sizes of towers up to 100 m, hot dip galvanizing for surface protection, routine and annual tower maintenance checks and tests, among many others.

3. Investigation on the collapsed tower and damages

The tower that collapsed in this instance is a self-standing triangular lattice structure constructed with pipe steel. Table 1 shows some of the regulations required for building towers and what was done in the failed mast. Fig. 1 shows documentary images of the tower after the wreck.

3.1. Material selection

The tower was constructed using 3 mm thick, Ø 77.5 mm carbon steel pipe as the main structural material, and rolled carbon steel as bracing bars. The carbon steels family of materials is broadly divided into low carbon steel, medium carbon steel and high carbon steels, with subdivisions such as mild steel, dead mild steel. With various combinations of composition and structural treatments, there are at least a total of 2714 carbon steel materials covered with various standard specifications (matweb.com) [15]. Composition, microstructures, treatments, properties and consequent suitable application for different carbon steels therefore spans quite a wide spectrum. But judging from the relics (Fig. 1) and the Elemental analysis in Tables 2–3, the pipe used is a low plain carbon steel. This is far from low-alloy or high strength steel recommended for the construction of tower (Table 1). Such pipe steel is commonly used for perimeter fencing, and it is sold in galvanized form. A point of note here is that the base alloy in any galvanized steel product is itself not corrosion resistant, hence the zinc coating to provide sacrificial anode cathodic protection (SACP) on the surface [7,10,21].

3.2. Fabrication

With evidences in Figs. 1 and 2, the tower structure was put together by welding 125 mm diameter by 10 mm thick steel discs on the ends of the 3-mm thick, Ø 77.5 mm carbon steel pipe, with the weld seam varying about 10 mm mean width. This is a kind of fillet type joint weld [2]. Through holes already drilled in the end plates, the pipes are then bolted with nuts together end to end to erect the tower. In this construction, to prevent the pipe from corrosion, the whole structure was painted with gloss or acrylic organic paint, but somehow not over the entire structure as in can be seen in Fig. 2.