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Causes of Failure in Storage Facilities and Their Supports

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----------**ABSTRACT**----------
Storage tanks in metallic or plastic forms are meant for storing water or other liquid substances for use either in industrial or domestic applications. This work looks into where failure occurs in metallic storage tanks, how there occur and why they occur. This study was important in other to proffer solutions and recommendations to the causes of failure recorded. The area of study was in Kaduna State, Nigeria, where four storage tanks were examined. The major causes of failure recorded were failure due to corrosion, failure due to malfunction of part, failure due to wrong construction methods among others. With corrosion of parts ranking highest on failure types, it was recommended that anti- corrosive materials like aluminum or stainless steel should be used for constructing storage tanks and their supports and when using mild steel materials it should be well protected using red oxide paint or hydrophobic polyester coatings.

Keywords : *Corrosion, failure red-oxide, stainless steel.*

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I. INTRODUCTION

These tanks fail due to a number of reasons. Subsequent research on the causes of failure on water storage tanks have basically and mainly been on the asymmetric loading. The wall strip is assumed to deflect as a beam on elastic foundation; therefore results present in general are elastic solutions for circular tanks that are based on finite difference method.

This method has been applied to other shapes of tanks different to the initial cylindrical shape with asymmetric loading [1]. The method which utilized the theory of plates and shell to design a paste tank having a funnel shape was done by presenting a set of equations to determine the hoop and the meridian moment at different heights of the tanks [2]. This method is based on static analysis and is found to be the leading approach in conservation design. In 2000, Ghali extended his work to include a one dimensional straight finite element represented as a conical frusta and can be generalized for any shape [3].

Intensive studies of water containing conical tanks started after catastrophic failure of a steel conical water in Belgium 1978, the research was conducted by gradually increasing the height of water inside the models, the height of water at which each model buckle was recorded, the experimental result computed and developed to an equation that can be used to access the stability of the tanks in general. Later on, studies on the elastic behaviour of conical vessel, using degenerates shell element was conducted and the results of the study showed that the buckling strength of the studied tanks is asymmetric imperfection [1].

In 1990, another catastrophic failure of an elevated storage tank occurred in Fredericton, Canada. [4] Related this failure inappropriate thickness of the lower parts of the tank, the miscalculation of the designer used buckling formulae that are valid for aerospace applications where the quality of the manufacturing is much higher than that in civil projects. [3] studied the elastic stability of a conical vessel under hydrostatic loading assuming perfect shells, in their study; the imperfection shape which leads to the lowest limit load was determined by a conducting elastic analysis of conical tanks with different imperfection. Furthermore, it was noticed that the smaller the thickness of the conical flask, the more sensitivity to geometric imperfection.

Putting the area of study Kaduna into account, series of catastrophe also occurred. The 33,000 litres water capacity tank that collapsed in Federal Government College, Soba (Zaria) in August 1996, and the research for the collapse of the result drawn was corrosion of the foundation bolts over the base plate. [5] Peter an engineer with Belmont Nigeria Limited investigated the failure and he came out with the findings:-

- Lean thickness of base plate.
- Corrosion of foundation bolts due to water leakage.
- Poor wind breaker (internal braze)

[5] Another catastrophe was the 2001 overhead tank collapse of the Ministry of Labour and productivity which had a capacity of 25000 litres. It failed due to buckling of the reservoir segment, the skeletal support provided in between the tank gave way and it failed. Series of research work on the causes of failure, and it was concluded that the weld-ability of the tank and its support were poorly done which could be as a result of;

- Wrong usage of electrodes size
- Wrong usage of electrode types
- Wrong welding angle among others.

Based on the information presented above, it can be concluded that most of the published literatures studied the structural behaviour of the steel storage tank, however there is scanty data available for the design performance of industrial water storage tank[6]. Moreover the effect of different load e.g. Dead hydrostatic, wind effects, earth revolution effect on the behaviour of the Support shaft that was investigated using finite element, while there is no clear understanding of the behaviour of the industrial storage water tank.

Many researchers investigated the behaviour and design of cylindrical and rectangular storage water tank. There are no particular provisions or standard that is available for industrial water storage tank. However it is important to review the causes of failure of industrial waters storage tanks in Kaduna. This can help in eradicating future hazard of its collapse (failure). The majority of designers use strength design method, yet some still are using work stress design approach [7]. In the working stress method, stresses are kept at fairly low levels to minimize cracking which leads to prevention of leakage. On the other hand, strength design method deals with cracked section analysis which may not sufficiently address the leakage problem and other failure causes.

II. MATERIALS AND METHOD

The study was carried out in the following industries in Kaduna state; Nigeria

- Nigerian bottling Company Kaduna Plant Industrial Layout
- Faith Academy Maraban Rido Water storage tank (120,000 litres)
- Kaduna State Water Storage Tank Barnawa Kaduna (500,000 litres)
- Federal Government college Soba Kaduna Water Storage Tank (130,000 litres)

All the storage tanks were made of mild steel and were coated from the onset with red oxide chemical to disallow reactions between water and the mild steel plate to avoid scale formation and corrosion. A study of the individual parts of the tank where failure could occur was examined. These parts are the roof, weld joints, wall plates, interior floor and the exterior floor.

THE ROOF

The opening on the roof was measured by means of a vernier calliper; the internal beam was also inspected for corrosion due to moisture. A magnifying lens was used to detect smaller leakages.

THE WELDED JOINTS

The joined parts were checked for leakages. The gasket was removed and subjected to an external force to see if the properties needed are still present. The welded joints were inspected for leakage using permanent dye method.

THE WALL PLATE

This form the most part of the tanks, the coatings were checked if still intact, four plates out of the wall plates of each tanks that both jointed was also picked at random and inspected. The plates thicknesses were also measured with the aid of a vernier calliper at the different sides. Wall plates of other facilities that were welded together were also inspected and measured using the same method.

INTERIOR FLOOR

The floors of the tanks were scraped off and the scales/dirt removed, the thicknesses were measured and the coatings provided were also checked if intact.

STANCHION

This is the vertical bars or shaft that is been used to erect the tank above the ground level. The bolted spot to the earth surface were inspected for rusting/corrosion, the surface of the stanchion was also checked to ascertain it rigidity and strength.

FITTINGS/COUPLINGS

These include sockets, unions, pipes, flanges, pumps, valves that are used to redirect pipes, joining of pipes etc. The spot of the joint were inspected for leakages, foamy/soapy testing were used to checked for leakages,

loosening of sockets ,unions etc. and blockages along the pipe ways were also tested if through. The pumps were also checked if functional and efficient.

WATER TO BE STORED

The constituents of the water to be stored in the tank were inspected. Hence the source of water is directly from the river and filtered, while others were both filtered and chlorinated before pumping to the plant reservoir where the tank is situated before finally pumping the water into the tank.

FLOOR

The earth surface, where the stanchion of the tank was installed, were checked for the following; base uniformly and blow holes that could result to pitting.

III. RESULTS/DISCUSSION

The results obtained from the study of storage facilities were generalized and summarized in the tables below.

Where Failure occurs.

	ROOF	WELDED JOINT	WALL PLATES	GASKET	COATING	INTERNAL FLOOR	STANCTION	FITINGS /COUPLING	EXTERNAL FLOOR
Initial description	Vent Hole	Welded joints properly done without leakage.	Coated with red oxide all through	Flexible with clearance free-fix	Red oxide coating of both internal and external.	coated with coal tar	Painted with Silver anti rust, bracket welded firmly	All sockets, unions, pump are rigidly and properly fixed	Painted with red oxide and suspended on the stanchion
New description	Average increase in hole size,	leakages noted along the welded joints.	Red oxide coatings bumped up, Wall plates buckles	It's not flexible with little clearance	All coatings already off due to moist concentrati on.	Scales formed on coal tar it with lots of dirt settlement	Rust and scales on foots, bolts already rusted	Gradual failure already forming on fittings, Leakages spotted along the sockets, flanges, edges and some pipes fractured while others ruptured	Scales already formed on the external surface of the tank due to moisture, Paint already faded off with scales form

How Failure occurs.

	WALL BLOWOUT	ROOF COLLAPSE	PINHOLE LEAKAGE	GENERAL CORROSION
Initial description	All part bolt jointed firmly	Roof firmly fixed to vertical support	All part were intact and firm	No rust, all parts are painted and coated against rusting
New description	Wall blowout along the horizontal bar to buckle	rusted holes on its surface, Roof already collapse with the vent holes ruptured. corrosion of roof surface all through noted, Roof sagged as a result of buckle body surface	Holes leakage along gasket and rust concentrated area, Leakages were noted on the surface of the tank, along the couplings links, the sockets, elbows and flanges	where moist is concentrated shows already corroded rust, Corrosion was suspected along the couplings i.e galvanize pipes, and the tank surface was filled with scale. Galvanic corrosion was suspected along the lines, joints of pipes and at the roof top of the tank

Why Failure occurs.

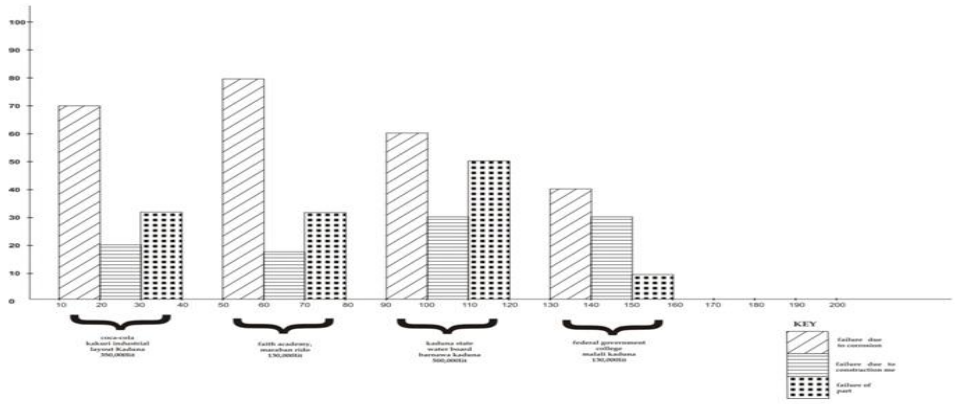
	CONSTRUCTION METHOD	SPECIFIC GRAVITY OF FLIUD	SEISMIC GROUND DESIGN
Initial description	Constructed with a bolt joint edge and all lap were fasten properly with no occurrence to effective leakage, Arc welding process and it was rigidly jointed, The construction method used the electric arc welding all parts were properly welded together	the specific gravity of the fluid is 1	No record of earthquake or volcano eruption of any kind
New description	The body of the tank still intact with little leakage spot noted along the joints/couplings. The roof top totally ruptured. Failure of parts was suspected from poor welding of the wall to the horizontal bars that pave way for the buckling	the specific gravity of the fluid is 1	As at the time of data completion there is no record or sign of any earthquake or volcano eruption which could result to seismic action

Failure in the tanks occurred in the following areas; the roof, the welded joint, the side wall. While failures occurred in the following ways; general corrosion, blow holes, pin holes and roof collapse. The failures could be attributed to the following;

a. Failure due to corrosion.
b. Failure due to construction method
c. Failure due to component used and other external factors

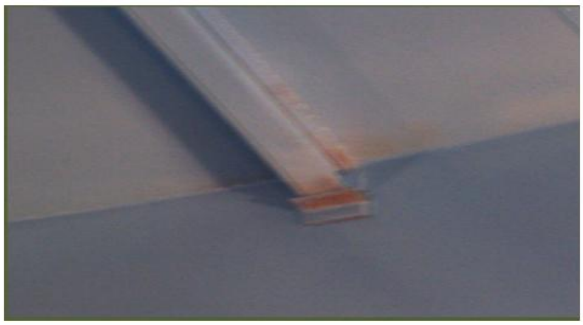
Figure 3.1 show a chart on the representation on the failures experienced and their degree of occurrence.
According to data obtained in this study, the frequency of failures on a scale of 10 shows shown;
Failure due to corrosion had a 50% , Failure due to construction method had 20% , Failure due to component used and other external factors had 30%.

BAR CHART REPRESENTING MAJOR CAUSES OF FAILURE.



Corrosion on joint due to poor welding procedure

Corrosion starting due to wall failure



SOME PICTORIAL VIEW OF FAILED TANKS DUE TO CORROSION

GENERAL CORROSION

Visual inspection was carried out on the tank; hence there are different types of corrosion methods e.g. pitting corrosion, general corrosion, galvanized corrosion etc [8]. which has different forms of commencement, depending on the cause. The available corroded spots were also taken into cognizance to ascertain if it is the cause of the failure in storage tank. Hence the use of mild steel plate, anti-corrosive materials like; red oxide paint, silver paint and tar coating should be engaged as they can only minimize the rate of corrosion formation.

IV. CONCLUSION/RECOMMENDATION

From the result compiled, corrosion makes the larger proportion of the major causes of failure in metallic industrial water storage tanks and their supports hence, virtually all the sites visited and among other research made gave a clear indication that there are corroded parts in the failed stanchions. Although there are other causes, but the extent of damage caused by corrosion cannot be underestimated, therefore corrosion can be ascertained to be the major cause of failure in metallic industrial water storage among others. To minimize failures that always occur in the industrial water storage tank which is caused majorly by corrosion, it is paramount to use parts that do not corrode in the manufacturing of the tanks. Also adequate application of anti-corrosive materials should be applied when using steel metal sheets and couplings .(Anti Corrode Sheets these include; Stainless steel sheets, Brass sheets, Bronze sheets, Poly-vinyl chloride materials.

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