Contents

1) Summary

This Report is to prove by experiment the dispensing system tubing can withstand the loads that would be experienced under a typical filled steel storage tank, The conducted experiment clearly proves by recorded video, that no deformation will occur. It is hereby recommended that this tubing can be used in this application.

2) Introduction

This report will evaluate, whether the dispensing system tubing can safely withstand the compressed sand loads of approximately 50cm below a typical tank as well the typical loadings that will be experienced from a full tank, that is approximately 20 meters high.

3) Background

A design is being considered, in which a dispensing tubing is to be installed underneath a storage steal tanks between 15 and 130 meters in diameter, typically used in the oil and water industries. Through these dispensing ring tubings, a volatile corrosion inhibitor is to be pumped, which shall result in corrosion protection of the bottom of the tanks for up to 10 years. Then, a repeat dispensing of the corrosion inhibitor through the pipes would protect the bottom of the tanks from corrosion for another five years. It is anticipated, that the system life is 30 years. Hence, the tank bottom can be efficiently controlled from corrosion for 30 years.

4) Experimental Setup

In order to simulate the installation the following simplifications are incorporated:

a) Due to dimensional constrains the 16mm polyethylene tubing (Appendix A) will only be installed at a depth of 14cm in washed sand. If it is to be installed 50cm deep, the additional 36cm would result in a lower load, hence the 14cm is a worst case scenario. If the tubing can withstand the 14cm loading, than, for sure, it can also withstand the same loading at 50cm depth.

b) In order to account for the weight of the tank, it is assumed that a 10mm thick plate is used throughout. Hence the highest weight per square meter is calculated to be 232kg / square meter (Appendix C)

c) The full tank will be replaced by a hydraulic press (Appendix B), which can be pressurized to the same levels as can be expected by a tank that is 20 meter tall and filled with water or oil. A one meter high column of water (which is denser and heavier than oil) would exert 1,000 kg per one square meter area. Hence

Eq 1: $$Pressure\ Bottom\ Tank\ Liquid_{\ Max} = \frac{\text{Force}}{\text{Area}} = \frac{1{,}000\ \text{kg}\ \text{x}\ 20}{1\ \text{m}^2}$$

Eq 2: $$Pressure\ Bottom\ Tank\ Liquid_{\ Max} = 20{,}000\ \frac{\text{kg}}{\text{m}^2} * \frac{1\ \text{bar}}{10{,}197.16\ \frac{\text{kg}}{\text{m}^2}}$$

See Ref A for all unit conversions

Eq 3: $$Pressure\ Bottom\ Tank\ Liquid_{\ Max} = 1.96\ \text{bar}\ \ (28.4\ \text{psi})$$

To include the weight of the empty tank, the two Pressures can be added as they are exerted over the same Bottom Tank Diameter

Eq 4: $$Pressure\ Bottom\ Tank\ Steel_{\ Max} = 232\ \frac{\text{kg}}{\text{m}^2} * \frac{1\ \text{bar}}{10{,}197.16\ \frac{\text{kg}}{\text{m}^2}} = 0.023\ \text{bar}\ (0.33\text{psi})$$

Eq 5: $$Pressure\ Bottom\ Tank\ Total_{\ Max} = Pressure\ Bottom\ Tank\ Liquid_{\ Max} + Pressure\ Bottom\ Tank\ Steel_{\ Max}$$

Eq 6: $$Pressure\ Bottom\ Tank\ Steel_{\ Max} = 1.96\ \text{bar} + 0.023\ \text{bar} = 1.98\ \text{bar}\ (28.7\ \text{psi})$$

Fig 1: Dispensing tubing inside acrylic pipe

A 17cm diameter clear acrylic pipe is placed on top of a round plate. The dispensing tubing tubing with open end, is inserted through an opening in the pipe (Fig 1). The tubing is about 1.5 cm from the plate and is touching the inside of the clear pipe. Washed sand is than added (Fig 2) and compressed with the use of a

5cm steel cylinder (Fig 3) until the pipe is fully filled (Fig 4). Then, a 15 cm disk is placed on top of the sand with several cylinders to fill up the gap to the ram of the hydraulic press.

Fig 2: Addition of washed sand to acrylic pipe surrounding dispensing tubing

Fig 3: Steel cylinder used for manual compacting of sand

Fig 4: Dispensing tubing buried under 14cm of compacted sand

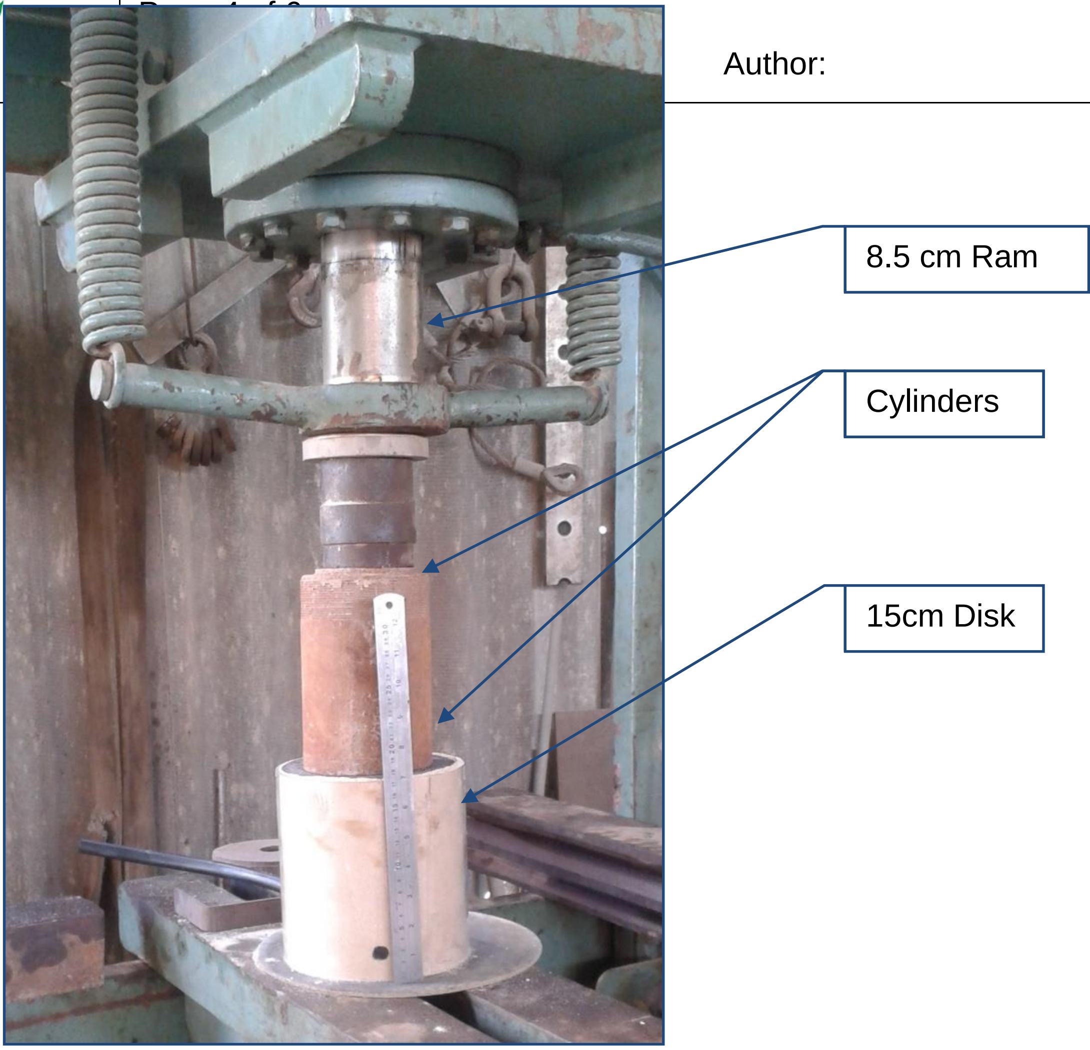

Fig 5: Steel plate placed on top of the compressed sand with several steel cylinders to fill the gap up to the ram of hydraulic press

In order to achieve the 1.98 bar as required from Eq 6, the required force on the disk is defined as

Eq 7: $$Pressure_{\text{ Disk}} = \frac{\text{Force}_{\text{ Disk}}}{\text{Area}_{\text{ Disk}}} = 1.98\text{ bar}$$, hence

Eq 8: $$\text{Force}_{\text{ Disk}} = Pressure_{\text{ Disk}} * \text{Area}_{\text{ Disk}} = Pressure_{\text{ Disk}} * \pi \left(\frac{\text{Diameter}_{\text{ Disk}}}{2}\right)^2$$

Eq 9: $$\text{Force}_{\text{ Disk}} = 1.98\text{ bar} * \pi \left(\frac{0.15\text{ m}}{2}\right)^2 * \frac{10{,}197.16\,\frac{\text{kg}}{\text{m}^2}}{1\text{ bar}} = 356.79\text{ kg}$$ (786.6 lb-f)

Since the force is transmitted from the disk to the ram and is equal to one another, we can then solve for the required pressure on the ram as follows:

Eq 10: $$Pressure_{\text{Ram}} = \frac{\text{Force}_{\text{Disk}}}{\text{Area}_{\text{Ram}}} = \frac{\text{Force}_{\text{Disk}}}{\pi\left(\frac{\text{Diameter}_{\text{Ram}}}{2}\right)^2} = \frac{356.79\ \text{kg}}{\pi\left(\frac{0.085\ \text{m}}{2}\right)^2} * \frac{1\ \text{bar}}{10{,}197.16\ \frac{\text{kg}}{\text{m}^2}}$$

Eq 11: $$Pressure_{\text{Ram}} = 6.17\ \text{bar}\ (89.5\text{psi})$$

Hence, if the Ram is pressurized to 6.17 bar, we would achieve the required 1.98 bar under the steel disk over the sand.

5) Experimental Results

Upon setup, the hydraulic press was manually pumped to 8 bars (Fig 6), while observing the end of the dispensing tubing tubing. A video was also recorded continuously to further document any change in deformation. (Fig 6 & Ref B). No deformation was observed. Naturally, the system was further pressurized to try to see at what point a deformation may occur. However, at 12 bars of pressure, the acrylic pipe ruptured abruptly. Nevertheless even at this pressure, the video shows no deformation.

Fig 6: 8 bar of pressure on Hydraulic Ram

Fig 6: No load on Ram – Time increment 00:29

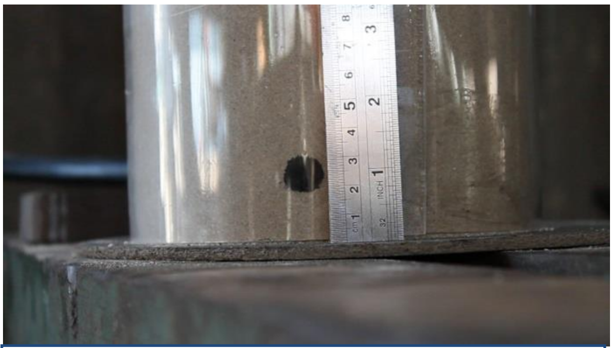

Fig 7: 8 bar pressure - Time increment 02:05

6) Error Analysis

Inaccuracies in measurement: Pressure

Pressure is measured at ± 0.5 bar based on the scale on the gage in Fig6. Due to this wide range pressure was raised from the required 6.17 to then to the next major increment, which was 8 bar, hence more than accommodating this inaccuracy.

7) Conclusion

It has been shown that the chosen dispensing tubing tubing, which is only 16mm diameter and made of polyethylene, can safely withstand the compressed sand as well as loading of up to 20 meter high of a steel tank. The maximum loading that the tubing was exposed to equals to approximately 40 meter high steel tank, at which point the experimental setup reached its limit.