

Above Ground Storage Tank

Preliminary Fatigue Comparison for the Annular Ring Weld

Introduction

Above ground steel storage tanks are subjected to fluctuating pressures from tank filling/emptying operations and thermal expansion. These pressures can introduce high stress ranges in the fillet weld between the tank shell and bottom annular ring plating (see Figure 1) which often results in low cycle fatigue damage and weld cracking.

SPS Overlay is a composite material that is routinely used to strengthen and reinstate steel plate structures. It can be installed on new storage tanks or retrofitted to existing storage tanks as a patch inside the tank to enhance fatigue performance of critical structural details. This makes SPS Overlay an ideal product for improving the through-life performance of the critical shell-to-bottom fillet weld connection detail on storage tanks.

Analysis

To demonstrate the improved fatigue performance of the SPS Overlay design, Intelligent Engineering (IE) conducted a representative analysis to compare a typical shell-to-bottom connection detail, both before and after the application of the SPS Overlay (see Figure 1). This technical note is a summary of the results.

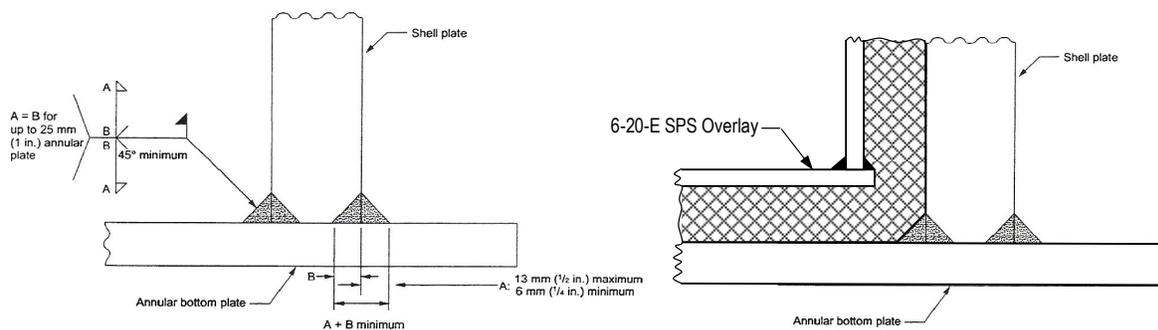


Figure 1. Detail of shell-to-bottom joint (API-650) before and after SPS Overlay

The performance of the shell-to-bottom fillet weld was calculated using the ANSYS finite element analysis package. Two models were created: (1) to represent a typical structure without SPS Overlay and (2) the typical structure with SPS Overlay applied (see Figure 2). The static linear elastic analysis was completed and the results compared.

A nominal uniform pressure of 0.15 MPa was applied to the inner surface of the shell and bottom plating. Gravity loads were excluded.

Results

The calculated von Mises stresses are illustrated in Figures 3 and 4 for both the designs. The maximum von Mises stress in the original structure (without SPS Overlay) adjacent to the weld toe of the shell-to-bottom fillet weld was 148MPa. This reduced to 18MPa at the same location once the SPS Overlay was applied which corresponds to a stress reduction of 88%. Given that the number of cycles to failure is inversely proportional to the magnitude of a stress range cubed, the fatigue life of this detail is enhanced by more than 2 orders of magnitude.

Once the SPS Overlay is fitted, there will be load sharing between the original structure and the installed SPS Overlay. Therefore, the stresses in the new SPS Overlay structure also need to be considered. As can be seen in Figure 3, the maximum stress at the welded corner of the top plate is 112MPa. The proposed welded connection detail is a double continuous fillet weld, similar to the shell-to-bottom fillet weld, so this corresponds to more than double the fatigue life without SPS Overlay.

The location of the high stress is on the inside weld of the connection between the vertical and horizontal SPS 6mm top plates (see Figure 4). This can be easily inspected during routine tank surveys and repaired if necessary. If a fatigue crack did occur, the elastomer core would protect against leaks and spills of liquids and the original structure would remain in tact. The stress levels on the opposite side of the vertical top plate are over 50% lower (53MPa) and are much less susceptible to fatigue damage.

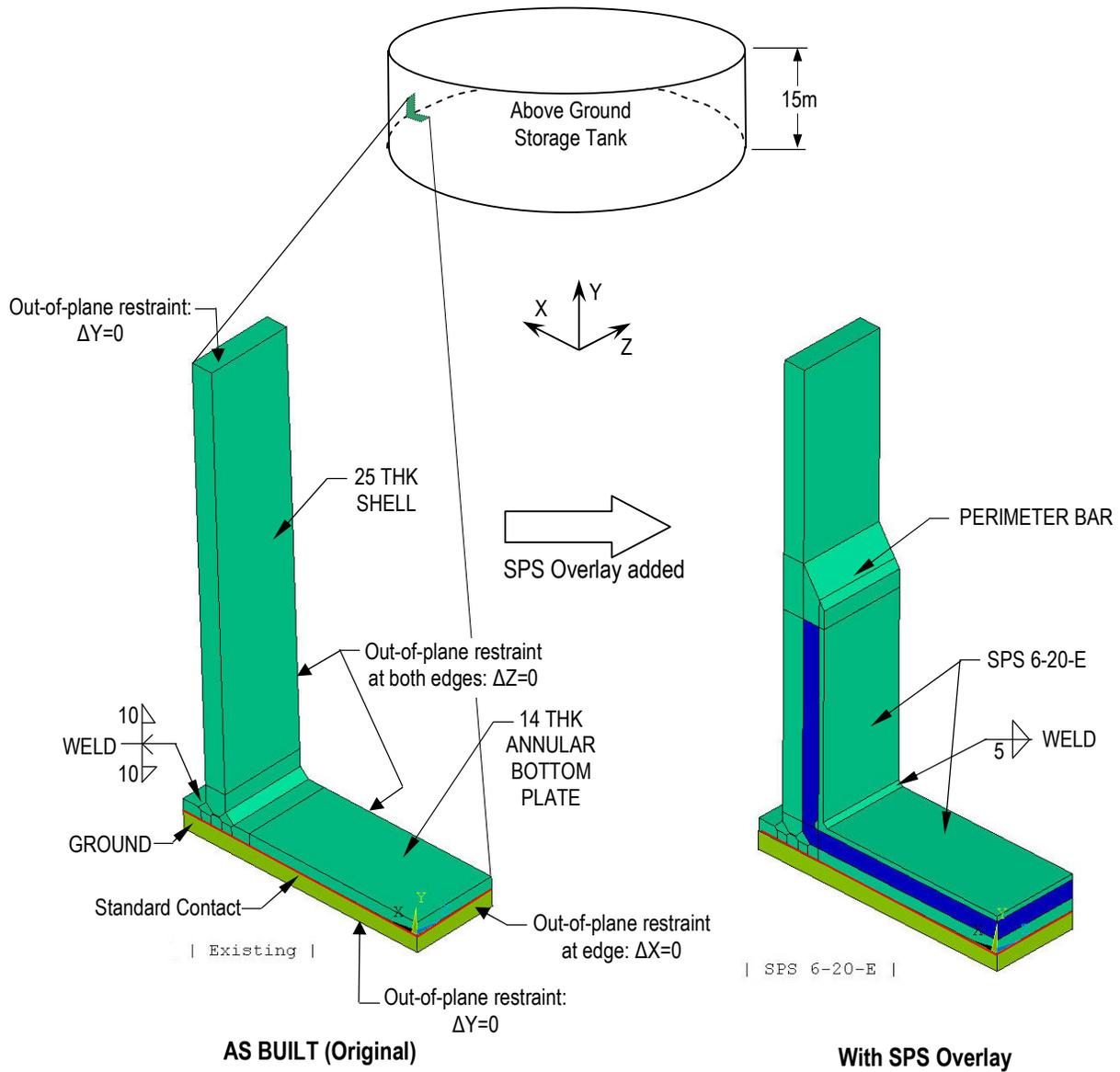
It should be noted that the fatigue performance of this construction detail could be further improved by increasing the core/steel thickness and/or using a radiused corner detail instead of a double continuous fillet weld between top plates.

Conclusions

The main conclusions of this investigation are as follows:

- SPS Overlay can be fitted to new or existing storage tanks to improve the fatigue performance of the critical shell-to-bottom fillet weld
- The fatigue performance of the original shell-to-bottom fillet weld is enhanced by more than 2 orders of magnitude
- The overall fatigue life is more than doubled
- The most critical location of the SPS Overlay design is the exposed fillet weld inside the tank and this can be readily inspected during routine tank surveys
- SPS Overlay provides an additional protective barrier to prevent leaks and spills

The results of this preliminary investigation indicate that the fatigue performance of the shell-to-bottom fillet weld can be dramatically enhanced by installing SPS Overlay. However, it should be noted that the design for each specific application will need to be considered in more detail and on a case-by-case basis.



Load: Uniform pressure to the inner surface of the bottom and shell plating 0.15 MPa

Figure 2. Details of FE Models

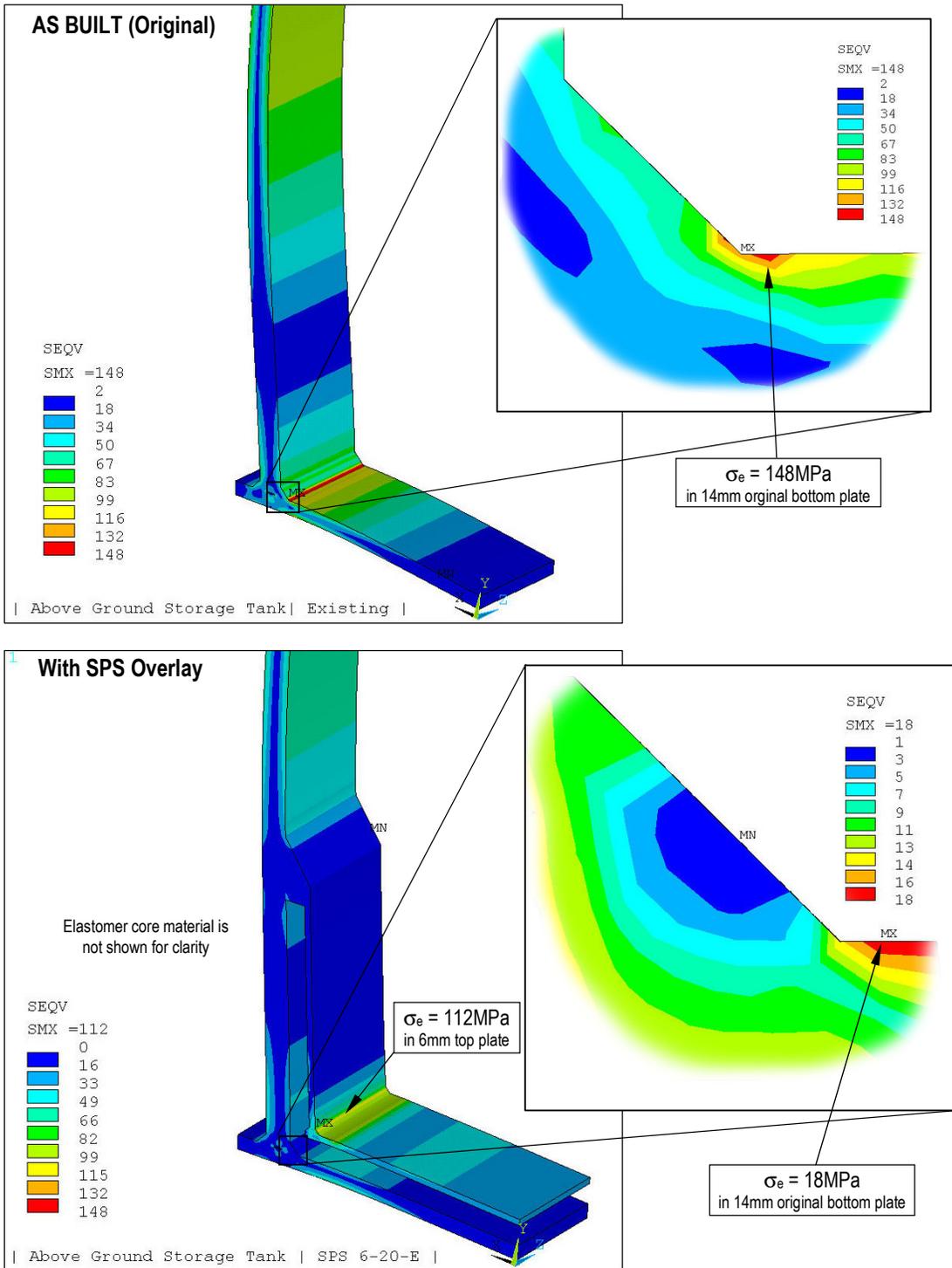


Figure 3. Von Mises stresses in shell-to-bottom joint

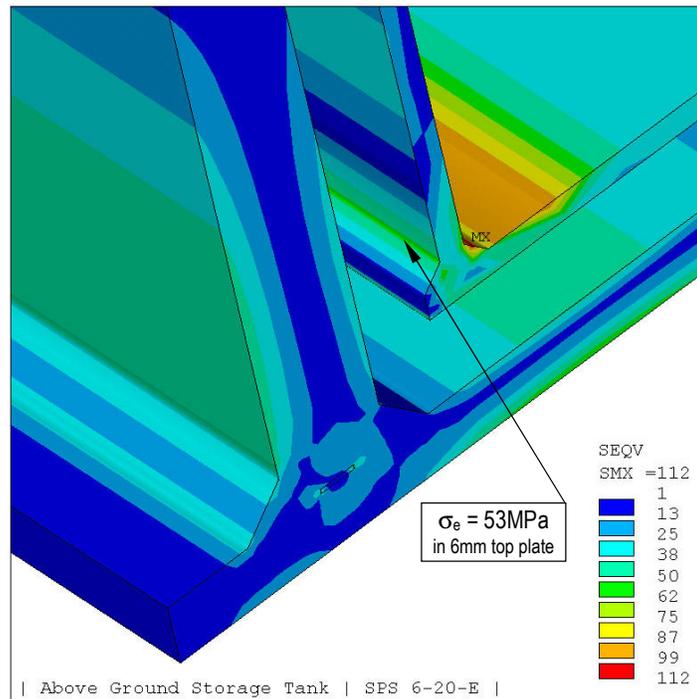
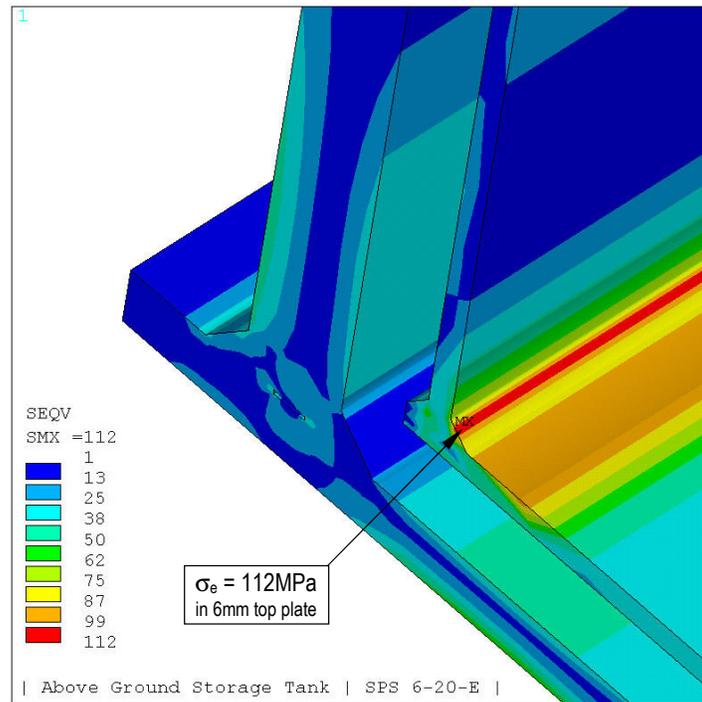


Figure 4. Von Mises stresses in SPS Overlay top plate
 (Elastomer core material has been removed for clarity)